MAT 399/599, CS 393/592/593 Syllabus

Semester:	Fall 2025
Course title:	Quantum Algorithms
Instructor:	Professor Matt Klassen
Email:	mklassen@digipen.edu
Phone:	(425) 895-4423
Office hours:	T,Th 10:00-11:30, or by appointment
Course Web Page:	http://azrael.digipen.edu/MAT399
Time/Place:	M,W 9:00-10:20, in CURIE

WEB PAGES AND MOODLE:

The Moodle page for MAT/CS 399/599 will contain a link to the course web page. The web page is the central repository for all course documents, including homework assignments. Updates to homework will be posted on the web page only. Scores for quizzes, homework, exams, and projects, will be posted through perl scripts on the course web page, as well as on the Moodle page. Additionally, the Moodle page will be used for chat, forums, and for submission of homework, projects, and quiz and exam scratch work.

MATERIALS:

Required Text: *Introduction to Quantum Algorithms*, by Johannes Buchmann. The course is based on this text, lecture material, notes, and homework.

Recommended References: *Quantum Computation and Quantum Information*, by Michael A. Nielsen and Isaac L. Chuang. *Mastering Quantum Computing with Qiskit*, by Devendrababu et al.

TARGET AUDIENCE:

This course is aimed at seniors in CS undergraduate programs and masters students in MSCS program.

BACKGROUND MATHEMATICS and CS:

Linear Algebra, Discrete Mathematics, strongly recommended

Recommended but not required: Algorithm Analysis, coding experience with python

COURSE DESCRIPTION:

This course explores the mathematical foundations of Quantum Algorithms with applications to quantum computing and programming. Topics include: classical computation, complexity, circuit models, Hilbert spaces and complex linear algebra, quantum states, qubits, quantum registers, unitary time evolution, quantum gates and circuits, measurement of quantum systems, geometry of unitary operators, controlled operators and gates, universal sets of gates, quantum complexity, algorithms of Deutsch and Simon, quantum Fourier transform, phase estimation, Shor's algorithm, quantum search and Grover's algorithm, linear systems and the HHL algorithm.

COURSE GOALS AND OBJECTIVES:

1) Students will learn some of the basic algorithms of quantum computation, including algorithms of Deutsch and Simon, quantum Fourier transform, phase estimation, Shor's algorithm, quantum search and Grover's algorithm, linear systems and the HHL algorithm.

2) Students will become familiar with basic concepts of classical computation, Hilbert spaces and complex linear algebra, quantum states, qubits, quantum registers, unitary time evolution, quantum gates and circuits, measurement of quantum systems, geometry of unitary operators, controlled operators and gates, universal sets of gates, and quantum complexity.

3) Students will solidify their knowledge of Linear Algebra and Calculus by using these subjects as tools to solve problems involving vector spaces of complex numbers, unitary transformations, and quantum gate implementation.

QUIZZES AND EXAMS:

Quizzes will be given periodically to test comprehension of lecture material. The lowest two quiz scores are dropped for the purpose of final grading. If a quiz is missed for any reason, the quiz will receive a zero. This way it is possible to miss two quizzes and not be penalized. The quizzes will last for approximately twenty minutes.

For multiplie choice quizzes and exams, please follow these procedures: Work out the quiz problems and circle your answers on the question sheet. When you are finished, transfer the answers to the answer sheet and then go to a web browser and enter the answers online. Under no circumstances are you allowed to discuss the quiz questions with any other student during the quiz or the data entry process. Your scores will be posted online by your student ID. Finally, there will be a Moodle submission box, where you should submit your written scratch work at the end of the quiz or exam.

There will be a midterm exam given during regular class hours, and a final exam. There are *NO* make up exams unless you have a *compelling and well documented reason* for missing a test.

Calculators are allowed on quizzes and exams.

HOMEWORK ASSIGNMENTS:

Homework will be assigned and posted on the web page and collected weekly. You are responsible for checking the web page and noting the assignments and the due date. You may work on homework together, as well as consult the tutors and the instructor. However, the final work that you turn in must be your own work.

COMPUTATIONAL RESOURCES:

Exercises in linear algebra implementation of quantum circuits will use python and IBM Qiskit. Students are encouraged to make an account through IBM's website and to familiarize themselves with python before the course begins if possible. Students are encouraged to do linear algebra and other calculations for the homework using a calculator or symbolic package such as SciLab. The symbolic algebra package SciLab is free and open-source, and is similar to MATLAB.

