TO: The Faculty of the College of Engineering

FROM: Elmore Family School of Electrical and Computer Engineering

RE: New Graduate Course, ECE 50435 Introduction to Quantum Science and Technology

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 50435 Introduction to Quantum Science and Technology
Sem. 1, Lecture 3, Cr. 3.
Prerequisite: (MA 26500 and MA 26600, or MA 26200) and ECE 30100 and ECE 30411; OR graduate student standing

Description:
This course introduces engineering students with no background in quantum mechanics to the fundamental concepts of quantum physics and how these principles are being used to create revolutionary quantum information technologies. The course aims to develop an understanding of quantum phenomena and identify engineering challenges and opportunities of various quantum information technologies. Topics covered include the fundamentals of quantum mechanics, the quantization of electrical circuits and electromagnetic fields, and the interactions between (artificial) atoms and electromagnetic fields. These topics are discussed in the context of popular hardware platforms and how they can be harnessed to create quantum computers, quantum communication systems, and quantum sensing systems.

Reason:
This course is essential training for many research groups and is a popular elective among online students interested in this emerging field.

Course History: Fall 2021 – 5, Fall 2022 – 9, Fall 2023 – 13, Fall 2024 – 35

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

PURDUE UNIVERSITY | Elmore Family School of Electrical and Computer Engineering

ECE 50435: Introduction to Quantum Science & Technology
Fall 2024

Class

Instructional Modality: Face-to-Face & Online Asynchronous
Face-to-Face Lecture: TuTh 9:00 - 10:15 AM
Location: WANG 2579

Each lecture will be held in person. Recordings of the lectures will be professionally produced by campus staff and posted on Brightspace for all students (in-person and online). It is expected in-person students will make every effort to attend class in person rather than relying on the lecture recordings.

Course Description

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Course Credit Hours

3.00

Prerequisite

(PHYS 241 or PHYS 272) and (MA 26500 and MA 26600, or MA 26200) and (ECE 30100) and (ECE 30411)

Professor

Thomas E. Roth
Office: WANG 3063
Ph: 765-496-5308
Email: rothte@purdue.edu

When emailing me about this course, please use your official Purdue email address. Further,

when starting a new email chain please begin the email subject line with [IQST] (including the square brackets) to help me be able to respond to you as promptly as possible.

Graduate Teaching Assistant

Shoaib Mahmud
Email: mahmud1@purdue.edu

Office Hours

Tu – 2:00 PM - 3:00 PM (Prof. Roth)
Tu – 7:00 PM - 8:00 PM (Prof. Roth, Zoom only)
W – 1:00 PM - 2:00 PM (Prof. Roth)
W – 8:00 PM - 9:00 PM (GTA, Zoom only)
Sa – 10:00 AM - 11:00 AM (GTA, Zoom only)

Prof. Roth's office hours will be held in-person in WANG 3063 and via a synchronous session (through Zoom) unless specified otherwise to discuss questions related to weekly readings, assignments, or projects. All times are in US Eastern time zone. The Zoom meeting information for Prof. Roth's office hours is included below.

Prof. Roth's Zoom: Meeting ID is 707 064 7734 and the Passcode is 47906.
GTA's Zoom: Meeting ID is 629 523 7709.

If you feel that you need to meet with Prof. Roth individually regarding this course, please schedule a time with him via email where you include a short description about the need for the meeting outside of normal office hours.

Required Textbook

- D. A. B. Miller, *Quantum Mechanics for Scientists and Engineers*, Cambridge University Press, 1st ed., 2008.

Additional References

- PDF of handwritten notes from each lecture, posted with the lecture number and date on Brightspace.
- Weekly typeset lecture notes, posted with week number at the end of the week on Brightspace.
- Recordings from each lecture, posted on Brightspace.
- Full lecture notes from a prior semester's 300-level version of this course can be found at the link below if you would like to prepare ahead of class for some topics. Similar content will be covered in this course, although at greater depth and breadth.
  Link: https://nanohub.org/resources/38552
- D. J. Griffiths and D. F. Schroeter, *Introduction to Quantum Mechanics*, Cambridge University Press, 3rd ed., 2018.
- M. Fox, *Quantum Optics: An Introduction*, Oxford University Press, 2006.
- M. A. Nielsen and I. L. Chuang, *Quantum Computation and Quantum Information: 10th Anniversary Edition*, Cambridge University Press, 2011.

