Phys 572 Quantum Information Theory **Spring 2019**

Course Instructor: Professor Elizabeth Crosson **Email:** crosson@unm.edu

Office Location: Physics and Astronomy, Room 13

Lectures: Tuesday and Thursday 11:00am – 12:15pm , P&A Room 5

Office hours: Tuesday 1:00pm – 3:00pm, Friday 10:00am – 12:00pm , P&A Room 13

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This course is a theory-oriented introduction to Quantum Information Science intended for students in physics, computer science, electrical and computer engineering, and other natural sciences. To address such a wide audience, the course will rely on the universal language of mathematics to present the theory in a self-contained way. The main objectives are to learn the formalism of quantum mechanics, and apply it to compare and contrast classical and quantum information processing. A major theme throughout the course will be the perspective of *asymptotic complexity,* which examines the way that quantities of interest scale as the size of the system becomes large without bound.

Course Content

The first part of this course will introduce the mathematical formalism of quantum information theory, and then detail several of the fundamental protocols and possibilities within the theory which illustrate the way in which quantum and classical information processing differ. The second part of the course will focus on the connection between quantum physics and computational complexity, which provides a powerful modern perspective for understanding and characterizing the non-classical behavior of quantum systems. An outline of topics to be covered can be found below.

Part 1: Quantum Information Processing

- Axiomatic Quantum Mechanics
- Probability and Statistics
- Mixed States and Quantum Operations
- Classical Information Theory
- Entanglement Measures and Local Operations
- Bell's Inequality and Hidden Variable Theories
- Quantum Communication and Cryptography

Part 2: Quantum Physics and Complexity

- Quantum Many-Body Physics
- Local Hamiltonians and Quantum Computation
- Phases of Quantum Matter
- Entanglement in Quantum Ground States
- Classical and Quantum Computational Complexity
- The Local Hamiltonian Problem
- Classical Simulations of Quantum Systems
- Sampling Complexity and Quantum Supremacy

Reading Material. There are several free online resources that cover the topics in this course, and supplementary lectures notes will be distributed as necessary. Online resources include:

"Lectures notes on Quantum Information and Computation", J. Preskill
"From Classical to Quantum Shannon Theory", M. Wilde
"Quantum Information Meets Quantum Matter", B. Zeng, X. Chen, D.L. Zhou, X.G. Wen

The following optional textbook is also recommended for students seeking to master the subject:

"Quantum Computation and Quantum Information", M. A. Nielsen and I. L. Chuang

Course Policies

Prerequisites. This course assumes familiarity with linear algebra, but will otherwise introduce and define all concepts in a self-contained way. Previous experience with quantum mechanics is not required, however students with no prior experience in QM are encouraged to attend office hours and/or devote extra time in the beginning of the semester to learning the fundamentals of the theory.

Evaluation. There will be 4 graded homework assignments and no exams. Your course grade will be based on homework scores (80%) as well as attendance and participation in lectures (20%). Students on the credit / no-credit track will receive a "CR" grade for attending the lectures and showing interest.

Each homework will be assigned at least two weeks in advance of its due date. Homework must be turned in during lecture on the day it is due, and late homework will not be accepted without a prior written arrangement. Students are allowed to discuss problems and study together, but the work that you turn in should be solely your own. As with any mathematical subject, these problems represent the minimum effort that you should invest in order to learn the material. Sometimes additional optional problems will be recommended, and you are always encouraged to attempt additional problems in any of the texts listed above (and you are welcome to discuss these during office hours).

Lectures. Course attendance accounts for 20% of your grade and you are strongly encouraged to attend all lectures and actively participate by asking and answering questions in class. Lectures notes will be made available but they are no substitute for in-person attendance and participation. The course will move at a quick pace and so if you expect to be absent then let me know, and you are encouraged to attend office hours so that I can advise you on staying current with the course.

University Policies

Accommodations. In accordance with University Policy 2310 and the Americans with Disabilities Act (ADA), academic accommodations may be made for any student who notifies the instructor of the need for an accommodation. It is imperative that you take the initiative to bring such needs to the instructor's attention, as she is not legally permitted to inquire. Students who may require assistance in emergency evacuations should contact the instructor as to the most appropriate procedures to follow. Contact Accessibility Resource Center at 277-3506 for additional information.

Title IX. A Note About Sexual Violence and Sexual Misconduct: As a UNM faculty member, I am required to inform the Title IX Coordinator at the Office of Equal Opportunity (oeo.unm.edu) of any report I receive of gender discrimination which includes sexual harassment, sexual misconduct, and/or

sexual violence. You can read the full campus policy regarding sexual misconduct at https://policy.unm.edu/universitypolicies/2000/2740.html. If you have experienced sexual violence or sexual misconduct, please ask a faculty or staff member for help or contact the LoboRESPECT Advocacy Center.

Academic Integrity. Each student is expected to maintain the highest standards of honesty and integrity in academic and professional matters. The University reserves the right to take disciplinary action, up to and including dismissal, against any student who is found guilty of academic dishonesty or otherwise fails to meet the standards. Any student judged to have engaged in academic dishonesty in course work may receive a reduced or failing grade for the work in question and/or for the course. Academic dishonesty includes, but is not limited to, dishonesty in quizzes, tests, or assignments; claiming credit for work not done or done by others; hindering the academic work of other students; misrepresenting academic or professional qualifications within or without the University; and nondisclosure or misrepresentation in filling out applications or other University records.

Citizenship and/or Immigration Status: All students are welcome in this class regardless of citizenship, residency, or immigration status. Your professor will respect your privacy if you choose to disclose your status. As for all students in the class, family emergency-related absences are normally excused with reasonable notice to the professor, as not ed in the attendance guidelines above. UNM as an institution has made a core commitment to the success of all our students, including members of our undocumented community. The Administration's welcome is found on our website: http://undocumented.unm.edu/.