MAT 4995 (also offered as MAT 5341) Quantum Computing

Fall 2023
Mondays 14:30-15:50 & Wednesdays 16:00–17:20
140 Louis-Pasteur (MRN); room 130

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Office Hours: see Brightspace for in-person and online options

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Syllabus

Welcome! You are welcome here. In this course, all students are welcome, including all races, colours, cultures, ethnicities, genders, and sexualities. This course is a space for respect for each other, including students, teaching assistants, staff, and professors.

Staying well and even thriving in light of the pandemic: This edition of the course is part of the second year of the full return to in-person classes at uOttawa since the onset of the pandemic. I recognize that many people faced additional hurdles due to the pandemic. I hope for your understanding as we adjust. Please do not hesitate to reach out with questions or suggestions about the course and how it can be adapted to your needs.
For Fall 2023, here is some information specific to the pandemic situation:

1. **In Person Lectures:** Lectures are in-person. All people present must comply with the University of Ottawa COVID-19 policies https://www.uottawa.ca/en/covid-19. I expect that you will attend class, unless sick. I will make every effort possible so that students who cannot attend due to sickness will be able to receive the course material. This may involve making classroom recordings available. If this is the case, you are advised that you or your voice may be recorded. Classroom recordings are not to be shared.

2. **Changes to Lectures:** Announcements regarding last-minute change of plans for the lectures (*e.g.* in the case the professor is sick) will be made on Brightspace. Please subscribe to the course announcements in Brightspace.

3. **Absence at Midterm:** In case you are sick during the midterm, please stay home. With a valid justification, this situation will be accommodated.

Learning Objectives
By the end of this course, students will be able to:

- recognize the differences between classical and quantum information in the context of computation;
- predict the outcomes of quantum operations on closed quantum systems;
- understand and construct quantum circuits;
- explain and apply paradigms of quantum information theory such as the no-cloning theorem, teleportation, entanglement, quantum algorithms and quantum error correction;
- understand and explain the advantages and limitations of quantum information in the context of cryptography;
- identify a number of advanced topics in quantum information processing as presented by classroom peers;
- **(MAT5341 only)** select, summarize and defend an advanced topic in quantum information processing; relate and compare this topic with material in the course;

Official Course Description: Space of quantum bits; entanglement. Observables in quantum mechanics. Density matrix and Schmidt decomposition. Quantum cryptography. Classical and quantum logic gates. Quantum Fourier transform. Shor's quantum algorithm for factorization of integers.

Target Audience: This course is open to all those who are curious about information processing in a quantum world. Students may have a background in Mathematics, Physics or Computer Science (this list is not exhaustive). No prior knowledge of quantum physics will be assumed, although a certain mathematical maturity (see below) is required.

Prerequisites: [Linear Algebra (MAT2141 or MAT3341) AND 12 course credits in mathematics (MAT) at the 3000 level or above] OR [Permission of instructor].

Course Homepage: See the course website on Brightspace for this syllabus, announcements, lecture information, grades, videos, and more (login and registration in the course required). You are responsible for checking this space regularly and subscribing to announcements.

Textbook: I recommend that you come prepared to class, having read the assigned readings, which will most often be taken from:

- Phillip Kaye, Raymond Laflamme, Michele Mosca. *An introduction to quantum computing*. Available online for free when connected to the uOttawa network: https://books.scholarsportal.info/en/read?id=/ebooks/ebooks0/oxford/2009-11-30/4/0198570007.

  Two other textbooks that are broader than the scope of MAT 4995 are the following (occasionally, readings may be given from these textbooks):

  - Michael A. Nielsen, Isaac L. Chuang. *Quantum Computation and Quantum Information*. Available online for free when connected to the uOttawa network: https://doi.org/10.1017/CBO9780511976667.

– Mark M. Wilde *Quantum Information Theory* (second edition). Available online for free when connected to the uOttawa network: https://doi.org/10.1017/9781316809976

Another online reference that is very pertinent for this course is:

- John Watrous. *Introduction to Quantum Computing (notes from Winter 2006)* https://cs.uwaterloo.ca/~watrous/QC-notes/.

Grade Distribution:

	MAT 4995	MAT 5341
Assignments	20%	10%
Project	—	10%
Midterm Exam	30%	30%
Final Exam	50%	50%
TOTAL	100%	100%

For details on the letter grade distribution, see University of Ottawa Academic Regulation 10.1.

Important Dates

First class:	Sept. 6
Midterm: (in class)	Oct. 18
Reading week (no class):	Oct. 23–27
Last class:	Wednesday, Dec 6.
	****Wednesday, Dec 6 is a Monday Schedule****
Final Exam:	TBD (during the final exam period, as scheduled by the Faculty of Science)

Assignments will generally posted on Wednesday and due on the following Wednesday. There will be approximately 5–6 assignments, thus more or less one every two weeks.

MAT 5341 (graduate-level course evaluation:) You will be graded on the same assignments, midterm and final exam as MAT4995, but may be asked to answer more questions and show a higher level of comprehension than the 4995-level students. In addition, you will be graded on a project that will consist in both a written and oral component. Details will be provided in a separate document.

Further course information:

1. **Exams:**
   - The midterm and exam are closed book, closed notes.
2. **Preparing your solutions:** In all work that you submit (assignments, midterms, exam, etc.), your answers will be evaluated according to your problem-solving process. This means that *you must show all your work*. It is not sufficient to simply state an answer. You will be graded on the clarity, conciseness and accuracy of your entire process of finding a solution.

3. **Collaboration:** Students are expected to work on assignments independently. Discussion amongst students is encouraged, but each student must write up his or her own solution. If you have extensively consulted a reference in order to prepare your solution, you must cite this reference.

4. **Academic Integrity:** Academic fraud is an act by a student that may result in a false academic evaluation of that student or of another student. You are responsible for being aware of and following the University Regulation to this effect: https://www.uottawa.ca/vice-president-academic/academic-integrity. When in doubt, direct your questions to the professor or teaching assistant.

And now a message from the Faculty of Science:

Academic support

Academic support is available to all, whether you're an experienced student or just starting out, you'll find some great resources to help you succeed.
For more information: https://www.uottawa.ca/study/academic-support

Health and Wellness

Your wellness is an integral part of your success. If you don't feel well, it can be hard to focus on your studies. Dedicated professionals and fellow students who care about you are always ready to provide advice and support. Depending on your needs, many activities and services exist to accompany you during your academic journey. Services include:

- opportunities to connect;
- counselling sessions
- peer support;
- physical activity;
- wellness activities and workshops;
- spiritual guidance.

If you want to connect with a counsellor, you can book an appointment online or go to their walk-in clinic at 100 Marie-Curie, fourth floor. You can also drop-in to our wellness space, chat online with a peer helper, or access 24/7 professional help through the website.
For more information and to access these services, go to https://www.uottawa.ca/campus-life/health-wellness.

Academic accommodations

We try to make sure all students with disabilities have equitable access to learning and research environments, the physical campus and University-related programs and activities. The Academic Accommodations service works with other campus services to create an accessible campus learning environment, where students with disabilities have an equitable opportunity to flourish. We offer a wide range of services and resources, provided with expertise, professionalism and confidentiality.
Some services we offer

- Help for students with disabilities in making the transition
- Permanent and temporary accommodation measures

- Learning strategy development
- Adaptive exams
- Transcriptions of learning material
- Interpretation (ASL and LSQ)
- Assistive technologies

If you think that you might need any of our services or supports, email the Academic Accommodations service (adapt@uOttawa.ca) or visit https://www.uottawa.ca/study/academic-support