TO: The Faculty of the College of Engineering

FROM: Elmore Family School of Electrical and Computer Engineering

RE: New Graduate Course, ECE 50650 Applied Quantum Computing 1 - Fundamentals

The faculty of the School of Electrical and Computer Engineering has approved the following new course. This action is now submitted to the Engineering Faculty with a recommendation for approval.

ECE 50650 Applied Quantum Computing 1 - Fundamentals
Sem. 2, Lecture 3, Cr. 1, 5 weeks.
Prerequisite: MA 26500 or MA 26200, PHYS 17200
Prerequisites by Topic: Undergraduate linear algebra, differential equations, physics, and chemistry

Description: This fundamentals course is part 1 of the series of quantum computing courses and covers aspects from fundamentals to present-day hardware platforms to quantum software and programming. This course provides the essential foundations required to understand computing models built from the principles of quantum mechanics. This course requires a minimal set of engineering and science prerequisites but will allow students to develop a physical and intuitive understanding of the topics.

Reason: This is an introductory course in applied quantum computing aimed at students want to enter the field. The course is offered as part of the Quantum MicroMasters program through edX. This course focuses on computing aspects quantum technologies and complements other quantum courses developed in ECE.

Course Enrollment History: Spring 2021 – 56, Spring 2022 – 53, Spring 2023 – 55, Spring 2024 - 71

T.S. Mithuna [signature]

Mithuna Thottethodi,
Associate Head for Teaching and Learning
Elmore Family School of Electrical and Computer Engineering

ECE 50650 Applied Quantum Computing I- Fundamentals

Spring 2024

Instructor(s) Contact Information

- **Name of instructor:** Pramey Upadhyaya
    - Assistant Professor Electrical and Computer Engineering, Purdue University
    - Email: prameyup@purdue.edu
    - Purdue Engineering Webpage

Course Description

- **Description:** This fundamentals course is part 1 of the series of quantum computing courses and covers aspects from fundamentals to present-day hardware platforms to quantum software and programming. This course provides the essential foundations required to understand computing models built from the principles of quantum mechanics.
- **Prerequisites:** Undergraduate linear algebra, differential equations, physics, and chemistry
- **Estimated effort:** 7-8 hours/week; 5 weeks
- **Outline by topical areas:**
    - Postulates of quantum mechanics
    - Gate-based quantum computing
    - Quantum errors and error correction
    - Adiabatic quantum computing
    - Quantum applications and NISQ-era

Learning Outcomes

- Learn the fundamental postulates of quantum mechanics and how they can be mapped onto present-day quantum information processing models

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Learning Resources, Technology & Texts

Required texts and materials:

- None required, lecture videos and handouts will serve as the main material

Recommended:

- Nielsen, M., & Chuang, I. (2010). Quantum Computation and Quantum Information: 10th Anniversary Edition. Cambridge: Cambridge University Press doi:10.1017/CBO9780511976667
- Qiskit

References:

- The course draws from a wide array of references that will be mentioned throughout the lectures.

Computer requirements:

- We will primarily use GNU Octave for statistical calculations. The software is available under GNU General Public license. GNU Octave is a Scientific Programming Language that is free and largely compatible with MATLAB. Octave runs on PCs, Mac and Linux, and uses the same function names as MATLAB and runs many scripts without modification.

Assignments

- **Homework:**
  - A total of 4 homework will be assigned over the semester. The assignments are meant to help understand concepts and provide practice for the tests.
- **Exams:**
  - Two exams, each 90 minutes long.
  - Exams will test your ability to synthesize the material learned in class and practiced in the homework.
  - Exams may not be identical in form to the homework.
  - There will not be a comprehensive final exam.
  - Exams will be **proctored** and timed.

  - **Refer to the course section, *Taking Exams in ECE 595*, for required Proctortrack onboarding task.**

- **Evaluation criteria:**

Assignment	Percent of Course Grade
Homework (equally weighted)	15% of course grade
Proctored exams (equally weighted)	85% of course grade

- **Late work policy:** Late work will be accepted, however, a penalty of 10% will be assessed for each day the assignment is late. This late penalty will not be assessed if you have a special situation such as illness.

