

Preliminary syllabus
ECSE 4964: Quantum Computer Programming
Department of Electrical, Computer, and Systems Engineering
Rensselaer Polytechnic Institute

Course Information

Course Title: Quantum Computer Programming
Transcript Title: Quantum Computer Programming
Course Number: ECSE 4964
Semester and Year: Fall 2020
Credit Hours: 3
Meeting Times: M R 4-5:20 PM
Classroom: TBD

Instructor

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TA(s): TBD

Course Description

Intro to quantum mechanics. Various physical realizations of quantum computing. The IBM Q. Quantum states and qubits. Quantum gates including Hadamard, Pauli-XYZ, Toffoli, Fredkin. Qiskit. Quantum algorithms, including Grover, Shor, and recent quantum algorithms. Investigating quantum hardware using qiskit.

Pre-requisites: ECSE 2610 and CSCI 2200 and PHYS 1200.

Suggested Textbooks

1. Noson S. Yanofsky and Mirco A. Mannucci, *Quantum Computing for Computer Scientists*, 2008.
2. Abraham Asfaw et al, *Learn Quantum Computation using Qiskit*, <http://community.qiskit.org/textbook>, 2020
3. N. David Mermin, *Quantum Computer Science An Introduction*, 2006.

Student Learning Outcomes: Students who successfully complete this course will be able to

1. Demonstrate proficiency with the mathematics behind quantum algorithms.
2. Identify the concepts with today's non-fault-tolerant quantum devices.
3. Apply these procedures to write code in Qiskit to implement quantum algorithms on IBM's cloud quantum systems.

Course Assessment Measures

1. Course assessment will be done through homeworks, class presentations, and a final project.
2. There will be approximately five homeworks. They may be done in teams of two students.
3. There will be two in-class presentations, which may be done in teams of two students. For the presentations, the students will select some relevant topic in quantum computing from a list suggested by the instructor, and present it to the class. Depending on the class size, each group of presentations will take one or two class days.

4. The final project may be done in teams of up to three students. Deliverables will include a report and a presentation, modeling a conference paper and presentation. The report will be in the form of a scientific conference paper. It will be about eight formatted pages long. The presentations will fill the last two class days.
5. Gradescope will be used to manage the grading process.
6. The instructor will use a static content management system on his private virtual web server provided by ECSE to maintain an online blog containing syllabus, homeworks, and lecture summaries. To see the blogs for the instructor's courses for the last few years, go to <https://wrf.ecse.rpi.edu/nikola/pages/teaching/>
7. Some programming assignments will use IBM quantum computing simulator that is available on github. That may be downloaded and run on any machine, such as a student's personal machine. For more serious computation, parallel.ecse.rpi.edu is available. It is a dual 14-core Intel Xeon with 256GB of main memory, which was bought by ECSE for Franklin's use for teaching and research.
8. Other assignments will use IBM's teaching quantum computer, which is available on the web. This will allow the students to see that the simulator is not perfect.

Grading policy

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|---------------------------------------|----------|
| 1. Homework assignments | 50% |
| 2. Two in-class presentations | 10% each |
| 3. Final project (paper/presentation) | 30% |

Course Policies

1. Students must justify absences from class to the instructor. E.g., absences for professional reasons, such as job trips are allowed.
2. Use of electronic devices during class that are not disruptive are allowed.
3. Students are allowed to record the lectures, but not to make money from this.
4. Lectures are open to the public.
5. Late homeworks will be allowed in a case-by-case basis.
6. Late projects will trigger RPI's incomplete-grade rules, with all that implies.
7. Students who discover a nontrivial error by the instructor will receive a bonus.
8. Students who provide extra material that the instructor uses will receive a bonus.
9. As this is a reading, writing, talking, and programming course, there are no lab safety issues.
10. Homeworks, and projects are encouraged to build on existing material that the student has legal access to, and which is acknowledged.
11. The in-class presentations will be summaries of intellectual material, such as conference presentations, created by others, who will be acknowledged.

Course Topics and Weekly Schedule (Subject to change)

1. Intro to quantum mechanics, Introduction to Python and Jupyter notebooks.
2. Various physical realizations of quantum computing, Quantum states and qubits
3. Quantum gates, Qiskit
4. Student in-class presentations, round 1
5. quantum algorithms, Grover's algorithm
6. Superdense Coding and Quantum Teleportation
7. Shor's algorithm, Quantum Algorithms for Applications
8. Implementations of Recent Quantum Algorithms
9. The Variational Quantum Linear Solver
10. Student in-class presentations, round 2
11. Investigating quantum hardware using qiskit
12. Simulating Molecules using the Variational Quantum Eigensolver (VQE)

13. Introduction to Quantum Error Correction via the Repetition Code
14. Final presentation

Academic Integrity

Student-teacher relationships are based on trust. For example, students must trust that teachers have made appropriate decisions about the structure and content of the courses they teach, and teachers must trust that the assignments that students turn in are their own. Acts which violate this trust undermine the educational process. Please refer to the *Rensselaer Handbook of Student Rights and Responsibilities and The Rensselaer Graduate Student Supplement* for definitions of various forms of academic dishonesty and the applicable penalties.

Specifics for this course are as follows.

1. You may collaborate on homeworks, but each team of 1 or 2 people must write up the solution separately (one writeup per team) using their own words. We willingly give hints to anyone who asks.
2. The penalty for two teams handing in identical work is a zero for both.
3. You may collaborate in teams of up to 3 people for the term project.
4. You may get help from anyone for the term project. You may build on a previous project, either your own or someone else's. However you must describe and acknowledge any other work you use, and have the other person's permission, which may be implicit. E.g., my web site gives a blanket permission to use it for nonprofit research or teaching. You must add something creative to the previous work. You must write up the project on your own.
5. However, writing assistance from the Writing Center and similar sources is allowed, if you acknowledge it, and it does not provide an intellectual contribution.
6. The penalty for plagiarism is a zero grade.
7. Cheating will be reported to the Dean of Students Office.
8. During any exams, you may not collaborate, nor use electronic devices, nor communicate with anyone except for the course staff, nor obtain any information except from explicitly allowed media, such as an allowed crib sheet.