MATH*4150/NANO 4700 Concepts in Quantum Computing (Fall 2020)

Department of Mathematics and Statistics/Department of Chemistry
University of Guelph

Course Description

This course introduces concepts in quantum computation and quantum information. Following an introduction to the basics of linear algebra, quantum mechanics, and computer science, presented from the viewpoint of quantum information theory, topics covered will include quantum computation, quantum algorithms, quantum error correction, quantum cryptography and quantum communication.

Credit Weight

0.50 credits

Prerequisites

MATH*1160, (CHEM*3860 or PHYS*3230)

Lectures

Asynchronous, but will be broadcast live Monday, Wednesday, Friday 11:30-12:20 on CourseLink Virtual Classroom

Instructor

Jeremy Levick

Email

levickje@uoguelph.ca

Office Hours

Online over CourseLink Virtual Classroom
Tuesday 2:30 - 3:30
Thursday 2:30 - 3:30
** Or by appointment

Teaching Assistants

Comfort Mintah
cmintah@uoguelph.ca

Textbooks

Required: None.
Recommended: David Mermin, Quantum Computer Science

Course Website

All course announcements, assignments, solutions, practice questions, and grades will be posted on the course website https://courselink.uoguelph.ca

Email Communication

As per university regulations, all students are required to check their ¡uoguelph.ca¿ e-mail account regularly: e-mail is the official route of communication between the University and its students.

Evaluations

Evaluations for the course are as follows:

60%	Assignments	Due Oct 2, Oct 16, Nov 20, Dec 4
40%	Final Project	Due in Exam Week

Marks

Assignments and term tests will be marked as quickly as possible and returned. All marks will be posted on CourseLink. It is your responsibility to check that the posted marks are accurate.

Assignments

Assignments will be distributed online via the course web page and are due online to https://crowdmark.com/ no later than 11:59 pm on the dates listed above. Late assignments will NOT be accepted. Of course, you can talk about assignment questions with me and with each other, but please make sure that the bulk of the work you submit is truly your own work. There will be low tolerance for plagiarism or what I deem to be excessive collaboration.

Final Project

Each student must complete a final project, an 8-12 page discussion of a topic in quantum computing/quantum information. Students will have the whole semester to work on this, and all work must be done individually, though consultation with the lecturer is strongly advised.

Lecture Schedule

Tentative Schedule and List of Topics

Week	Lecture Topics
1	Mathematical Background
2	Linear Algebra review
3	Introduction to Finite Dimensional Quantum Mechanics
4	Quantum Computing Framework
5	Quantum Circuits
6	Quantum Algorithms: Deutsch-Josza
7	Quantum Algorithms: Bernstein-Vazirani, Simon's Problem
8	Quantum Algorithms: Shor's Algorithm, Grover's Algorithm
9	Quantum Error Correction
10	Quantum Information Protocols: BB84
11	Quantum Information Protocols: Dense Coding, Teleportation
12	Quantum Information Protocols: Gate Teleportation, Review and Wrap-up

Course Objectives

This course is an introduction to quantum computing. The objective of the course is to develop the mathematical background necessary to understand the quantum model of computation, and to learn about the fundamentals of quantum computation, including specific algorithms, error correction techniques, and quantum protocols.

Learning Outcomes

Upon successful completion of this course, the student will have demonstrated the ability to:

1. - Learn the basics of finite dimensional quantum mechanics (observables, measurements, unitary evolution etc.). Students should be able to use the postulates of quantum mechanics and basic liner algebra to compute probabilities of observing outcomes for observables, and should be able to use the basic tools of the spectral theory on normal matrices to do computations

2. - Learn basic computing (functions on bits, basic complexity classes: P vs. Exp); students should be able to compute truth tables and simple circuits for classical functions, and be able to identify the complexity of a circuit

3. - Learn the quantum model of computation (Unitary implementation of functions)

4. - Learn to work with and understand quantum circuits. Students should be able to evaluate quantum circuits, or construct quantum circuits from given data, and should be able to identify the complexity of simple circuits

5. Learn important quantum algorithms (Deutsch, Shor, Grover, Simon, Bernstein-Vazirani if time permits); students should understand the basic ideas behind the quantum Fourier transform, and quantum search.