Grading Scale

A+ = 93-100%	A = 90-93%	A - = 87-90%
B+ = 83-87%	B = 80-83%	B - = 77-80%
C+ = 73-77%	C = 70-73%	C - = 67-70%
D+ = 63-67%	D=60-63%	D - = 57-60%
F = 57% and below		

Course Help

- **Technical difficulties:** If you experience technical difficulties with the edX platform, contact edX Support using the Contact Us form in the Connect section at the bottom of your screen.
- **Course content issues:** If you experience any issues with course content, post your concern or question to the discussion forum.
  - **Verified track** students will have access to the course Piazza discussion forum.
  - **Audit track** students may contact edX support using the Contact Us form.
- **For general questions** about using the edX platform, we recommend viewing the edX Demo Course.
- **Other edX Resources**
  - Technical Help
  - Learner Help Center

Discussion Guidelines

Please follow these guidelines when contributing to the Piazza forum in this course.

- Do not use offensive language. Present ideas appropriately.
- Be cautious in using the Internet language. For example, do not capitalize all letters since this suggests shouting.
- Avoid using vernacular or slang language. This could possibly lead to misinterpretation.
- Do not hesitate to ask for feedback.
- Be concise and to the point.
- Think and edit before you push the "Send" button.

Academic Integrity

Academic integrity is one of the highest values that Purdue University holds. Individuals are encouraged to alert university officials to potential breaches of this value by either emailing or by calling 765-494-8778. While the information may be submitted anonymously, the more information that is submitted provides the greatest opportunity for the university to investigate the concern.

The Purdue Honor Pledge

"As a Boilermaker pursuing academic excellence, I pledge to be honest and true in all that I do. Accountable together - we are Purdue"

Nondiscrimination Statement

Purdue University is committed to maintaining a community which recognizes and values the inherent worth and dignity of every person; fosters tolerance, sensitivity, understanding, and mutual respect among its members; and encourages each individual to strive to reach his or her own potential. In pursuit of its goal of academic excellence, the University seeks to develop and nurture diversity. The University believes that diversity among its many members strengthens the institution, stimulates creativity, promotes the exchange of ideas, and enriches campus life.

Purdue's Nondiscrimination Policy Statement

Diversity & Inclusion

In our discussions, structured and unstructured, we will principally engage in challenging technical issues. The specific lens in which the issues are viewed and perceived as well as the engagement in discussions, depend on each individual's past personal experiences. everyone should remember the following points:

- We are all in the process of learning about others and their experiences. Please speak with me, anonymously if needed, if something has made you uncomfortable.
- Intention and impact are not always aligned, and we should respect the impact something may have on someone even if it was not the speaker's intention.
- We all come to the class with a variety of experiences and a range of expertise, we should respect these in others while critically examining them in ourselves.

Accessibility

Purdue University strives to make learning experiences as accessible as possible. If you anticipate or experience physical or academic barriers based on disability, you are welcome to let me know so that we can discuss options.

- Instructor: Professor Pramey Upadhyaya
- Email: prameyup@purdue.edu

Disclaimer

This syllabus is subject to change.

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AQC I: Fundamentals Schedule (SPR '23)

