PHY 410/563: Introduction to Quantum Information and Computing

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Description and Modality

What can we achieve if we base computation on quantum principles? What light, if any, does doing so shed on quantum theory itself? And how can such computers be built? This course explores the emerging answers to these questions and the fields of quantum information and quantum computation that these answers have given rise to. We will learn about quantum information processing, quantum cryptography and code-breaking, and the new perspectives on quantum theory's enduring mysteries that quantum computation provides.

A previous course in quantum mechanics is useful, but students who have not taken such a course can enroll in this course with the permission of the instructor. Knowledge of linear algebra will be very helpful. However, the course is designed to be self-contained and will provide an introduction to all the necessary content.

This is a 3 credit course.

Modality

The course is taught in person.

Recommended Texts

Primary reference: My notes / videos (made available as we progress)

Secondary references (Optional, listed in order of usefulness for this course):

Quantum Computation and Information, by Michael A. Nielsen and Isaac L. Chuang
[ISBN-13: 9781107002173]
(This is still the main textbook covering the standard topics.)

Q is for Quantum, by Terry Rudolph
[ISBN-13: 9780999063507]
(This is a more popular, yet surprisingly in-depth, account of quantum information ideas. Written by Schrodinger's grandson!)

Quantum Computing Since Democritus, by Scott Aaronson
[ISBN-13: 9780521199568]
(This is a wide-ranging work by the theoretical computer scientist, Scott Aaronson. The course this was based on combined computer science, quantum physics, and philosophy. The book is a fantastic and intellectually stimulating read.)

Additional references (freely available on line):

Introduction to Quantum Information Science, by Scott Aaronson
Notes for Quantum Computation, by John Preskill (for Caltech's Ph219/CS219)

Other Resources

IBM Quantum Computing: https://quantum-computing.ibm.com/
The Quantum Game v.1: http://play.quantumgame.io/
The Quantum Flytrap: https://quantumflytrap.com/

Feel free to drop me a line and let me know if you find other useful resources!

Course Components

Lectures/Discussions

The course will typically be conducted in a standard lecture style, though I encourage you to participate with questions and observations. I may assign reading occasionally, which will form the basis for a discussion during our lecture time.

While I will be releasing notes and videos from our lectures, I highly recommend having a notebook and taking notes for yourself and using the materials I release to supplement your own notes. Taking notes helps you to actively engage with the material! I encourage you to jot your own thoughts, questions, and confusions in your notes and return to them and use them as the basis for questions and comments. The more actively you engage in this way, the better the course will be!

Problem Sets

There are many levels of understanding. You can certainly gain *something* from just sitting and listening to me talk. You gain more from taking notes and trying to follow things closely. But to attain a deeper level of understanding, you must work through problems!

Are due as indicated on the course schedule.

Homework problems will not generally be graded by me in detail. Instead, solutions to selected problems will be released which should be used as the basis for *your own corrections*.

Homework grades will be based on timely submission of your first attempt and then your corrections.

I strongly encourage you to work with others and to ask lots of questions!

Projects

There are no midterms or final exams for this course. Instead, there will be midterm and final **projects**. A list of project ideas will be provided early in the term.

Phase 1: Identify a topic of interest and let me know what you've chosen. I will group you in an "advising committee" with other peers in the course. Due around 1/3rd through the semester.

Phase 2: Outline key points for your term project. Note that the project **must involve a series of substantial calculations, which you should propose in your outline.** Send me the outline and share it with your fellow advising group members. Due around 2/3rds through the semester.

- **Advising Meeting 1:** You should review the outlines from your other group members and come up with one question to ask each of them about their outlines. You will go around asking your questions and answering the questions you are asked. **This meeting should be recorded and sent to me to review.**

Phase 3: Record your final project presentation. (Maximum 15 minutes.) This should be sent to me and to your advising group members. Watch the recordings of your group members' project presentations and write at least two questions to ask them when you have your second advising meeting (see below). Share your questions with me. Due early in finals week.

- **Advising Meeting 2:** You should watch the presentations of your peers in your advising group and prepare at least two questions to ask them during your advising meeting. During the meeting, you will go around answering the questions from your peers and asking them your questions. The meeting should be recorded and sent to me to review.

