COURSE: ECE405C/ECE730-T37

COURSE TITLE: **Programming of Quantum Computing Algorithms**

INSTRUCTOR: Prof. Na Young Kim
Office: RAC1 2101, x30481
Office hours: TBD or by appointment via email
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Note: Do not use LEARN email to reach the instructor

LECTURES: ~22 Lectures M/F 1:00-2:20 pm, E7-4433 (01/06/-04/04/2025)
TUTORIALS only ECE405C W 7:00-7:50 pm, E7-4433

TA: TBA
TA OFFICE HOURS: TBD Location: TBD

DESCRIPTION

The course introduces basic elements to create quantum circuits in quantum computers: qubits, single-qubit gates, two-qubit gates, quantum operators, and measurements. The principles and practical aspects of quantum algorithms are covered. Students are expected to gain hands-on programming experience with a quantum programming language (e.g. Qiskit, q#, Pennylane) and to implement representative quantum circuits on quantum simulators or real quantum computers through a cloud service such as IBM Q experience, Microsoft Azure, or Xanadu.

COURSE OBJECTIVE

The course is developed for students to

- Learn the basic elements of quantum circuits;
- Learn the fundamentals of representative quantum algorithms;
- Learn how to program quantum circuits and quantum algorithms via quantum simulators or quantum cloud services;
- Learn how to analyze the results from quantum programming.

Prerequisite: ECE405 or an equivalent introductory-level Quantum Mechanics course

Expected Background: Python programming, Some familiarity with basic quantum information processing and basic quantum circuit models, Introduction to classical machine learning

(Tentative) **SYLLABUS**

1. **PART 1: Basics of Quantum Information Processing and Programming Interfaces** (4 weeks)
    a. Introduction to Quantum Computation
        i. Qubits and Quantum Gates
        ii. Density matrices and Quantum Parallelism
        iii. Quantum Circuits
        iv. Quantum Algorithms
        v. Computation complexity and Quantum advantages
    b. Introduction to Quantum Programming Interface
        i. Qiskit setup
        ii. Simple quantum programming
2. **PART 2: Fundamental Quantum Algorithms** (5 weeks)
    a. Simple Algorithms
        i. Deutsch-Jozsa
        ii. Simon
        iii. Hands-on Programming
    b. Quantum Fourier Transform (QFT) Algorithms
        i. Mathematical descriptions
        ii. Hands-on Programming
        iii. Applications: e.g. Shor's factoring algorithm

   c. Grover's Search Algorithms
      i. Mathematical descriptions
      ii. Hands-on Programming
      iii. Applications: e.g Matrix product verification
   d. Quantum Simulation Algorithms
      i. Mathematical descriptions
      ii. Hands-on Programming
      iii. Applications: e.g. Transverse Ising model simulation
3. **PART 3: Advanced Topics** (2 weeks)
   a. Quantum Error Correction
   b. Classical and Quantum Algorithm Comparison

TEXTBOOK AND RESOURCES

None required. Article handouts provided and lecture slides will supplement course lectures.
Qiskit tutorials for quantum programming: https://learning.quantum.ibm.com/

COURSE WEBSITE

The course homepage is on LEARN, where the course syllabus, lecture notes, and assignments are uploaded. Any important updates will be announced as well.

GRADE DISTRIBUTION

ECE730-T37
- **Assignments:** 30%
- **Final Project (Individual):** 40% (Presentation 20%, Final Report 20%)
    - This final project is to be completed individually. The presentation is expected to be a level of an oral presentation at an IEEE conference, and the term paper should follow the IEEE Transactions on Quantum Engineering Journal author guideline.
- **Final Exam**: 30%

ECE405C
- **Assignments:** 30%
- **Final Project (Team):** 20% (Presentation 20%)
    - This mini-project is to be completed by a team of two undergraduate students.
- **Final Exam:** 50%

- **Assignments/Lab Reports:** 30%
  Late Policy
  $S(t) = S(0)*(10-t)*0.1$ if $t < t_s$ or $S(t) = 0$ if $t > t_s$,
  where $t = 0$ is the due date, t is the turn-in date, and t_s is the feedback posting date.
  An exception to this policy can be made in special circumstances by contacting the instructor in advance. Note that any evidence violating the Honor code (e.g. plagiarism, copying etc.) will yield $S(t) = 0$ regardless of t.
- **Final Project:**
    - **ECE405C 20%** - Team
    - **ECE730T37 40%** - Individual
    - **Final Presentation (TBD: MM/DD/YYYY) - ECE405C/ECE730T37**
        - Present the final project results in an IEEE conference-contributed talk format.
    - **Final Report (TBD: Due: MM/DD/YYYY) - ECE730T37**
        - IEEE Transactions on Quantum Engineering Journal Paper Style.
- **Final Exam**: In-class, closed-book
    - ECE405C: 50%
    - ECE730T37: 30%

UW POLICY 71-STUDENT DISCIPLINE

https://uwaterloo.ca/secretariat/policies-procedures-guidelines/policy-71

We honor this policy throughout the course.