# PHY 315, CS 316, EE 312: Introduction to Quantum Computing

Summer I, 2020-21

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| **Communication** | Zoom, LMS, and Email | **Office Address** | SSE, 9-119A |
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## Course Teaching Methodology

Online synchronous mode of teaching will be used using ZOOM. However, these live sessions will be recorded and available for later viewing. Programming sessions to develop quantum computer programs will be conducted online using zoom and DISCORD. Live class activities and assessments will take place via LMS, the learning management tool of LUMS.

## Course Information

**Description:** Quantum computers are the computers of future because they seem to be much faster than the current computers for many tasks. Many companies like IBM, Google, Microsoft are investing heavily to develop quantum computers and are making them available in the cloud at the initial stage. This course will be your first introduction and hands-on interaction with quantum computers. We will learn designing quantum algorithms and implementing them on actual quantum computers. The course is specifically designed for broader group of students to introduce quantum computer programming without requiring any previous knowledge of quantum physics. We will study algorithms to solve practical problems like searching a database, factoring prime numbers, optimization, etc. and demonstrate the quantum advantage over currently used classical computers. The algorithms will be implemented using QISKIT package in Python and students will learn to write the programs and run them on IBM's quantum computers. This course will also cover all the syllabus of recently announced IBM's certification exam for quantum developers.

**Pre-Requisite Knowledge:** We will need minimal previous background in quantum physics. However, some experience with programming a classical (current) computer will be helpful. Students are encouraged to familiarize themselves with python's Jupyter Notebook before starting the course.

**Mandatory Pre-Requisite Courses:**
**Undergrad Students:** PHY 104: Modern Physics & CS 100: Computational Problem Solving
**Graduate Students:** None

**Course Learning Objectives (CLOs):** After the course, you should be able to

1. Develop basic quantum algorithms and turn them into programs to run on actual quantum computer
2. Prove the quantum advantage using fundamental algorithms
3. Apply quantum algorithms to solve searching and prime factoring problems
4. Characterize and compare different quantum computers and analyze various sources of noises and errors in quantum measurements
5. Use quantum computer to distribute and interpret secure messages

## List of Topics

| Weeks | Topics | CLOs |
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| 1 | Qubits, Quantum Measurements, Single Qubit Gates, Multiple Qubit Gates, Phase Kickback, Quantum Circuit Model of Computation, Introduction to QISKIT, Bloch and Q Spheres | CLO1 |
| 2 | Entanglement, Qubit Teleportation, Deutsch—Jozsa, Bernstein—Vazirani, and Simon's algorithms demonstrating quantum advantage, Quantum Oracles, Programming IBM's Quantum Computer, | CLO2, CLO1 |
| 3 | Grover's Search Algorithm, Quantum Fourier Transform, Phase Estimation, Shor's Factoring Algorithm, HHL Algorithm for linear equations, Grover's Algorithm for Satisfiability Problems | CLO3, CLO1 |
| 4 | Superdense Coding, Quantum Key Distribution, Quantum Error Correcting Codes, Error Mitigation, Benchmarking Quantum Computers and Finding Quantum Volume, | CLO4, CLO5 |

## Books

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| Neilson & Chuang, Quantum Computation and Information, 2010 Edition | This is the bible of quantum computing, though it is getting old. I will be using parts of Ch. 4, 5, and 6. |
| Online Qiskit Textbook https://qiskit.org/textbook/preface.html | This is excellent resource with worked-out example codes that can be directly run. Easy to use for self-learning. I will be following it quite extensively as it has all the recent and important algorithms. |

## Class Logistics

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| **Live Lectures** | Five live sessions each week, each session of 110 minutes. We will have graded class activities and programming session during the class (Recording on Youtube) | Each live session is mandatory for students to attend as it will feature graded activities |
| **Home works** | One HW each week requiring students to write quantum programs using Jupyter Notebook. | Install anaconda distribution of python before start of the course |

## Assessments

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| **Home works** | 4 Assignments that include algorithm analysis and quantum programs | Total Weight: 30 % |
| **Class Activities** | Each class will usually have one activity. (Total 15 Activities) | Total Weight: 30 % |
| **Exams** | One Midterm exam on third Monday.<br>Final exam according to LUMS schedule. | Mid: 20 %<br>Final: 20% |
| **Grading** | Absolute Grading | A~88%, A-~83%, B+~77%<br>B~72%, B-~67%, C+~61%<br>C~56%, C-~51%, D~45% |

## Course Policies

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| Late/Missed Assignment | Late Assignments will be accepted with 10% deduction for each late day, with a maximum penalty of 50% |
| Missed Class Activity | Missed Activity will not be replaced. N-2 will be used on missed activities to account for unforeseen circumstances |
| Late Midterm/Final Exam | Late exams will be accepted with 20% penalty for each late hour |
| Disability/Sickness/Internet Access | Any disability, sickness, are chronic internet issues should be brought to instructor immediately, as soon as possible. Also, help can be sought from the office of student affairs (OSA) and office accessibility and inclusion (OAI). We will follow the policy of university and decisions made by the OSA accordingly. |
| Plagiarism/Cheating | Any discussion with and help from anybody else including from people remotely that directly solves the problems in assignments, quizzes, and exams is prohibited. However, students are allowed to take help from any notes/books. A violation of this policy in exams and assignments will result in referral to university's disciplinary committee. |

| Academic Honesty |
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| The principles of truth and honesty are recognized as fundamental to a community of teachers and students. This means that all academic work will be done by the student to whom it is assigned without unauthorized aid of any kind. Plagiarism, cheating and other forms of academic dishonesty are prohibited. Any instances of academic dishonesty in this course (intentional or unintentional) will be dealt with swiftly and severely. Potential penalties include receiving a failing grade on the assignment in question or in the course overall. For further information, students should make themselves familiar with the relevant section of the LUMS student handbook. |
| Harassment Policy |
| SSE, LUMS and particularly this class, is a harassment free zone. There is absolutely zero tolerance for any behaviour that is intended, or has the expected result of making anyone uncomfortable and negatively impacts the class environment, or any individual's ability to work to the best of their potential.<br>In case a differently-abled student requires accommodations for fully participating in the course, students are advised to contact the instructor so that they can be facilitated accordingly.<br>If you think that you may be a victim of harassment, or if you have observed any harassment occurring in the purview of this class, please reach out and speak to me. If you are a victim, I strongly encourage you to reach out to the Office of Accessibility and Inclusion at oai@lums.edu.pk or the sexual harassment inquiry committee at harassment@lums.edu.pk for any queries, clarifications, or advice. You may choose to file an informal or a formal complaint to put an end of offending behavior. You can find more details regarding the LUMS sexual harassment policy here.<br>To file a complaint, please write to harassment@lums.edu.pk. |
| SSE Council on Equity and Belonging |
| In addition to LUMS resources, SSE's **Council on Belonging and Equity** is committed to devising ways to provide a safe, inclusive and respectful learning environment for students, faculty and staff. To seek counsel related to any issues, please feel free to approach either a member of the council or email at cbe.sse@lums.edu.pk |
| Rights and Code of Conduct for Online Teaching |
| A misuse of online modes of communication is unacceptable. TAs and Faculty will seek consent before the recording of live online lectures or tutorials. Please ensure if you do not wish to be recorded during a session to inform the faculty member. Please also ensure that you prioritize formal means of communication (email, lms) over informal means to communicate with course staff. |