GRADING:

Homework	20%
Quizzes	20%
Project	20%
Midterm Exam	20%
Final Exam	20%

Grades will be determined based on total course percentage. Percentage scores will determine letter grades according to the scale: (in the worst case)

A: $93 - 100$, A-: $90 - 92.9$, B+: $87 - 89.9$, B: $83 - 86.9$, B-: $80 - 82.9$,

C+: $77 - 79.9$, C: $73 - 76.9$, C-: $70 - 72.9$, D: $60 - 69.9$, F: < 60

PROJECTS:

The full description of the programming project will be found on the course web page. Submission of projects should be in a zipped folder which contains source and executable and which can be uploaded on the Moodle page.

ACADEMIC INTEGRITY:

Academic dishonesty in any form will not be tolerated in this course. Cheating, copying, plagiarizing, or any other form of academic dishonesty (including doing someone elses individual assignments) will result in, at the extreme minimum, a zero on the assignment in question, and could result in a failing grade in the course or even expulsion from DigiPen.

All students are asked to help in promoting a culture of academic integrity by discouraging cheating in all forms.

TEAMS and STREAMING:

Students may request that an individual class be streamed to accommodate an illness which requires that they be off campus. Such a request must be documented and be sent to the instructor before class starts. Streaming is not for convenience or for other situations than those which are officially documented. If a student has questions about this they should contact Student Services for the description and requirements for official accommodations which can be used to justify requests for streaming of classes. At the beginning of each class, I will check to see if there are any official accommodations for streaming to be in effect. If there are not, then I will not stream.

If a student misses class without an accommodation, there are still ways to recover the course content. For example, a student may have a classmate who takes notes, or records the lecture as audio or video or a sequence of photos during the class. All recording methods are approved by the instructor, for the purpose of personal study, and may be shared between students. The only request is to please not post such materials online with public access.

In the case that a lecture is being streamed, students are welcome to record in Teams or to use OBS to record the live stream for later viewing. The Teams recordings can be very poor quality, both video and audio, so OBS is recommended.

GUEST LECTURES:

Various DigiPen faculty in CS and Physics have volunteered to give guest lectures in this course. Given the interdisciplinary nature of the subject, this will give an important perspective to topics in physics and computer science. In addition to these speakers, we have the possibility of engaging with our industry colleagues to tap some expertise in quantum computing.

DISABILITY STUDENT SERVICES:

If students have disabilities and will need formal accommodations in order to fully participate or effectively demonstrate learning in this class, they should contact the Disability Support Services Office at (425)629-5015 or dss[at]digipen[dot]edu. The DSS Office welcomes the opportunity to meet with students to discuss how the accommodations will be implemented. Also, if you may need assistance in the event of an evacuation, please let the instructor know.

RELIGIOUS ACCOMMODATION: DigiPen Institute of Technology provides reasonable accommodations to students who may be absent from activities or incur significant hardship due to religious holidays or observances. These holidays or observances must be part of a religious denomination, church, or religious organization, and the course instructor must be notified in writing during the first two weeks of the course. The institutes policy for grievances is published in the course catalog.

TENTATIVE WEEKLY TOPICS:

Week	Dates	Topics
1	Sep 2 - Sep 5	Overview of quantum algorithms, classical computation
2	Sep 8 - 12	complexity, circuit models
3	Sep 15 - 19	complex linear algebra, inner products, unitary matrices
4	Sep 22 - 26	quantum states, qubits, unitary time evolution
5	Sep 29 - Oct 3	quantum circuits and ancillary gates
6	Oct 6 - 10	geometry of unitary operators, controlled gates
7	Oct 13 - 17	universal sets of gates, quantum complexity
8	Oct 20 - 24	oracle complexity and Deutsch's algorithm
9	Oct 27 - Oct 31	Simon's algorithm
10	Nov 3 - Nov 7	quantum Fourier transform, phase estimation
11	Nov 10 - 14	Shor's algorithm
12	Nov 17 - 21	linear systems and the HHL algorithm.
13	Nov 24 - 26	quantum search and Grover's algorithm,
14	Dec 1 - Dec 5	quantum simulation
15	Dec 8 - 12	Final Exams