CS378 - M375T - PHY341 - ES377
Introduction to Quantum Information Science

UT Austin, Fall 2024

https://utexas.instructure.com/courses/1401755

Discussion site: https://piazza.com/class/m0beeow9t3n252/

Lecture notes: https://www.scottaaronson.com/blog/?p=3943

Place and Time	Tuesdays and Thursdays 2-3:30PM, GDC 1.304
Instructor	Scott Aaronson aaronson@cs.utexas.edu www.scottaaronson.com GDC 4.422 Office hours: TBD or by appointment
TAs	Aditya Parulekar (adityauparulekar@utexas.edu) Jiawei Li (davidlee@cs.utexas.edu) - Office hours TBD
Recitation Sections	TBD
Midterm Exam	*Not* in class, 90 minutes—exact date/time TBD
Final Exam	TBD
Homework Schedule	TBD

This is an undergraduate-level introduction to the theory of quantum computing and information. We'll cover the rules of quantum mechanics (qubits, unitary transformations, density matrices, measurements); quantum gates and circuits; entanglement; the Bell inequality; protocols for teleportation, quantum key distribution, and other tasks; basic quantum algorithms such as Shor's and Grover's; basic quantum complexity theory; basic quantum error correction; decoherence and the measurement problem; and the challenges of building scalable quantum computers. Previous exposure to quantum mechanics is not required.

Prerequisites. Since some of the course assumes knowledge of classical algorithms, the prerequisite is CS331 with a grade of at least B, or permission of instructor. However, the *most important* prerequisite is a good level of comfort with linear algebra: vector spaces, bases, eigenvalues, rank, inner product, etc.

Requirements and Grading. There will be a short problem set approximately every week, beginning the second week. Problem sets will be due approximately one week after being assigned. There will also be one midterm exam and one final exam (dates and times to be determined). Course grading will be done as follows:
35% problem sets

30% midterm exam
35% final exam
In borderline cases, extra credit will also be given for regular participation in class and recitation sections, coming to office hours, and participation on the Piazza site.

Problem Set Policies. Submission of problem sets will be entirely electronic, and done through the Canvas page at http://canvas.utexas.edu/. We are planning to use GradeScope. If you prefer to write your solutions by hand, you can upload hi-res photos of your solutions (e.g., using a mobile phone). Otherwise, you can type solutions in Word, LaTeX, or other software of your choice.

A single problem set (the one with the lowest score) will automatically be dropped. For all other problem sets, 20% will be taken off for each day the problem set is handed in late, *unless* late permission is obtained for a reason such as illness, family emergency, religious observance, or UT-related travel. General busyness or other coursework are never valid reasons.

You're free to discuss the problem sets with classmates, but solutions must be written up entirely on your own. If you discuss with classmates, list the names of everyone you discussed with at the beginning of the problem set.

Piazza Site. You're encouraged to ask questions and discuss the lectures at the Piazza site:
https://piazza.com/class/m0beeow9t3n252/
Questions might be answered by Prof. Aaronson, the TAs, or your fellow students.

Lecture Notes. A complete set of lecture notes is available for the course! You can find them here: www.scottaaronson.com/blog/?p=3943. Thanks so much to Paulo Alves, a former student, for help preparing them.

Textbook. While we won't be following it closely, we recommend *Quantum Computer Science: An Introduction* by N. David Mermin. This is a short book that nevertheless covers much of the course material in a friendly, accessible way. Here are some other useful resources (which also cover more advanced topics than we'll get to in this course):

- Prof. Aaronson's *Quantum Computing Since Democritus*: www.scottaaronson.com/democritus/
- Some of Prof. Aaronson's other lecture notes: stellar.mit.edu/S/course/6/fa14/6.845/materials.html and www.scottaaronson.com/barbados-2016.pdf
- John Watrous's lecture notes: cs.uwaterloo.ca/˜watrous/LectureNotes/CPSC519.Winter2006/all.pdf
- Umesh Vazirani's lecture notes for Qubits, Quantum Mechanics, and Computers (UC Berkeley): www-inst.eecs.berkeley.edu/˜cs191/sp05/

Disabilities notice. The University of Texas at Austin provides upon request appropriate academic accommodations for qualified students with disabilities. For more information, contact the Office of the Dean of Students at 471-6259, 471-6641 TTY.

Approximate List of Topics.

The Church-Turing Thesis
Classical Probability Theory
The Basic Rules of Quantum Mechanics
Quantum Gates and Circuits
The Zeno Effect
The Elitzur-Vaidman Bomb
The Coin Problem
Inner Products

Multi-Qubit States
Entanglement
Mixed States
The Bloch Sphere
The No-Cloning Theorem
Wiesner's Quantum Money
BB84 Quantum Key Distribution
Superdense Coding
Quantum Teleportation
Entanglement Swapping
The GHZ State and Monogamy of Entanglement
Quantifying Entanglement and Mixed State Entanglement
Interpretation of QM (Copenhagen, Dynamical Collapse, MWI, ...)
Hidden Variables
Bell's Inequality
Nonlocal Games
Universal Gate Sets
Quantum Query Complexity
Deutsch-Jozsa Algorithm
Bernstein-Vazirani Algorithm
Simon's Algorithm
Shor's Algorithm (Quantum Fourier Transform, Continued Fractions...)
Grover's Algorithm
Optimality of Grover's Algorithm
Applications of Grover's Algorithm
Quantum Error Correction
Experimental Realizations of Quantum Computing