

NANO 4700/MATH 4150

Concepts in Quantum Computing

F19

General Information

Course Title: Concepts in Quantum Computing

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: .5

Academic Department (or campus): Chemistry

Campus: University of Guelph Main Campus

Semester Offering: F19

Class Schedule and Location: M,W,F 2:30-3:20, MINS 037

Instructor Information

Instructor Name: Jeremy Levick

Instructor Email: levickje@uoguelph.ca

Office location and office hours: Wed 3:30-4:30, others TBD by student schedule

GTA Information

GTA Name: Ningping Cao

GTA Email: ncao@uoguelph.ca

Course Content

Specific Learning Outcomes:

- 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 linear 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
- 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
- Learn the quantum model of computation (Unitary implementation of functions)
- 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
- 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.
- Learn the basics of quantum error correction (bit-flip errors, phase-flip errors, Shor's 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
- 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.

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Lecture Content:

- Mathematical background: Hermitian, unitary matrices, spectral decomposition.
- Postulates of quantum mechanics in finite dimensions: measurement, observables, quantum states
- Basics of functions on bits and classical circuits and gates
- The quantum model of computation
- Quantum algorithms:
 - Deutsch's algorithm
 - Bernstein-Vazirani algorithm (time-permitting)
 - Simon's problem (time-permitting)
 - Shor's algorithm
 - The quantum Fourier transform
 - Grover's algorithm
- Classical error correction
 - Correcting bit flip errors
 - Correcting phase flip errors
- Shor's code

- Seven qubit Code
- Five qubit code
- The threshold theorem
- Quantum cryptography:
 - BB84
 - Dense coding
 - Quantum teleportation
 - Gate teleportation

Course Assignments and Tests:

Five quizzes, one for each major unit. Each quiz is 10% of the total mark, for 50% total

Final examination date and time:

Dec 11, 11:30am-1:30pm

Final exam weighting:

50%

Course Resources

Recommended Texts:

David Mermin, Quantum Computer Science

Lab Manual:

Course Policies

Grading Policies

Quizzes are for full class-time, and are handed in at the end of class directly, and will be returned directly.

Course Policy on Group Work:

All quizzes are entirely individual.

Course Policy regarding use of electronic devices and recording of lectures

Electronic recording of classes is expressly forbidden without consent of the instructor. When recordings are permitted they are solely for the use of the authorized student and may not be reproduced, or transmitted to others, without the express written consent of the instructor.

University Policies

Email Communication

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

When You Cannot Meet a Course Requirement

When you find yourself unable to meet an in-course requirement because of illness or compassionate reasons please advise the course instructor (or designated person, such as a teaching assistant) in writing, with your name, id#, and e-mail contact. The grounds for Academic Consideration are detailed in the Undergraduate and Graduate Calendars.

Undergraduate Calendar - Academic Consideration and Appeals

<https://www.uoquelp.ca/registrar/calendars/undergraduate/current/c08/c08-ac.shtml>

Graduate Calendar - Grounds for Academic Consideration

<https://www.uoquelp.ca/registrar/calendars/graduate/current/genreg/index.shtml>

Associate Diploma Calendar - Academic Consideration, Appeals and Petitions

<https://www.uoquelp.ca/registrar/calendars/diploma/current/index.shtml>

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.uoquelp.ca/registrar/calendars/undergraduate/current/c08/c08-drop.shtml>

Graduate Calendar - Registration Changes

<https://www.uoquelp.ca/registrar/calendars/graduate/current/genreg/genreg-reg-regchg.shtml>

Associate Diploma Calendar - Dropping

Courses <https://www.uoquelp.ca/registrar/calendars/diploma/current/c08/c08-drop.shtml>

Copies of Out-of-class Assignments

Keep paper and/or other reliable back-up copies of all out-of-class assignments: you may be asked to resubmit work at any time.

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. For Guelph students, information can be found on the SAS website <https://www.uoguelph.ca/sas>

For Ridgetown students, information can be found on the Ridgetown SAS website

<https://www.ridgetownc.com/services/accessibilityservices.cfm>

Academic Integrity

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 University's policy on academic misconduct regardless of their location of study; faculty, staff, and students have the responsibility of supporting an environment that encourages academic integrity. 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. Undergraduate Calendar - Academic Misconduct

<https://www.uoguelph.ca/registrar/calendars/undergraduate/current/c08/c08-amisconduct.shtml>

Graduate Calendar – Academic Misconduct

<https://www.uoguelph.ca/registrar/calendars/graduate/current/genreg/index.shtml>

Recording of Materials

Presentations that are made in relation to course work - including lectures - cannot be recorded or copied without the permission of the presenter, whether the instructor, a student, or guest lecturer. Material recorded with permission is restricted to use for that course unless further permission is granted.

Resources

The Academic Calendars are the source of information about the University of Guelph's procedures, policies, and regulations that apply to undergraduate, graduate, and diploma programs.

[Academic Calendars https://www.uoguelph.ca/academics/calendars](https://www.uoguelph.ca/academics/calendars)