EE 520   Introduction to Quantum Information Processing

Instructor: Prof. Todd A. Brun   **Phone:** (213) 740-3503
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Office hours: Mon 2-4 pm, Thu 10-11 am

Lectures: Tu-Thu 2-3:20 pm in GFS 223

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: Tue 24 October 2017 in class (2:00-3:20 pm)

Final exam: Thu 7 December 2017, 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   This class will give a one-semester graduate-level introduction
Description: to the theory behind quantum computers and quantum
                     information processing in general, aimed at students without
                     previous exposure to the subject.

Required   A strong knowledge of complex linear algebra and probability
Preparation: 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. Mixed states and density matrices. Completely positive maps.	Sec. 6.1
10	**Midterm Exam.** 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 22-24 November 2017.

Statement on Academic Conduct and Support Systems

Academic Conduct:
Plagiarism – presenting someone else's ideas as your own, either verbatim or recast in your own words – is a serious academic offense with serious consequences. Please familiarize yourself with the discussion of plagiarism in *SCampus* in Part B, Section 11, "Behavior Violating University Standards" policy.usc.edu/scampus-part-b. Other forms of academic dishonesty are equally unacceptable. See additional information in *SCampus* and university policies on scientific misconduct, http://policy.usc.edu/scientific-misconduct.

Support Systems:
Student Counseling Services (SCS) – (213) 740-7711 – 24/7 on call
Free and confidential mental health treatment for students, including short-term psychotherapy, group counseling, stress fitness workshops, and crisis intervention. engemannshc.usc.edu/counseling

National Suicide Prevention Lifeline – 1 (800) 273-8255
Provides free and confidential emotional support to people in suicidal crisis or emotional distress 24 hours a day, 7 days a week. www.suicidepreventionlifeline.org

Relationship and Sexual Violence Prevention Services (RSVP) – (213) 740-4900 – 24/7 on call
Free and confidential therapy services, workshops, and training for situations related to gender-based harm.
engemannshc.usc.edu/rsvp

Sexual Assault Resource Center
For more information about how to get help or help a survivor, rights, reporting options, and additional resources, visit the website: sarc.usc.edu

Office of Equity and Diversity (OED)/Title IX Compliance – (213) 740-5086
Works with faculty, staff, visitors, applicants, and students around issues of protected class. equity.usc.edu

Bias Assessment Response and Support
Incidents of bias, hate crimes and microaggressions need to be reported allowing for appropriate investigation and response. studentaffairs.usc.edu/bias-assessment-response-support

The Office of Disability Services and Programs
Provides certification for students with disabilities and helps arrange relevant accommodations. dsp.usc.edu

Student Support and Advocacy – (213) 821-4710
Assists students and families in resolving complex issues adversely affecting their success as a student EX: personal, financial, and academic. studentaffairs.usc.edu/ssa

Diversity at USC
Information on events, programs and training, the Diversity Task Force (including representatives for each school), chronology, participation, and various resources for students. diversity.usc.edu

USC Emergency Information
Provides safety and other updates, including ways in which instruction will be continued if an officially declared emergency makes travel to campus infeasible. emergency.usc.edu

USC Department of Public Safety – UPC: (213) 740-4321 – HSC: (323) 442-1000 – 24-hour emergency or to report a crime.
Provides overall safety to USC community. dps.usc.edu