ECE 547/PHYS 581: Quantum Error Correction

Term: Spring 2026

Instructor: Milad Marvian (mmarvian@unm.edu)

Time: Tuesdays, Thursdays 14:00-15:15

Location: EECE-210

Credit hours: 3

Office hours: Mondays 5-6pm both in-person and on zoom;
Email me for additional hours.
Zoom: https://unm.zoom.us/my/marvian
Office: ECE 235-D

Course Description: Quantum computers have the potential to be more powerful than classical computers. For example, they can solve particular computational problems, such as integer factoring, exponentially faster than classical computers. But quantum computers are also extremely susceptible to noise. Therefore any successful implementation of quantum algorithms needs to deal with the effect of noise. Currently, this is the major obstacle to engineering large-scale reliable quantum computers.

In this course, we will cover the fundamentals of noisy quantum processes and will see how genuine quantum effects, such as entanglement, can be utilized to reduce the effect of noise. We will introduce frameworks to take advantage of the extremely successful theory of classical error correction codes in designing quantum codes. We will explore techniques to mitigate the noise on the currently available small-scale quantum system. We will also explore techniques to make large-scale quantum computers, that will become available in the future, fault-tolerant.

Basic knowledge of (pure state) quantum computation is expected (e.g. at the level of ECE 445/545: An Introduction to Quantum Computing). No prior knowledge of classical error correction is assumed.

Course Goals: The course will introduce students to the fundamentals of quantum noise channels, and the theory of quantum error correction and fault-tolerance.

Course Outline:

- The fundamentals of the theory of open quantum systems, quantum noise, and decoherence. Density operator formalism; quantum channels
- Examples of noise channels; Markovian and non-Markovian noise; Distances on quantum states and channels

- The Knill-Laflamme quantum error correction conditions
- Classical error correction; linear codes
- Quantum error correcting codes; CSS codes; stabilizer codes; subsystem codes
- Error prevention and mitigation schemes
- Quantum fault tolerance theory
- Topological codes
- Final project presentations

We will follow the following two references closely:

1- Surviving as a Quantum Computer in a Classical World, Daniel Gottesman, Available here

2- "Quantum Computation and Quantum Information" by Michael Neilson & Isaac Chuang.

Links to other resources will be provided on the course website.

Grading:

- 60%: Problem sets
- 40%: Final project

Problem sets: Expect around 10 problem sets. The lowest grade is not counted in the final score. A clean presentation of the solutions is evaluated and is part of the grading. Both Latex generated PDF or a clean scan of handwritten solutions (in one PDF file) are accepted. Discussions on the problem sets are encouraged. The final solution must be written individually, and any collaboration/discussion on the problem set needs to be acknowledged in the returned solutions.

Final project: The final project consists of an oral presentation (30 minutes) to the class accompanied by a written report (6 to 8 pages). A list of suggested projects will be provided, but students are encouraged to suggest the topic of their interest. The chosen topic needs to be confirmed by the instructor.

The goal of the final project is to carefully read two or three key papers related to the topic of your choice and present them to your classmates. The expectation is to be able to digest the basic concepts and the main questions that are answered in the paper, critically examine the assumptions and limitations, compare and contrast them to each other, and effectively present them to your classmates by connecting to the topics that have been discussed in the class, both orally and in written form. There will be a mid-point check-in meeting, where we will meet one-on-one for 30

min to discuss the progress and your plans. This will contribute to the grade of the final project. The expectation for this meeting is to have a good understanding of the motivation and questions that papers are trying to answer (without necessarily knowing the details of methods to answer them.)

A detailed feedback on both oral presentation and written report will be provided.

Grade distribution: Graduate students must earn a C or higher to earn credit for the course. Percentage breakdown to grading breakdown:

Score	>93	90-93	87-90	83-87	80-83	77-80	73-77	<73
Grade	A	A-	B+	B	B-	C+	C	F

Accommodations: UNM is committed to providing equitable access to learning opportunities for students with documented disabilities. As your instructor, it is my objective to facilitate an inclusive classroom setting, in which students have full access and opportunity to participate. To engage in a confidential conversation about the process for requesting reasonable accommodations for this class and/or program, please contact Accessibility Resource Center at arcsrvs@unm.edu or 505-277-3506.

UAP 2720 and 2740. Our classroom and university should foster mutual respect, kindness, and support. If you have concerns about discrimination, harassment, or violence, please seek support and report incidents. Find confidential services at LoboRESPECT Advocacy Center, the https://women.unm.edu/, and the LGBTQ Resource Center. UNM prohibits discrimination on the basis of sex (including gender, sex stereotyping, gender expression, and gender identity). All instructors are "responsible employees" who must communicate reports of sexual harassment, sexual misconduct and sexual violence to Compliance, Ethics and Equal Opportunity. For more information, please see UAP 2720 and UAP 2740.

Credit-hour statement: This is a three-credit-hour course. Class meets for two 75-minute sessions of direct instruction for fifteen weeks during the Fall 2025 semester. Please plan for a minimum of six hours of out-of-class work (or homework, study, assignment completion, and class preparation) each week.

(for Albuquerque undergraduate students only) Course Materials Access: Your digital course materials are directly available now on the My Shelf link in Canvas. Your physical course materials, such as books and required lab/studio course kits, are available at the UNM Bookstore, and you will receive an email about how to pick them up. To simplify your course materials access, you are automatically enrolled in a Complete option at a flat rate of $279 per semester. This will show

up on your bursar bill. The Complete option covers all your required course materials for all your Albuquerque campus courses, including any graduate courses you may be taking (branch campus course materials are billed and available separately). If you are interested in course materials access for only selected courses, or if you want to opt out entirely, you will need to select the option you want in the My Shelf link in Canvas. You can change your selected option in the My Shelf link in Canvas until the registrar's "Last Day to Drop Without a 'W' Grade and 100% Tuition Refund." Make sure that you review the video and information here to understand cost and the options for Complete (automatic enrollment), Select (take action), and Opt-out (take action).

Respectful Conduct Expectations: I am committed to building with you a positive classroom environment in which everyone can learn. I reserve the right to intervene and enforce standards of respectful behavior when classroom conduct is inconsistent with University expectations. Interventions and enforcement may include but are not limited to required meetings to discuss classroom expectations, written notification of expectations, and/or removal from a class meeting. Removal from a class meeting will result in an unexcused absence. Three or more unexcused absences may result in permanent removal and a drop from the course (see attendance policy). The University of New Mexico ensures freedom of academic inquiry, free expression and open debate, and a respectful campus through adherence to the following policies: D75: Classroom Conduct, Student Code of Conduct, University Policy 2240 – Respectful Campus, University Policy 2210 – Campus Violence.

Responsible Learning and Academic Honesty: Cheating and plagiarism (academic dishonesty) are often driven by lack of time, desperation, or lack of knowledge about how to identify a source. Communicate with me and ask for help, even at the last minute, rather than risking your academic career by committing academic dishonesty. Academic dishonesty involves claiming that work created by another source is your own original work. It is a Student Code of Conduct violation that can lead to a disciplinary procedure. When you use a resource in work submitted for this class, document how you used it and distinguish clearly between your original work and the material taken from the resource.

Thriving and Finding Support: Students are especially successful at UNM when they take advantage of support and get involved in campus and academic life. Your MyUNM login page provides direct links to wellbeing resources, including financial capability, mental health, food, jobs, and resource centers. MyUNM will help you identify academic resources like peer tutoring and opportunities like study abroad. You can contact academic advisors and resource advisors for information and guidance via Student Hub on MyUNM. I look forward to providing you with information about academic opportunities related to our class and to helping you find support resources.