2.111/8.370/18.435 Course Info — Fall 2021

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Syllabus: I plan to go through the material faster than Prof. Lloyd does when he teaches the course, but slower than Prof. Chuang does. My current outline of what we will be covering is at the end of this document, although I am probably not going to go through the material in exactly the same order it is listed there. For example, there is probably too much material in the syllabus to cover all of it in class, so some of it will be put into the homework exercises.

Grading: There are several components to your grade:

- one in-class midterm (20%), and one final (30%).
- homework: 50%.

Exams: There will be one in-class midterm exam, on October ????. You will be allowed to bring two sides of letter-size pages of notes (one two-sided sheet or two one-sided sheets). There will also be a final during finals week, where you are allowed 2 pages (4 sides) of notes.

Class website: this will be on Canvas: https://canvas.mit.edu/courses/10398 .

Textbook: Two excellent references for the material in this course are the textbook *Quantum Computation and Quantum Information,* by Nielsen and Chuang, and John Preskill's lecture notes (online at http://theory.caltech.edu/~preskill/ph229). These are not required, but if you have difficulty understanding the material using just the course notes (which I will be writing), they are highly recommended.

I will be posting the sections relevant to the material we're covering on the course website each week.

Homework: There will be weekly problem sets, due on Gradescope. You can turn in psets 24 hours late for a 10% penalty. Without a note from S^3, late psets will not be accepted after the solutions are posted, which we plan to do 24 hours after they are due.

Collaboration: Collaboration on homework is encouraged. However, please write up your solutions on your own. The purpose of the homework is for you to learn the material, and getting help from somebody will let you learn it better than staring at a blank piece of paper for hours trying to figure out a way to attack the problem. Copying the solutions verbatim from somebody else will not, and if we notice it, you may end up getting a 0 on that pset.

I plan to give a few tricky exercises, but I don't intend to give you exercises where there's no way to figure out how to proceed — if I do, please complain.

You must list all collaborators on every assignment. If you make significant use of some resource other than the textbook or Preskill's notes, please note this on your homework, as well. If you have no collaborators, please state that on your assignment, too.

Piazza: There will be a piazza for this course. I, the TAs, and any other students who want to will be responding to questions that you ask on it. I am not planning on check Piazza more than once every day or so, so if you have an urgent question, email me at shormit.edu ((not that I check my email hourly, either).

Problem Set Collaborators: Andrew Sutherland has developed a pset partner website that will help you find pset collaboratorsr: https://psetpartners.mit.edu/ . I plan to put 18.435/2.111/8.370 on it.

Student Support Services (S^3): If you are dealing with a personal or medical issue that is impacting your ability to attend class, complete work, or take an exam, please discuss this with S^3. Their friendly staff provides support and advice, as well as advocacy and consultation with faculty, administration, housing, financial services, and other offices on your behalf. The deans in S^3 will verify your situation, and discuss with you how to address the missed work. For an extension on a pset longer than a day or two, you will need to get the support of S^3.

Student Disability Services: MIT is committed to the principle of equal access. Students who need disability accomodations are encouraged to speak with Kathleen Monagle, Associate Dean, prior to or early in the semester so that accomodation requests can be evaluated and addressed in a timely fashion. Not sure if you have a disability? Many students do not get diagnosed until college. SDS staff members can help you and determine your next steps. Theresa Cummings in MAS (Math Academic Services) can help arrange the logistics of student disability accomodation.

Detailed Syllabus:

Unit 1 Qubits

- qubits — polarizations and spins.
- Pauli matrices
- Operations on qubits — unitary matrices
- The space of more than one qubit: tensor products
- Measurements on qubits (von Neumann measurements and Hermitian observables)
- entanglement
- EPR pairs and Bell States

terlude (1-2 lectures): The Classical Gate Model of Computation

- Boolean formulas
- The universality of AND, OR and NOT gates
- the invisible gate — FAN-OUT
- reversible computation

- linear Boolean formulas
- The Toffoli gate (and possibly the Fredkin gate).

Unit 2 More than One Qubit

- Two-qubit gates (The CNOT gate in particular)
- Partial measurement (measuring one qubit out of many)

Unit 3 Multiple Qubits and Quantum Weirdness

- The Bloch sphere
- interferometers
- Teleportation
- Wiesner's quantum money.
- Superdense coding
- The Clifford group
- The EPR paradox and Bell's Theorem
- The GHZ paradox
- Density matrices and the partial trace

Unit 4: Quantum Algorithms

- The Deutsch-Jozsa Algorithm
- The Factoring Algorithm, and maybe the Discrete Log algorithm
- Grover's Algorithm
- Hamiltonian Simulation

Unit 5 Quantum Error Correcting Codes

- The 9-qubit code
- CSS codes
- The BB84 quantum key distribution protocol
- CSS code proof of security of BB84.
- Kitaev's Surface Code.
- Last Week (not on final): Some of the basics of fault tolerant quantum computing.