CMSC 657 : INTRODUCTION TO QUANTUM INFORMATION PROCESSING FALL 2020 SYLLABUS

GORJAN ALAGIC

People

Instructor: Gorjan Alagic (galagic@umd.edu); office hours: by appointment.
TA: Jessica Thompson (jktho@umd.edu); office hours: **TBA**

Resources

- Course page (rarely used, check ELMS and Piazza instead): http://www.alagic.org/cmsc-657-introduction-to-quantum-information-processing-fall-2020/
- Textbook (primary): *An Introduction to Quantum Computing*; Kaye, Laflamme, Mosca.
- Textbook (secondary): *Quantum Computation and Quantum Information*, Nielsen and Chuang.
- Piazza (discussions): https://piazza.com/umd/fall2020/cmsc657
- Check ELMS for slides, lecture recordings, assignments, etc.
- We will be using Gradescope to grade all homeworks and the final exam. Log into it via ELMS.
- Learning Assistance Services (www.counseling.umd.edu/LAS) Shoemaker 2202

Weekly schedule

We will try to follow this schedule for every week of the course.

Monday	Lecture 1 (L1) posted, *weekly homework set posted;*
Tuesday	12:30-13:45 Zoom meeting: discuss L1, Q&A, class polls and/or exercises;
Wednesday	Lecture 2 (L2) posted;
Thursday	12:30-13:45 Zoom meeting: discuss L2, Q&A, class polls and/or exercises;
Friday	*weekly homework set due at 5pm Eastern time.*

Subject matter

Goals. Quantum computers harness the power of quantum mechanics to perform information processing tasks. For some applications, devices engineered to take advantage of the laws of quantum mechanics show the promise of eventually surpassing any “classical” approach. These potential applications range from advanced physics simulations to fast attacks on public-key cryptography. This course will introduce students to the main theoretical ideas behind the quantum model of computation and communication. The goal is to prepare students for pursuing further studies in this field, including research.

Prerequisites. Familiarity with complex numbers and basic concepts in linear algebra (e.g., eigenvalues, eigenvectors, Hermitian and unitary matrices) is required. Previous background in quantum mechanics or theory of computation is not required.

Topics Covered. Basic model of quantum computation (reversible computing, qubits, unitary transformations, measurements, quantum protocols, quantum circuits); quantum algorithms (simple query algorithms, the quantum Fourier transform, Shor's factoring algorithm, Grover's search algorithm and its optimality); quantum complexity theory; mixed quantum states and quantum operations; quantum information theory (entropy, compression, entanglement transformations, quantum channel capacities); quantum error correction and fault tolerance; quantum nonlocality; quantum cryptography (key distribution and bit commitment); selected additional topics as time permits.

Key dates

- September 1st: first meeting;
- September 14th: add/drop;
- November 9th: drop with a "W";
- November 24th and 26th: no meeting (Thanksgiving recess);
- December 10th: last lecture;
- December 21: Final exam (1:30-3:30pm.)

Grading policy. The final grade will be 60% homework, 10% participation, and 30% final exam. We will be using Gradescope for grading homework assignments and the final exam. If you want to dispute a homework or exam grade you received, you must contact a TA or me within one week of receiving the grade. Please be mindful of matters of academic integrity, and the UMD course policies in general (see UMD course policies.)

The participation grade will be assessed informally, and is split evenly between participation in Zoom meetings and online discussions on Piazza. You are strongly encouraged to post questions on Piazza regularly, and to help your fellow students by answering them. Don't restrict yourselves to questions about homework only. Informal discussions about current events in the field (including, e.g., impact on society in general) are encouraged. If you can only watch the Zooms after the fact, compensate appropriately by being more active on Piazza.

Since this course is about a mathematically rigorous subject, here are some things to keep in mind when solving problems on homeworks and exams.

- All answers must be accompanied by complete and clear explanations. In some cases, the "explanation" will be a proof of some kind. A correct answer with no explanation or calculation will receive a zero score.
- Your goal in proofs is to convince the grader that, without any doubt, your answer is correct *and you understand why it is correct.* It is often impossible to do this without at least some writing. Please be thorough and clear in your write-ups (e.g., use complete sentences.)
- You must use clear, standard, and rigorous mathematical notation, following the examples set in lectures and the textbooks.
- For open-ended questions, think carefully about what constitutes a proof that your response is correct. Sometimes, all it takes is a counterexample (and an explanation of why it is a counterexample.)

Homework. There will be one homework set every week. Homeworks are due on the date specified on the homework set, typically Friday 5pm. *Late homework will not be accepted.* However, your lowest homework grade will be dropped when calculating the final grade. Use this "free pass" with caution: you only get one.

Collaboration on homeworks is allowed, but each student must write up their own solutions individually, in their own words. If you want to use a theorem from the lectures or the book, you have to state it clearly or provide an unambiguous reference (e.g., "Theorem 1.17 on page 53 of

KLM.") If you want to use a theorem from outside lectures or the book (e.g., from a paper online), you have to provide a complete statement and a complete proof in your own words.

While collaboration is allowed, I strongly encourage you to spend some quality time studying the subject and doing the homeworks on your own. I recommend reasonably long (e.g., 25+ minute) chunks of uninterrupted time with no distractions. Take notes, work lots of examples (starting from the simplest ones you can imagine), and "play" with the new concepts until you develop an intuitive understanding of them.

Final exam. The final exam will be closed-resource, i.e., no books, no notes, no outside resources (online, human, or otherwise.) In particular, collaboration is not allowed. There will be a time limit, and you will submit your exam on Gradescope.