TOPICS: QUANTUM INFORMATION

Phys 396 Fall 2026

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Office Hours:	M 1-2pm, T 1 – 2pm, W 9 – 10am, Th 11am – 12noon, F 2 – 3pm
Class Meetings:	MWF 10:00am – 10:50am, WS 117
Course Website:	Phys 396 Website, Fall 2026
Required Text:	A. Al-Qasimi and D. F. V. James, *Quantum Information: A First Course,* Cambridge (2025).
Prerequisites:	Phys 231, and Math 236 or Math 260

Overview

Quantum information concerns how quantum systems can be used for information processing tasks in ways that are not possible for conventional, classical, systems and devices. During the last 40 years a wide variety of theoretical quantum information processing schemes have been developed. These include cryptographic key distribution protocols, algorithms that can factorize numbers efficiently, efficient methods for simulating real quantum systems such as complex molecules and sensing or measurement schemes offering an accuracy surpassing conventional protocols. Separately classical information theory has been adapted for quantum systems and used to assess communication and measurement tasks involving quantum systems and even inform our understanding of the foundations of quantum physics.

Recently, experimental realizations of quantum information processing have advanced rapidly and many private enterprises offer commercial quantum cryptography and computing platforms. Developing these requires understanding theoretical ideas in quantum information and a slew of experimental and computational techniques.

This course introduces you to the ideas of quantum information. It does not assume any knowledge of formal quantum physics and it will include a development of the key foundational ideas of quantum physics.

The course covers:

1. Basic ideas of classical computing.
2. Fundamentals of quantum physics.
3. Quantum cryptography and teleportation.

4. Quantum computing and algorithms.
5. Experimental implementations of quantum information processing.

Assignments

An undergraduate student should expect to spend on this course a minimum of two hours outside the classroom for every hour in the classroom. The outside hours may vary depending on the number of credit hours or type of course. More details are available from the faculty member or department office and in CMU's Curriculum Policies and Procedures Manual.

1. **Homework:** There will typically be one homework assignment per week. This will be due by 5:00pm on the date indicated on the assignment. Late homework will be subject to a penalty of at least a 2% reduction in maximum grade for each hour that the work is late. It is in your best interests to work by yourself on the homework problems but collaboration is acceptable. You can discuss the broad outlines of problem solutions with your colleagues but must write your final solutions independently. You are also encouraged to consult me for help with homework problems.

2. **Term paper:** There will be research/review paper due on Friday, December 4, 2026. The term paper will report on a single topic within the realm of quantum information beyond those covered in the lectures. A topic must be selected by Friday, October 30, 2026 and must meet with the instructor's approval.

3. **Presentation:** You will be required to give a short presentation on the topic that you have chosen for your term paper. As much as possible, you will present these during the final exam period, at **10:00am on December 7, 2026**.

Exams and Quizzes

1. **Class Exams:** There will be two exams during class on the following days:

   Exam 1: September 21, 2026
   Exam 2: October 19, 2026
   Exam 3: November 16, 2026

   Exams will be closed book and closed notes although you will be able to bring a formula sheet. Calculators will be allowed.

Grades

Individual assignments and exams will be graded using suitable scales. In general, to get full credit (100%) for a problem your solution must be correct and well justified. Partial credit will be given for incomplete or partly correct solutions. No credit (0%) will be given for problems not attempted, assignments not turned in or quizzes and exams missed without good reason.

The numerical grades for each component will be totaled and a final numerical grade will be computed according to the following distribution.

Homework	20%
Class Exams	45%
Term Paper	20%
Presentation	15%

The following final numerical scores will guarantee letter grades:

90%	A
80%	B
70%	C
60%	D

Policies

1. **Helpful Resources:** The Center for Academic Support (CAS) provides FREE tutoring and writing support across all disciplines to CMU and CMU Tech students in a variety of subject areas. Peer tutors are available to support your learning and help you with your questions. CAS offers four different tutoring options to students: in-person tutoring (one-on-one), online tutoring, group tutoring, and writing help. Check out the CAS website or or email tutoring@coloradomesa.edu with any questions.

   In coordination with Educational Access Services, reasonable accommodations will be provided for qualified students with disabilities. Students should contact Educational Access Services at 970-248-1856 or Houston Hall 108 as soon as possible. Please visit Educational Access Services for additional information.

