Quantum Information Science 3 (8.S372 / 18.S996)
Spring 2020
Syllabus

Lecture

Prof. Aram Harrow (aram@mit.edu)

Lectures: TR 1–2:30pm Eastern Time zoom

Office Hours: TBD

Teaching Assistant

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Office Hours: TBD

Course Goal

This is a third course in quantum information and computing theory, focused on special topics that may change from year to year. This year the focus is on quantum information theory, both understanding the core theory of the field, as well as application to many-body physics.

Prerequisites

You should have taken an introductory class in quantum computing, such as 2.111/8.370/18.435, or learned the equivalent material via self study. Ideally you would have also taken a second class such as 6.443/8.371/18.436 but this is not essential. We will also assume familiarity with probability and linear algebra. If you have any questions about your background, please come and talk with Prof. Harrow.

Texts

There are no required texts but you may find several of the following helpful.

- M. A. Nielsen and I. L. Chuang, *Quantum Computing and Quantum Information*
- A. Yu. Kitaev, A. H. Shen and M. N. Vyalyi, *Classical and Quantum Computation*
- M. Wilde, *Quantum Information Theory*, arXiv:1106.1445

- John Preskill's lecture notes: http://www.theory.caltech.edu/people/preskill/ph229/
- David Mermin's lecture notes: http://people.ccmr.cornell.edu/~mermin/qcomp/CS483.html
- John Watrous' lecture notes: https://cs.uwaterloo.ca/~watrous/LectureNotes.html
- Andrew Childs' lecture notes on quantum algorithms: https://cs.umd.edu/~amchilds/qa/

Grading

The final grade will be based on:

60%: **Problem Sets**
10%: **Lecture Scribing or Paper Responses**
20% : **Project Paper**
10% : **Project Presentation**

Use of the Web

The main course webpage is:

https://mit-qis3.gitlab.io/

Check here for problem sets, lecture notes, and other materials.
Content available only to registered students can be found on https://canvas.mit.edu/courses/5605

If you are attending as a listener then it is important that you are properly registered in order to have access to class-restricted material that will be posted on the web page.

Scribing

Each lecture should be scribed by two students. This means typing latex lecture notes that flesh out the notes from class. One way to this would be a shared overleaf document where one student quickly types notes live and the other one cleans it up later. If you prefer not to do this in real time, then you can make use of lecture videos and board images later.

Project

The final project for this class is due on Tuesday, Dec 8, 2020. It involves writing an 10-15 page paper (11pt, PRA, 2-column) on a topic related to the material in the class, either individually or with a partner. A project proposal is due on Tuesday, November 3. We will provide a list of suggested topics, and please check with us before devoting significant time to a topic not on the list.

Your paper may or may not contain original research. If you do not do any original research, then try to write a paper that prepares you for doing research. For example, if you do a survey, then identify important open questions and describe plausible approaches for tackling them.

Each student or team should also give a presentation based on the project. The last few lectures of the class will be devoted to these presentations.

Late policy

There is a global pandemic going on, affecting us all in unpredictable ways. If you are having trouble meeting a deadline, let us and S^3 know and we will work with you. You do not owe us any personal information, but we are also available to talk if you would like.

Tentative Outline

Lecture	Topic
1-2	**Basics:** States, metrics, bit commitment
2-10	**Information theory:** classical information theory (entropy, channel coding, hypothesis testing); quantum information theory; decoupling, merging, and complementary channels; random states and unitaries. *Applications:* black holes as mirrors, entanglement distillation and quantum repeaters
11-13	**Symmetries:** de Finetti theorems. *Applications:* security of quantum key distribution, mean-field theory.
14-16	**Condititional mutual information**, recovery maps and monogamy of entanglement. *Applications:* Optimization algorithms. Preparing states without topological order on quantum computers.
17-18	**Codes.** Error-correcting codes, the toric code and topological order.
19-23	**Correlations and complexity in interacting quantum systems.** Matrix product states, area laws, and QMA-completeness.
24-26	**Project Presentations.**

Other possible topics that could appear based on class interest include: quantum walk algorithms, superconducting qubits and the recent demonstration of quantum supremacy.