6. - Learn the basics of quantum error correction (bit-flip errors, phase-flip errors, Shors code, threshold theorem). Students should be able to show how simple codes correct simple errors, and explain why, even in the presence of certain obstructions, quantum error correction is possible

7. - Learn basic quantum information protocols (dense-coding, teleportation, etc.). Students should be able to recapitulate the protocols for dense-coding and teleportation, and understand the role of entanglement in these protocols.

Disclaimer

Please note that the ongoing COVID-19 pandemic may necessitate a revision of the format of course offerings and academic schedules. Any such changes will be announced via CourseLink and/or class email. All University-wide decisions will be posted on the COVID-19 website https://news.uoguelph.ca/2019-novel-coronavirus-information/ and circulated by email.

Missed Evaluation due to Illness or Compassionate Reasons

When you find yourself unable to meet an in-course requirement because of illness or compassionate reasons, please advise the course instructor in writing, with your name, student ID, and e-mail contact. See the academic calendar for information on regulations and procedures for Academic Consideration: http://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-ac.shtml

The University will not normally require verification of illness (doctor's notes) for fall 2020 or winter 2021 semester courses. However, requests for Academic Consideration may still require medical documentation as appropriate.

Recording of Materials

By enrolling in a course, unless explicitly stated and brought forward to their instructor, it is assumed that students agree to the possibility of being recorded during lecture, seminar or other live course activities, whether delivery is in-class or online/remote.

If a student prefers not to be distinguishable during a recording, they may:

turn off their camera mute their microphone edit their name (e.g., initials only) upon entry to each session use the chat function to pose questions. Students who express to their instructor that they, or a reference to their name or person, do not wish to be recorded may discuss possible alternatives or accommodations with their instructor.

Academic Misconduct

The University of Guelph is committed to upholding the highest standards of academic integrity and it is the responsibility of all members of the University community faculty, staff, and students to be aware of what constitutes academic misconduct and to do as much as possible to prevent academic offences from occurring. University of Guelph students have the responsibility of abiding by the Universitys policy on academic misconduct regardless of their location of study; faculty, staff

and students have the responsibility of supporting an environment that discourages misconduct. Students need to remain aware that instructors have access to and the right to use electronic and other means of detection. Please note: Whether or not a student intended to commit academic misconduct is not relevant for a finding of guilt. Hurried or careless submission of assignments does not excuse students from responsibility for verifying the academic integrity of their work before submitting it. Students who are in any doubt as to whether an action on their part could be construed as an academic offence should consult with a faculty member or faculty advisor.

Accessibility

The University promotes the full participation of students who experience disabilities in their academic programs. To that end, the provision of academic accommodation is a shared responsibility between the University and the student. When accommodations are needed, the student is required to first register with Student Accessibility Services (SAS). Documentation to substantiate the existence of a disability is required, however, interim accommodations may be possible while that process is underway. Accommodations are available for both permanent and temporary disabilities. It should be noted that common illnesses such as a cold or the flu do not constitute a disability. Use of the SAS Exam Centre requires students to book their exams at least 7 days in advance, and not later than the 40th Class Day. More information: www.uoguelph.ca/sas

Drop Date

Students will have until the last day of classes to drop courses without academic penalty. The deadline to drop two-semester courses will be the last day of classes in the second semester. This applies to all students (undergraduate, graduate and diploma) except for Doctor of Veterinary Medicine and Associate Diploma in Veterinary Technology (conventional and alternative delivery) students. The regulations and procedures for course registration are available in their respective Academic Calendars.

Undergraduate Calendar - Dropping Courses
https://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-drop.shtml

Graduate Calendar - Registration Changes

https://www.uoguelph.ca/registrar/calendars/graduate/current/genreg/genreg-reg-regchg.shtml

Associate Diploma Calendar - Dropping Courses

https://www.uoguelph.ca/registrar/calendars/diploma/current/c08/c08-drop.shtml