

Dalhousie University

Mathematics and Statistics
MATH 4680.03/5680.03 : Topics in Logic and Computation
An Introduction to Quantum Computation

Winter 2020
MWF, 09:35 – 10:25, Mona Campbell Building 1108

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Course Description

This course covers topics of current interest in logic and/or the foundations of computation. In the 2020 winter term, we will study quantum computation, a vibrant field of study which lies at the intersection of mathematics, computer science, and physics and provides a wide variety of fascinating mathematical problems. Quantum computers harness quantum mechanical phenomena to solve certain computational problems more efficiently than classical computers. We will cover the fundamental concepts of quantum information, quantum algorithms that outperform classical methods, and techniques for performing quantum computation reliably in the presence of noise.

Topics

Fundamentals of quantum information, quantum entanglement and quantum protocols, quantum circuits and universality, quantum algorithms, and quantum error correction and fault tolerance.

Course Prerequisites

The course is suitable for advanced undergraduates, as well as graduate students, from mathematics, computer science, and physics. The pre-requisites are: MATH 3032, or MATH 3502, or MATH 3031 and MATH 3501, or CSCI 3110 and CSCI 3136, or permission of the instructor. Students should be comfortable writing mathematical proofs. If in doubt about prerequisites, please contact the instructor.

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

1. explain the fundamental concepts of quantum computation,
2. demonstrate their mathematical understanding of quantum computation by proving standard results,
3. discuss well-known quantum algorithms and their advantages over classical methods, and
4. critically read and assess current research in quantum computation.

Learning Management System Site Information

Lecture notes and assignments will be posted on Brightspace (<https://dal.brightspace.com/>).

Suggested Texts

There is no required textbook for the course, but the following texts are good resources for supplementary reading.

- Kaye, Laflamme, and Mosca, *An Introduction to Quantum Computing*, Oxford University Press, 2007.
- Nielsen and Chuang, *Quantum Computation and Quantum Information*, Cambridge University Press, 2010.
- Mermin, *Quantum Computer Science*, Cambridge University Press, 2007.

In addition, several high-quality lecture notes are freely available online, some of which are listed below.

- John Preskill's notes on quantum computation: <http://www.theory.caltech.edu/people/preskill/ph229/>
- Andrew Childs's notes on quantum algorithms: <https://www.cs.umd.edu/~amchilds/qa/>

Course Schedule

The schedule below is subject to change.

Week	Dates	Topic
1	06/01 – 10/01	Overview
2	13/01 – 17/01	Mathematical prerequisites I
3	20/01 – 24/01	Mathematical prerequisites II
4	27/01 – 31/01	Fundamentals of quantum information I
5	03/02 – 07/02	Fundamentals of quantum information II
6	10/02 – 14/02	Quantum circuits I
7	17/02 – 21/02	Winter study break
8	24/02 – 28/02	Quantum circuits II
9	02/03 – 06/03	Quantum algorithms I
10	09/03 – 13/03	Quantum algorithms II
11	16/03 – 20/03	Quantum algorithms III
11	23/03 – 27/03	Quantum error Correction I
12	30/03 – 03/04	Quantum error Correction II
13	06/04	Review

Detailed recommendations for reading to complement the lecture notes will be given throughout the term.

Important dates

- January 31st 2020: last day to drop without a W,
- February 7th 2020: Munro Day (university closed),
- March 9th 2020: last day to drop with a W, and
- April 8th to 24th 2020: exam period.

For further information, please consult: https://www.dal.ca/academics/important_dates.html

Course Assessments

The final grade for the course will be computed as follows:

- assignments: 25%,
- midterm: 25%, and
- final: 50%.

The conversion of numeric to letter grades follows the Dalhousie grading scale which can be found at:

https://www.dal.ca/dept/university_secretariat/policies/academic/grading-practices-policy.html

The midterm examination will last one hour and will take place in class on Friday February 14th 2020. The final examination will last three hours, will take place during the exam period, and will be scheduled by the registrar. There will be five assignments throughout the term. The assignments will be posted on Brightspace. Dates for the assignments are detailed in the table below.

Assignment	Posted	Due
Assignment 1	24/01	31/01
Assignment 2	31/01	07/02
Assignment 3	14/02	28/02
Assignment 4	28/02	13/03
Assignment 5	20/03	03/04

Course policies

- *Assignments*
 - Assignments must be submitted at the beginning of class on the due date.
 - Late assignments will not be accepted and will be given a grade 0 unless a prior arrangement was made.
 - Assignments must be legible. Marks will be deducted for poor readability.
 - Students are encouraged to work collaboratively on problems but their submissions should be prepared individually.
 - Additional problems will be assigned to graduate students.
- *Examinations*
 - Missed exams will be given a grade 0 unless a prior arrangement was made.
 - Textbooks, course notes, and calculators are not permitted during exams.
- *Recordings*
 - Students are not permitted to record the lectures.

