PHYS 4393/5393 Special Topics in Physics
Introduction to Quantum Computing

CRN: 20170(PHYS4393), 17446(PHYS5393)
Term: Fall 2022
Prerequisite: Quantum Mechanics, Linear Algebra

Lecture
Lecture hours: TR 8:00 am – 9:20 am
Location: Classroom Building C2303
Instructor: Prof. Yun-Pil Shim
Office: PSCI 121A
E-mail: yshim@utep.edu
Office hours: Flexible by appointment

Course Description and Objectives
This course provides a self-contained introduction to quantum information and quantum computing science. The course presents a quick review of quantum mechanics and linear algebra necessary to understand how quantum computing is different from classical computing and how it can be useful for solving complex problems. Basic ingredients of a quantum computer such as qubit, quantum gates, readout, coherence will be introduced, and simple quantum algorithms will be explained as examples of how quantum computing works. Various physical implementations of quantum computing devices and practical applications of such quantum computers will be discussed.

Upon completion of the course, the student should
1) be able to understand and use mathematical tools and basic quantum mechanics concepts.
2) be proficient with basic concepts of quantum computing, such as qubit, quantum gate, quantum circuit, quantum algorithm.
2) understand the difference between classical computing and quantum computing.
3) be able to explain the basic structures of simple quantum algorithms.
4) be able to explain what quantum advantage is expected with quantum information technology.
4) be familiar with mainstream quantum computing devices.

Textbook
Textbook is not mandatory, but strongly encouraged to get one:
Quantum Computation and Quantum Information by Michael A. Nielsen & Isaac L. Chuang
(10th Anniversary Edition)

Other references:
Quantum Computer Science by N. David Mermin
Qiskit textbook (https://qiskit.org/textbook/preface.html)

Communication
The main communication method is the Blackboard announcement and email.
When you email me, include the following: your name and UTEP ID, the course name and CRN
Do NOT use the Course Messages in Blackboard. I am not checking it.
Grading Policy:

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<tr>
<th>Component</th>
<th>Weight</th>
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<tbody>
<tr>
<td>Attendance</td>
<td>20%</td>
</tr>
<tr>
<td>Mid-term exam</td>
<td>20%</td>
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<tr>
<td>Final presentation</td>
<td>20%</td>
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<tr>
<td>Final report</td>
<td>20%</td>
</tr>
<tr>
<td>Homework</td>
<td>20%</td>
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The final grade will be determined by your score and the overall performance of the class. If your final score is:
- 90 or above: your grade will be A
- 80 or above and below 90: your grade will be B or better
- 70 or above and below 80: your grade will be C or better
- 60 or above and below 70: your grade will be D or better

Homework

Homework will be posted on Blackboard. See the weekly course schedule on the last page for the homework schedule.

Midterm exam

Midterm Exams (20%):
- The midterm exam will be on October 18.
- It will be on Blackboard.

Details about the midterm exam will be announced before the exam.

Final report and final presentation

You will choose one topic that you will independently learn through the semester. You will give a presentation to the class on the topic of your choice near the end of the semester. You will also submit a final report on the topic of your choice by the due date.

More details about the final report and the final presentation will be announced shortly.

Technology Requirements

Lectures are given person-to-person in the classroom, unless there is a change in the COVID-19 situation and the class is turned into online.

Course communication will be via email and Blackboard. Ensure your UTEP email account is working. Check the Blackboard for announcements.

When having technical difficulties, update your browser, clear your cache, or try switching to another browser.

IMPORTANT: If you encounter technical difficulties beyond your scope of troubleshooting, please contact the UTEP Help Desk ([https://www.utep.edu/technologysupport/](https://www.utep.edu/technologysupport/)) as they are trained specifically in assisting with the technological needs of students. Please do not contact me for this type of assistance. The Help Desk is much better equipped than I am to assist you!
Course Policies

COVID-19 Precautions:
Please stay home if you have been diagnosed with COVID-19 or are experiencing COVID-19 symptoms. If you are feeling unwell, please let me know as soon as possible, so that we can work on appropriate accommodations. If you have tested positive for COVID-19, you are encouraged to report your results to covidaction@utep.edu, so that the Dean of Students Office can provide you with support and help with communication with your professors. The Student Health Center is equipped to provide COVID 19 testing.

The Center for Disease Control and Prevention recommends that people in areas of substantial or high COVID-19 transmission wear face masks when indoors in groups of people. The best way that Miners can take care of Miners is to get the vaccine. If you still need the vaccine, it is widely available in the El Paso area. For more information about the current rates, testing, and vaccinations, please visit epstrong.org

Students with Disabilities:
If you have a disability and need classroom accommodations, please contact The Center for Accommodations and Support Services (CASS) at 747-5148, or by email to cass@utep.edu, or visit their office located in UTEP Union East, Room 106. For additional information, please visit the CASS website at https://www.utep.edu/student-affairs/cass/. Accommodations might include but are not limited to note takers, readers, or extended time on exams and assignments. Please take care of this as soon as possible and before the first exam.