Week	Lecture Topic	Graded Assessments (verified students only)
1 1/9 - 1/15	**Module 1: Quantum Postulates: Closed System** L 1.0 Overview: Module 1 L1.1 Postulate 1: How to Describe Q-states? L1.2 Example: (Q-bit/Spin) L1.3 Postulate 2: How Do Q-States Evolve? L1.4 Example: Quantum Gate/Spin in Magnetic Field—NOT & Hadamard L1.5 Postulate 3: How to Extract Information? L1.6 State Measurement L1.7 Example: Measuring Q-bits/Spins L1.8 Example: Stern-Gerlach Experiment L1.9 Postulate 4: How Do Q-Systems Combine? L1.10 Example: Entanglement	Proctortrack Onboarding (verified students only) **Due:** Wednesday, 1/18, 11:59 PM ET (1/19, 04:59 UTC) **Homework 1** **Assigned**: Monday, 1/9, 12:00 AM ET (05:00 UTC) **Due**: Wednesday, 1/18, 11:59 PM ET (1/19, 04:59 UTC)
2 1/16 - 1/22	**Module 2: Quantum Postulates: Open System** L2.0 Overview: Module 2 L2.1 Quantum Ensembles L2.2 Revisit Postulate 1&3: Density Matrix Language L2.3 Example: Density Matrix for Qubits /Spins L2.4 Example: Ensemble Measurements of Qubits/Spin L2.5 Revisit Postulate 4: Density Matrix Language L2.6 Revisit Postulate 2: Density Matrix Language L2.7 Example: Evolution of Qubit Interacting with Environment- Phase Damping L2.8 Example: Quantum Errors— Phase-Flips L2.9 Example: Types of Quantum Errors	**Homework 2** **Assigned:** Monday, 1/16, 12:00 AM ET (05:00 UTC) **Due**: Wednesday, 1/25, 11:59 PM ET (1/26, 04:59 UTC)

Week	Lecture Topic	Graded Assessments (verified students only)
3 1/23 - 1/29	**Module 3a: Q-Gate Model: Closed System** L3.0 Overview: Module 3 L3.1 From Postulates to Q Circuits-I L3.2 From Postulates to Q Circuits-II L3.3 Example: No Cloning Theorem L3.4 Example: Entangle/Disentangle Circuit L3.5 Example: Q-Teleportation L3.6 Gate Model: Universal Q Computing L3.7 Why Build Q-Computer-I L3.8 Why Build Q-Computer-II L3.9 Why Build Q-Computer-III	**Homework 3** **Assigned:** Monday, 1/23, 12:00 AM ET (05:00 UTC) **Due:** Wednesday, 2/1, 11: 59 PM ET (2/2, 04:59 UTC) **Proctored Exam 1** (To cover modules 1 and 2) **Assigned:** Thursday, 1/26, 12:00 AM ET (05:00 UTC) **Due:** Saturday, 1/28, 11:59 PM ET (1/29, 04:59 UTC) • Timed: 90 minutes
4 1/30 - 2/5	**Module 3b: Q-Gate Model: Error Correction** L3.10 Classical vs Quantum Error Correction (QEC) L3.11 Example 1: Two-Qubit Bit Flip Code L3.12 Example 2: Three-Qubit Bit Flip Code L3.13 Example 3: Three-Qubit Phase Flip Code L3.14 Example 4: Shor's Code L3.15 Practical Considerations for QEC **Module 4: Adiabatic Q-Computing (Part 1)** L4.0 Overview: Module 4 L4.1 Spin in Rotating Magnetic Field: Adiabatic Evolution L4.2 Adiabatic Theorem & Adiabatic Q-Computing (AQC)	**Homework 4** **Assigned:** Monday, 1/30, 12:00 AM ET (05:00 UTC) Due: Wednesday, 2/8, 11: 59 PM ET (2/9, 04:59 UTC)

Week	Lecture Topic	Graded Assessments (verified students only)
5 2/6 - 2/12	**Module 4: Adiabatic Q-Computing (Part 2)** L4.3 Example: 2-Bit Disagree and Gate-Model L4.4 Example: Quantum Annealing **Module 5: Road Toward Fault Tolerance: NISQ & Beyond** L5.0 Fundamentals: Summary and Outlook L5.1 Quantum Supremacy Experiments L5.2 NISQ-Era Computing	**Proctored Exam 2** (To cover modules 3 and 4) **Assigned:** Thursday, 2/9, 12:00 AM ET (05:00 UTC) **Due:** Saturday, 2/11, 11: 59 PM ET (2/12, 04:59 UTC) • Timed: 90 minutes
	Course closes	Sunday, February 12, 11:59 PM ET (2/13, 04:59 UTC)
	Certificates available	Saturday, February 18, 2022