2. **Withdrawals:** There are several ways to drop this course. The deadline for dropping without penalty is **September 1, 2026.** Please consult the CMU academic calendar and catalog for more details about adding and dropping courses.

3. **Attendance:** Attendance policies are described in the Maverick Guide. You are expected to attend all the class meetings and attendance will be recorded. In case of an absence due to illness, another emergency, or a conflicting CMU-sanctioned event, you must be able to produce the *appropriate documentation from someone other than you* that attests to the conflict or absence. If you miss a class for a *documented* valid reason, turn in any assignments due within two business days after the end of the documented absence period. If you miss more than half of the class meetings in the first week of the semester, you will be dropped from the course.

   The dates of the class exams and final exam are set at the beginning of the semester and these have priority over any other events. If you have an event that conflicts with these **and** that was scheduled before the start of the semester, you must notify the instructor about this prior to **August 21, 2026**, provide documentation from

someone other than you that attests to the event and I will arrange an alternative test time. If you notify the instructor about a conflict after **August 21, 2026**, the possibility of taking the test at an alternative time will depend on the nature of the conflict (e.g. illness, CMU athletic events, other emergencies). In this case you must explain the nature of the conflict to the instructor, provide documentation from someone other than you that attests to the conflict and the instructor will decide whether the absence warrants an alternative testing time or arrangement. Alternative testing times will be decided by the instructor.

4. **Academic Integrity:** You are expected to present your own work in assignments, exams and quizzes. Fabrication of data, plagiarism, and copying from any source, particularly in closed book exams, are serious violation of academic norms. CMU has extensive policies on these matters and penalties for infringement can be severe. For more details, consult the academic integrity policies in the Maverick Guide.

   You are prohibited from using sources, of any type, which provide solutions to homework assignment or exam problems. These include AI sources that generate solutions to homework problems. Students who are discovered to have submitted any assignment or exam problem to any such service that provides solutions or have used any such service to obtain or view solutions to any assignment or exam problem will receive zero credit for that entire assignment and the instructor will submit a Report of Academic Dishonesty with the Office of Academic Affairs. Additional penalties may be levied in such cases.

Objectives

1. Assign states to quantum systems, and use the states to describe measurement outcomes.
2. Evaluate how quantum systems evolve, using quantum gates.
3. Construct states for multiple quantum systems, evaluate these for the presence of entanglement, determine outcomes of measurements on these and assess the presence of correlations in outcomes.
4. Construct basic computational protocols, including function evaluation and oracle invocation, using quantum gates.
5. Describe and evaluate quantum cryptographic and computation protocols.
6. Describe how to construct basic quantum gates for selected physical platforms.

Schedule

The following schedule is tentative, except for the dates of the class exams.

Week	Dates	Topic
1	8/17– 8/21	Introduction to computing. Quantum states (Ch 2.1).
2	8/24 – 8/28	Vectors and matrices. Spin-1/2 quantum states and measurements (Ch 2.1).
3	8/31 – 9/4	Spin-1/2 quantum states and measurements. Single qubit states and measurements. (Ch 2.2).
4	9/7 – 9/11	Single qubit states and measurements. (Ch 2.2).
5	9/14 – 9/18	Quantum cryptography (Ch 12.1).
6	9/21	**Exam I**.
6	9/23 – 9/25	Evolution and gates (Ch 2.3 – 2.4).
7	9/28 –10/2	Evolution and gates (Ch 2.3 – 2.4).
8	10/5 - 10/7	Multiple qubits (Ch 3.1 - 3.2).
9	10/12 – 10/16	Multiple qubits. Teleportation (Ch 3.2, 3.4).
10	10/19	**Exam II**.
10	10/21 – 10/23	Function evaluation. Oracles (Ch 4.1–4.2).
11	10/26 – 10/30	Deutsch-Jozsa algorithm. Bernstein-Varizani algorithm (Ch 4.3 – 4.4).
12	11/2 – 11/6	Grover's algorithm (Ch 4.5).
13	11/9 – 11/13	Grover's algorithm (Ch 4.5).
14	11/16	**Exam III**.
14	11/18 – 11/20	Realizations (Ch 6.1 – 6.2).
15	11/30 – 12/4	Realizations (Ch 6.1 – 6.2).