ECSE 4969/6969 – Quantum Information Processing

Department of Electrical, Computer, and Systems Engineering
Rensselaer Polytechnic Institute

Course Information

Course Title: Quantum Information Processing
Transcript Title: QUANTUM INFO PROCESSING
Course Number: ECSE 4969 / ECSE 6969
Semester and Year: Fall 2026
Credit Hours: 3
Meeting Times: T F: 10:00 – 11:20 AM
Classroom: JONSSN 6309
Co-Listed and/or Cross-Listed: ECSE 4969 and ECSE 6969 are co-listed. Students cannot obtain credit for both co-listed courses. Graduate students should take ECSC 6969

Instructor

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Office Hours: TBD
TA(s): TBD

Course Description

This course offers a unified foundation in quantum information, blending concepts from physics, computer science, and mathematics, assuming only basic science and math backgrounds. It covers quantum information principles such as quantum qubits, measurement, gates, entanglement, algorithms, teleportation, and applications. This course is designed to be a gateway for undergraduates and graduates into the areas of quantum information and computation.

Pre-requisites

For ECSE 4969: MATH 2010. Knowledge of basic probability (e.g., ENGR 2600 or ECSE 2500).
For ECSE 6969: Knowledge of basic probability (e.g., ENGR 2600 or ECSE 2500).

Textbooks

1. Al-Qasimi, Asma, and Daniel F. V. James. Quantum Information: A First Course. Cambridge University Press, 2025.

Other References or Supplements

1. Nielsen and Chuang, Quantum Computation and Quantum Information, Cambridge University Press.
2. Kaye, Laflamme, and Mosca, An Introduction to Quantum Computing, Oxford University Press.

Student Learning Outcomes (for ECSE 4969): Students who successfully complete this course will be able to

1. Demonstrate an understanding of qubits, superposition, and entanglement as foundational concepts in quantum information.
2. Apply quantum measurement theory to analyze state collapse and probabilistic outcomes.
3. Demonstrate the ability to design and interpret basic quantum circuits and logic gates.
4. Apply quantum algorithms to solve computational problems.

5. Apply principles of quantum communication and teleportation to model simple information-transfer systems.
6. Demonstrate ability to understand further quantum information topics on their own by preparing a report and presentation on a topic approved by the instructor.

Student Learning Outcomes (for ECSE 6969): Students who successfully complete this course will be able to

1. Demonstrate an understanding of qubits, superposition, and entanglement as foundational concepts in quantum information.
2. Apply quantum measurement theory to analyze state collapse and probabilistic outcomes.
3. Demonstrate the ability to design and interpret basic quantum circuits and logic gates.
4. Apply quantum algorithms to solve computational problems.
5. Apply principles of quantum communication and teleportation to model simple information-transfer systems.
6. **ECSE 6969 only:** Demonstrate deep understanding of the principles by conducting a focused investigation in quantum information topics (e.g. model quantum noise channels, evaluate quantum error-correction schemes, etc.).
7. **ECSE 6969 only:** Demonstrate an ability to communicate the research problem and results as a short paper or technical report.

Course Assessment Measures

Course assessment will be done through homeworks, in-class activities, two midterm exams, and a final report. Homeworks will mostly consist of quantitative problems, but will also include a few programming assignments. The two mid-terms will be open book, open notes, and time-limited, and will be conducted during the class hours. For the final project, the students can work individually or in teams to apply one of the techniques learnt in the course to a real-life application. The topic of the final report needs to be chosen by week 5, and in agreement with the instructor. A final report presentation will be held in the last week of classes.

Students taking the course at the 6969 level will be required to do some additional or complex questions in the homeworks that are focused on more advanced analysis. Additionally, they will have to submit a research report along with the final presentation. The details of the grading policy are provided below.