Project ideas / inspiration

- Quantum machine learning
- Quantum programming languages and environment
- Architecture of physical quantum bits and/or gates
- Pictorial approaches to quantum theory (inspired by quantum circuits)
- Quantum computing through gaming (see examples like the quantum flytrap and the quantum game. One student previously created a 3D environment with puzzles based on running quantum circuits!
- Other quantum computing coding/simulation projects
- Quantum error correction
- Report on the use of quantum tech in banking and/or other industries

Grading

Your grade will be determined on the following basis:

- 20% Homework
- 10% Project Selection
- 30% Midterm meeting and outline
- 40% Final meeting, presentation, and report/other

A+	100		C+	73 to 77		F	0 to 57
A	93 to 100		C	70 to 73			
A-	87 to 93		C-	67 to 70			
B+	83 to 87		D+	63 to 67			
B	80 to 83		D	60 to 63			
B-	77 to 80		D-	57 to 60			

NOTE: I reserve the right to adjust this grading scale should the need arise.

Communicating With Me

I enjoy personal communication with students, either face-to-face (when possible) or through email. In order to help facilitate the best email communication please note the following:

- Interact with me in a professional manner: I am easygoing, but aim to make a good impression.
- Make sure your full name displays properly in the "From" line of your emails.
- Use a concise, descriptive subject line for your email.
- When initiating a conversation, unless your professor explicitly says otherwise, address them as "Dear Professor [their last name],"
- Use good grammar, spelling, and punctuation
    - This is important for both clarity and the impression you give

You may find this document on email etiquette informative. I do not agree with all the points made in the article: in particular, I *prefer* to be emailed if you have an excused absence from class or lab. I am also happy to take questions about your academic standing in the course once or twice a semester.

Here is another good article on the subject of student/professor interaction.

Classroom / Online Meeting Policy

- I endeavor to start each class promptly at the scheduled time and to make sure we end on time.

- I will ask students who are disruptive to leave.
- I reserve the right to bar students who are late from entering that particular session.
- For in-person classes: laptops, phones, and other such devices should be switched off and stored in your bag or pocket once class has begun. All note-taking should be done in a notebook with pen or pencil.
- Please take a look at this article as an explanation for the previous policy.
- For online meetings: please refrain from having multiple windows featuring unrelated content open during our sessions.)

Academic Integrity

All UMass Dartmouth students are expected to maintain high standards of academic integrity and scholarly practice. The University does not tolerate academic dishonesty of any variety, whether as a result of a failure to understand required academic and scholarly procedure or as an act of intentional dishonesty.

A student found responsible of academic dishonesty is subject to severe disciplinary action which may include dismissal from the University. The procedure for responding to incidents of academic dishonesty may be found in Section III of this document. You may also refer to the Student Handbook for information about the judicial process.

A high standard of academic integrity promotes the pursuit of truth and learning and respect for the intellectual accomplishments of others. These are values that are fundamental to the mission of this University. Such values are undermined by academic dishonesty.

Academic freedom is a fundamental right in any institution of higher learning. Honesty and integrity are necessary preconditions of this freedom. Academic integrity requires that all academic work be wholly the product of an identified individual or individuals. Joint efforts are legitimate only when the assistance of others is explicitly acknowledged and deemed appropriate by the instructor of the course. Ethical conduct is the obligation of every member of the University community, and breaches of academic integrity constitute serious offenses.

Maintenance of the standards of academic integrity and the successful administration of this policy depend on the mutual cooperation of faculty and students.

Faculty cooperation is essential for successful application of the procedures defined by this Academic Integrity Policy. Faculty members promote academic integrity by making clear on their syllabi their expectations concerning homework assignments, collaborative student efforts, research papers, examinations, computer-based infractions, and the like. Efforts should be made to detect and to prevent cheating and plagiarism in all academic assignments. If faculty members have evidence of academic dishonesty, they are expected to report such evidence promptly.

Students must assume responsibility for maintaining honesty in all work submitted for credit and in any other work designated by the instructor of the course. Students are also expected to report incidents of academic dishonesty to the instructor or dean of the instructional unit.

The intent of this policy is to make clear the standards of academic integrity at UMass Dartmouth.

**For additional information on violations, infractions, and consequences visit the UMass Dartmouth Student Academic Integrity Policy at the link below.*

http://www.umassd.edu/studentaffairs/studenthandbookintroduction/studentconductpolicies/academicintegritypolicy/