Learning and Support Resources

- General Academic Support – Advising
 - Halifax: https://www.dal.ca/campus_life/academic-support/advising.html
 - Truro: <https://www.dal.ca/about-dal/agricultural-campus/student-success-centre/academic-support.html>
- Fair Dealing Guidelines
 - <https://libraries.dal.ca/services/copyright-office/guidelines/fair-dealing-guidelines.html>
- Black Students https://www.dal.ca/campus_life/communities/black-student-advising.html
- International Students https://www.dal.ca/campus_life/international-centre.html
- Indigenous Students https://www.dal.ca/campus_life/communities/indigenous.html

- The Elders in Residence program provides students with access to First Nations elders for guidance, counsel and support. Contact the elders at the Indigenous Student Centre (1321 Edward Street), by email at elders@dal.ca or by phone at 902-494-6803.
- Student Health Services http://www.dal.ca/campus_life/health-and-wellness/health-services.html
- Counselling https://www.dal.ca/campus_life/health-and-wellness/counselling.html
- Dalhousie Libraries <http://libraries.dal.ca>
- Copyright Office <https://libraries.dal.ca/services/copyright-office.html>
- E-Learning website <http://www.dal.ca/dept/elearning.html>
- Writing Centre https://www.dal.ca/campus_life/academic-support/writing-and-study-skills.html
- Faculty or Departmental Advising Support: Studying for Success Program http://www.dal.ca/campus_life/academic-support/study-skills-and-tutoring.html
- Student Finance page: https://www.dal.ca/admissions/money_matters.html
- On Track (helps you transition into university, and supports you through your first year at Dalhousie and beyond) https://www.dal.ca/campus_life/academic-support/On-track.html
- Black Student Advising Centre https://www.dal.ca/campus_life/communities/black-student-advising.html
- International Centre http://www.dal.ca/campus_life/student_services/international-centre.html
- South House Sexual and Gender Resource Centre <https://southhousehalifax.ca/about/>
- LGBTQ2SIA+ Collaborative - <https://www.dal.ca/dept/hres/education-campaigns/LGBTQ2SIA-collaborative.html>
- Dalhousie Student Advocacy Services <http://dsu.ca/dsas>
- Dalhousie Ombudsperson https://www.dal.ca/campus_life/safety-respect/student-rights-and-responsibilities/where-to-get-help/ombudsperson.html
- Human Rights and Equity Services <https://www.dal.ca/dept/hres.html>
- Writing Centre https://www.dal.ca/campus_life/academic-support/writing-and-study-skills.html
- Study Skills/Tutoring http://www.dal.ca/campus_life/academic-support/study-skills-and-tutoring.html
- Academic Advising: <https://www.dal.ca/faculty/science/math-stats/programs/academic-advising.html>

University Policies, Statements, Guidelines

This course is governed by the academic rules and regulations set forth in the University Calendar and the Senate. <https://academiccalendar.dal.ca/Catalog/ViewCatalog.aspx?pageid=viewcatalog>

University Statements

- *Territorial Acknowledgement*
Dalhousie University is located in Mi'kma'ki, the ancestral and unceded territory of the Mi'kmaq. We are all Treaty people.
- *Academic Integrity*
At Dalhousie University, we are guided in all of our work by the values of academic integrity: honesty, trust, fairness, responsibility and respect. As a student, you are required to demonstrate these values in all of the work you do. The University provides policies and procedures that every member of the university community is required to follow to ensure academic integrity. (read more: http://www.dal.ca/dept/university_secretariat/academic-integrity.html)
- *Accessibility*
The Student Accessibility Centre is Dalhousie's centre of expertise for student accessibility and accommodation. The advising team works with students on the Halifax campus who request accommodation as a result of: a disability, religious obligation, or any barrier related to any other characteristic protected under Human Rights legislation (NS, NB, PEI, NFLD).

If there are aspects of the design, instruction, and/or experiences within this course that result in barriers to your inclusion please contact:

- the Student Accessibility Centre (https://www.dal.ca/campus_life/academic-support/accessibility.html) for all courses offered by Dalhousie with the exception of Truro.
- the Student Success Centre in Truro for courses offered by the Faculty of Agriculture (<https://www.dal.ca/about-dal/agricultural-campus/student-success-centre.html>)
- *Student Code of Conduct*
Everyone at Dalhousie is expected to treat others with dignity and respect. The Code of Student Conduct allows Dalhousie to take disciplinary action if students don't follow this community expectation. When appropriate, violations of the code can be resolved in a reasonable and informal manner—perhaps through a restorative justice process. If an informal resolution can't be reached, or would be inappropriate, procedures exist for formal dispute resolution. (read more: https://www.dal.ca/campus_life/safety-respect/student-rights-and-responsibilities/student-life-policies/code-of-student-conduct.html)
- *Diversity and Inclusion – Culture of Respect*
Every person at Dalhousie has a right to be respected and safe. We believe inclusiveness is fundamental to education. Dalhousie is strengthened in our diversity and dedicated to achieving equity. We are committed to being a respectful and inclusive community where everyone feels welcome and supported, which is why our university prioritizes fostering a culture of diversity and inclusiveness. (read more: <https://www.dal.ca/cultureofrespect.html>)
- *Fair Dealing policy*
The Dalhousie University Fair Dealing Policy provides guidance for the limited use of copyright protected material without the risk of infringement and without having to seek the permission of copyright owners. It is intended to provide a balance between the rights of creators and the rights of users at Dalhousie. (read more: https://www.dal.ca/dept/university_secretariat/policies/academic/fair-dealing-policy-.html)

University Policies and Programs

- Important Dates in the Academic Year (including add/drop dates)
http://www.dal.ca/academics/important_dates.html
- Dalhousie Grading Practices Policy
https://www.dal.ca/dept/university_secretariat/policies/academic/grading-practices-policy.html
- Grade Appeal Process
https://www.dal.ca/campus_life/academic-support/grades-and-student-records/appealing-a-grade.html
- Sexualized Violence Policy
https://www.dal.ca/dept/university_secretariat/policies/health-and-safety/sexualized-violence-policy.html
- Scent-Free Program
<http://www.dal.ca/dept/safety/programs-services/occupational-safety/scent-free.html>