UNIVERSITY OF SOUTHERN CALIFORNIA
MING HSIEH DEPARTMENT OF ELECTRICAL ENGINEERING

EE 520 Introduction to Quantum Information Processing

Instructor: Prof. Todd A. Brun **Phone:** (213) 740-3503
Office: EEB 502 **Email:** tbrun@usc.edu
Office hours: Mon 2-4 pm, Thu 3:30-5 pm

Lectures: Tu-Thu 2-3:20 pm in VHE 206

Text: *Quantum Computation and Quantum Information*
Michael A. Nielsen and Isaac L. Chuang (Cambridge, 2000);
Lecture Notes

Homework: Five problem sets will be assigned at 2-3 week intervals

Exams: There will be one midterm exam (given in class) and one final exam. The exams will be open book/open notes.

Midterm Exam: Thu 22 October 2015, 2 -- 3:20 pm

Final exam: Thu 10 December 2015, 2 pm -- 4 pm

Project: This project can be either a review of some topic in the research literature, or an original piece of research. It will include a 5-10 page report and an oral presentation in class.

Course Grade:

Problem Sets	15%
Student Project	15% (7.5% written report, 7.5% oral presentation)
Midterm	25%
Final Exam	45%

Course Description: This class will give a one-semester graduate-level introduction to the theory behind quantum computers and quantum information processing in general, aimed at students without previous exposure to the subject.

Required Preparation: A strong knowledge of complex linear algebra and probability theory, such as that obtained from EE 441 and EE 464

Learning Objectives

The class will begin by introducing the mathematical notation used in the field (Dirac notation), then giving a brief introduction to those aspects of quantum mechanics

necessary for the rest of the course: quantum states and tensor products, unitary transformations, generalized measurements, density operators, entanglement and decoherence. We will also introduce the basics of computational complexity.

We then cover the basic concepts of quantum information processing, and some of the algorithms and protocols developed in the last few years. The topics covered will include: quantum bits and registers; quantum cryptography; quantum gates and circuits; universal sets of quantum gates; basic quantum algorithms, including Deutsch's algorithm, Shor's factoring algorithm, and the search algorithm of Grover; decoherence, quantum error correction, and the idea of fault-tolerant quantum computation; and a brief overview of some of the proposals to implement quantum computing, their advantages and disadvantages, and current experimental progress.

Course Outline

Week	Subjects	Text pages & Homeworks
1	General overview. The Stern-Gerlach experiment and spin-1/2 particles. Quantum bits.	Secs. 1.1, 1.2, 1.5
2	Review of linear algebra; Dirac notation; projectors; decompositions of the identity; tensor products. Postulates of quantum mechanics. Quantum registers.	Secs. 2.1, 2.2.1-5
3	Unitary transformations and time evolution. Schrödinger equation. No-cloning theorem. Entangling interactions.	Sec. 1.3 HW #1 due
4	Examples of implementations using optical systems. Quantum gates. Quantum circuits. Entanglement. Quantum teleportation. Measurement and interference. Born rule. Complementarity and uncertainty.	Secs. 4.1, 4.2, 4.3, 1.6, 2.2.6-9, 2.3
5	BB84 quantum cryptography. Quantum operations. Shannon entropy.Classical bits, circuits and Boolean functions. Reversible and irreversible gates.	Sec. 4.4, Chap. 3 HW #2 due
6	Computational complexity classes. Quantum oracles and Deutsch's algorithm.	Sec. 1.4
7	Universal sets of quantum gates. Circuits and general unitary transformations. Quantum Fourier transform and period finding.	Secs. 4.5, 4.6, 5.1 HW #3 due
8	Phase estimation and Shor's factoring algorithm. Computational complexity of Shor's algorithm. Comparison to best classical algorithm.	Secs. 5.2, 5.3, 5.4

Week	Subjects	Text pages & Homeworks
9	Grover's search algorithm. **Midterm Exam.**	Sec. 6.1
10	Mixed states and density matrices. Completely positive maps. Partial trace. Von Neumann entropy. Decoherence and effect of environment. Schmidt basis. Effective evolutions. Master equations.	Secs. 2.4, 2.5, 2.6, 8.1, 8.2 Choose projects, HW #4 due
11	Quantum trajectories. Random error model. Simple error correction. Quantum error correcting codes. Stabilizer codes.	Secs. 8.3, 8.4, 8.5, 10.1, 10.2, 10.3, 10.4
12	Operations on encoded q-bits. Concatenated codes. Fault-tolerant quantum computation. Threshold theorem. Brief overview of other topics in quantum information.	Secs. 10.5, 10.6 HW #5 due,
13	Implementations. The DiVincenzo criteria. Linear ion trap. NMR. Achievements to date. Prospects of other techniques. Other potential applications.	Chap. 7 Projects due
14-15	Presentation of student projects.	

Thanksgiving holiday 25-27 November 2015.

Academic Responsibilities:

Academic Integrity

"The University, as an instrument of learning, is predicated on the existence of an environment of integrity. As members of the academic community, faculty, students, and administrative officials share the responsibility for maintaining this environment. Faculties have the primary responsibility for establishing and maintaining an atmosphere and attitude of academic integrity such that the enterprise may flourish in an open and honest way. Students share this responsibility for maintaining standards of academic performance and classroom behavior conducive to the learning process. Administrative officials are responsible for the establishment and maintenance of procedures to support and enforce those academic standards. Thus, the entire University community bears the responsibility for maintaining an environment of integrity and for taking appropriate action to sanction individuals involved in any violation. When there is a clear indication that such individuals are unwilling or unable to support these standards, they should not be allowed to remain in the University." (Faculty Handbook, 1994:20)

Academic dishonesty includes: (Faculty Handbook, 1994: 21-22)
Examination behavior – any use of external assistance during an examination shall be considered academically dishonest unless expressly permitted by the teacher.
Fabrication – any intentional falsification or invention of data or citation in an academic exercise will be considered a violation of academic integrity.
Plagiarism – the appropriation and subsequent passing off of another's ideas or words as one's own. If the words or ideas of another are used, acknowledgment of the original source must be made through recognized referencing practices.
Other Types of Academic Dishonesty – submitting a paper written by or obtained from another, using a paper or essay in more than one class without the teacher's express permission, obtaining a copy of an examination in advance without the knowledge and consent of the teacher, changing academic records outside of normal procedures and/or petitions, using another person to complete homework assignments or take-home exams without the knowledge or consent of the teacher.

The use of unauthorized material, communication with fellow students for course assignments, or during a mid-term examination, attempting to benefit from work of another student, past or present and similar behavior that defeats the intent of an assignment or mid-term examination, is unacceptable to the University. It is often difficult to distinguish between a culpable act and inadvertent behavior resulting from the nervous tensions accompanying examinations. Where a clear violation has occurred, however, the instructor may disqualify the student's work as unacceptable and assign a failing mark on the paper.

Students with Disabilities

Any student requesting academic accommodations based on a disability is required to register with Disability Services and Programs (DSP) each semester. A letter of verification for approved accommodations can be obtained from DSP. Please be sure the letter is delivered to me as early in the semester as possible. Your letter must be specific as to the nature of any accommodations granted. DSP is located in STU 301 and is open 8:30 am to 5:30 pm, Monday through Friday. The telephone number for DSP is (213) 740-0776.