Scholastic Integrity:
Academic dishonesty is prohibited and is considered a violation of the UTEP Handbook of Operating Procedures. It includes, but is not limited to, cheating, plagiarism, and collusion. Cheating may involve copying from or providing information to another student, possessing unauthorized materials during a test, or falsifying research data on laboratory reports. Plagiarism occurs when someone intentionally or knowingly represents the words or ideas of another as ones’ own. Collusion involves collaborating with another person to commit any academically dishonest act. Any act of academic dishonesty attempted by a UTEP student is unacceptable and will not be tolerated. All suspected violations of academic integrity at The University of Texas at El Paso must be reported to the Office of Student Conduct and Conflict Resolution (OSCCR) for possible disciplinary action. To learn more, please visit HOOP: Student Conduct and Discipline.
Course Overview and Weekly Schedule

Course overview

- **Overview**: introduction to quantum computing, brief history and prospect
- **Linear algebra for QC**: vector space, linear operators, inner product, eigenvectors, and eigenvalues
- **Quantum mechanics for QC**: postulates of QM, superposition, time evolution, unitary transformation, quantum measurement
- **Qubit**: qubit vs bit, superposition, Bloch sphere
- **Two qubits and entanglement**: two-qubit state, Bell state, entanglement
- **Quantum gates**: single- and two-qubit gates, quantum circuits
- **Simple quantum algorithms**: simple quantum algorithms (Deutche-Jozsa, Simon’s, …)
- **Quantum communication**: no-cloning theorem, quantum teleportation, quantum cryptography
- **Decoherence and errors in QC**: density matrix formalism, quantum error correction
- **Quantum algorithms**: quantum FT, quantum PE, Shor’s algorithm, Grover’s search algorithm
- **Quantum simulation**: Hamiltonian mapping, variational algorithms
- **Physical systems for QC**: semiconductor qubit, superconducting qubit, trapped ion qubit

Weekly Course Schedule (subject to change)

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<tr>
<th>Week</th>
<th>Dates</th>
<th>Lecture</th>
<th>Homework</th>
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<tr>
<td>Week1</td>
<td>Aug 23 &amp; Aug 25</td>
<td>Introduction, overview</td>
<td></td>
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<tr>
<td>Week2</td>
<td>Aug 30 &amp; Sep 1</td>
<td>Linear algebra review</td>
<td>Homework #1</td>
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<tr>
<td>Week3</td>
<td>Sep 6 &amp; Sep 8</td>
<td>Quantum mechanics review</td>
<td></td>
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<tr>
<td>Week4</td>
<td>Sep 13 &amp; Sep 15</td>
<td>Qubit and Bloch sphere</td>
<td>Homework #2</td>
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<tr>
<td>Week5</td>
<td>Sep 20 &amp; Sep 22</td>
<td>Two qubits and entanglement</td>
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<tr>
<td>Week6</td>
<td>Sep 27 &amp; Sep 29</td>
<td>Quantum gates &amp; quantum circuits</td>
<td>Homework #3</td>
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<tr>
<td>Week7</td>
<td>Oct 4 &amp; Oct 6</td>
<td>Simple quantum algorithms</td>
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<tr>
<td>Week8</td>
<td>Oct 11 &amp; Oct 13</td>
<td>Quantum Communications</td>
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<tr>
<td>Week9</td>
<td>Oct 18 &amp; Oct 20</td>
<td><strong>Midterm exam</strong>, Physical Qubit I</td>
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<tr>
<td>Week10</td>
<td>Oct 25 &amp; Oct 27</td>
<td>Physical Qubit I</td>
<td>Homework #4</td>
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<tr>
<td>Week11</td>
<td>Nov 1 &amp; Nov 3</td>
<td>Physical Qubit II</td>
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<tr>
<td>Week12</td>
<td>Nov 8 &amp; Nov 10</td>
<td>Physical Qubit II</td>
<td>Homework #5</td>
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<tr>
<td>Week13</td>
<td>Nov 15 &amp; Nov 17</td>
<td>Decoherence and Errors</td>
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<tr>
<td>Week14</td>
<td>Nov 22 &amp; Nov 24</td>
<td><strong>Final presentation</strong>, Thanksgiving</td>
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<tr>
<td>Week15</td>
<td>Nov 29 &amp; Dec 1</td>
<td>Quantum algorithms: Shor’s algorithm</td>
<td>Final Report Due</td>
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<td>Week16</td>
<td>Dec 6</td>
<td><strong>No Final Exam</strong></td>
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