Grading Policy

Component	ECSE 4969	ECSE 6969
Homework assignments	20%	20% *
In-class Activities	10%	10%
Two midterm exams	20% each	20% each
Final Exam	None	None
Final Report + presentation	30%	30% **

Additional Requirements for ECSE 6969

* The 6969 students will have additional or complex questions in the homework (compared to the 4969 level) that requires more advanced computational work and/or mathematical analysis and proofs (listed as #6 under ***Student Learning Outcomes for 6969*** above).

** The 6969 students have to submit a research report in a short paper or technical report format, which is not required of the 4969 students (listed as #7 under ***Student Learning Outcomes for 6969*** above).

Homework: Homework problems will be regularly assigned. These problems are required to be done individually in a professional manner (neatness and thoroughness count!). Graded homework will be returned in class approximately one week after they are due. Collaboration in the solution of the homework problems is permitted and is indeed encouraged if it enhances the learning process, but mere copying of the solution from another student is not allowed. In general, **no** late assignments will be accepted. However, extensions may be requested **in writing prior to the assignment due date** and evaluated on a case-by-case basis. Homework is a key part of your preparation for the midterms.

In-class Activities: Brief in-class activities — a short question answered live via a Webex poll — will be held at the start of approximately 6–8 sessions, covering key ideas from the lecture. Your best 6 scores count toward the final grade. Because they are done live in class, they are individual work.

Final Report (Project): Course projects will be performed individually and involve choosing a research paper/topic to investigate in depth. Students may choose from a list of recommended topics or propose own custom projects, subject to instructor approval. Projects should involve a detailed analysis of the chosen topic. For 6969 projects, they must include computation/simulation or advanced analytical evaluation.

Exam: There will be two midterm exams, but no final exam. Exams will be held in class, and will be open book, open notes. No computer, calculator, cell phone, Internet access, smart watches are allowed in exams.

Course Topics and Schedule (Subject to change)

Week	Topic
Week 1	Overview. Review of Linear Algebra topics
Week 2	Foundations of Quantum Information: Qubits and superposition
Week 3	Quantum States and Representations
Week 4	Quantum Measurement
Week 5	Quantum Entanglement
Week 6	Quantum Gates and Circuits I
Week 7	Quantum Gates and Circuits II
Week 8	Quantum Algorithms I
Week 9	Quantum Algorithms II
Week 10	Quantum Communication
Week 11	Quantum Noise
Week 12	Quantum Error Correction (including the threshold theorem, discussed qualitatively)
Week 13	Quantum Information Applications
Week 14	Final project presentations

Academic Integrity

Student-teacher relationships are built 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 that violate this trust undermine the educational process. The Rensselaer Handbook of Student Rights and Responsibilities and The Graduate Student Supplement define various forms of Academic Dishonesty and you should make yourself familiar with these. In this class, all assignments that are turned in for a grade must represent the student's own work. In cases where help was received, or teamwork was allowed, a notation on the assignment should indicate your collaboration.

In this class, all homework assignments that are turned in for a grade must represent the student's own work. In cases where help was received, or teamwork was allowed, a notation on the assignment should indicate your collaboration. Submission of any assignments that is in violation of this policy will result in a *penalty of removing the entire grade of the assignment*. Repeat violations will be reported to the office of the Dean of Students. Exams will be held in class, and will be open book, open notes; no collaboration of information exchange with any individual other than the instructor is permitted, however. Teamwork may be allowed the final project, but only after discussion with the instructor.

Academic Accommodations:

Rensselaer Polytechnic Institute is committed to reasonable and appropriate accommodations to ensure equal access for student with disabilities, and accommodations are individualized and are made on a case-by-case basis. If you anticipate or experience academic barriers due to a disability, please contact the Office of Disability Services for Students (DSS) (dss@rpi.edu; 518-276-8197) to establish reasonable accommodations. Once you have been approved for accommodations, please provide your Faculty Memorandum (a letter provided to students by DSS) to all faculty members at the very beginning of the semester. Please visit Disability Student Services website https://studenthealth.rpi.edu/list-services/disability-student-services for more details and/or updated information.