Course Outcomes

A student who successfully fulfills the course requirements will have demonstrated an understanding of:

1. Apply fundamental quantum mechanical principles to analyze simple quantum systems
2. Analyze the properties of quantum electrical circuits and electromagnetic fields
3. Analyze the interactions between (artificial) atoms and classical and quantum electromagnetic fields
4. Use engineering judgement to assess the capabilities and challenges of revolutionary quantum technologies

You will have more than one opportunity to satisfy each of the Course Outcomes. The primary means will be through the exams and course project. Questions will be written for each exam around each of the Course Outcomes. You will satisfy each Course Outcome when your score for the test question(s) or project equals or exceeds a value specified as representing a minimal competency (generally, a 70%). If you fail to meet this level of minimal competency on a specific Course Outcome, you will have a second chance to demonstrate attainment of the learning outcomes using a method deemed appropriate by the instructor (e.g., solving additional problems).

Course Outline

A detailed summary of each lecture's content will be updated throughout the semester on Brightspace.

Grading

Homework	20 points
Exam #1	30 points
Exam #2	30 points
Final Project	20 points
Total	**100 points**

We will use the plus/minus grading system with standard lines drawn between different grade levels in determining final course grades. In general, Prof. Roth only applies a small curve to the final grades in his courses (usually around 2 - 3% boost). Do not expect a large curve at the end of the class.

Homework

Homework assignments will typically be assigned on a weekly basis and be due on Thursday's prior to the start of class. As a general rule, late homework will be accepted for 3 days after the original due date (so if an assignment is due at 8:00am on Thursday it will stop being accepted for points at 8:00am on Sunday). A penalty of 20% will be deducted off the total achieved score for each day it is late (i.e., 1 day late = 20% deduction, 2 days late = 40% deduction, and so on). **Note:** Prof. Roth is strict on assignment due dates. If the assignment is late by 1 minute, it will suffer the associated late penalty.

Please write your solutions legibly and in an organized manner so that the grader can follow your work easily, and, where possible, draw a box around your final answer.

You may work together as you solve your homework problems, as this can be an effective means of learning the material. If you do work in a group, be sure that the solution you turn in is your own work. This is the only way to learn the material. All people submitting identical copies of a solution will receive zero credit.

Homework assignments will be distributed through Brightspace. Student submissions of completed assignments will also be collected through Brightspace. All solutions to a homework assignment should be assembled into a single PDF document and uploaded to Brightspace. Please name your files with the following format: "firstname_lastname_hw#" where "#" should be replaced with the homework number you are submitting. If you have technology concerns for being able to submit assignments in this way, please email me during the first week of the course so we can discuss alternatives.

Final Project

Depending on the total number of students in the course, individual students or student teams will be formed to research a topic relevant to the course. Each student/team will prepare a presentation to teach the class about their research topic. Topics will be determined approximately two-thirds of the way through the course and the final presentations will be conducted either during the last week of classes or during finals week. Grades will be determined based on a detailed grading rubric that will be distributed when the project is assigned.

Hardware and Software Requirements

Certain homework assignments will require writing simple programs in software like Python or Matlab to facilitate investigating certain effects that are tedious to solve by hand. You will need to have access to computer hardware and software of your choice to be able to complete these mathematical computations. None of these computations will be "intense", so standard laptops or computing resources provided by your department should suffice.

Exam Schedule

All exams will use a take-home format and you will have approximately 1 week to complete the exam. Late exams will suffer the same penalties as late homework assignments, with 20% deduction per day late up to a max of 3 days late.

The *tentative date* and time provided is for availability. More exact dates will be conveyed via class announcements and on Brightspace as we reach those points in the semester.

Event	**Date**
Exam 1	Thursday, October 3
Exam 2	Thursday, November 7

Requirements, Availability, and Submission Procedure for Exams

As mentioned previously, a take-home format will be used for all exams. Along with this format is the expectation that this exam will take *longer* to complete than a traditional in-person exam. Ensure that you start your exams early so that you have plenty of time to complete them before the submission deadline.

The exams will be open book. This means that you can use any information that is available, but are not allowed to get support from another person (with the exception of the instructor) related to the solution of any of these problems. There will be a statement on the front page

of the exam booklet that you must sign that will state that this is your work and that you did not collude in the preparation of your solutions.

All questions about the exam should be asked as *private posts* on Piazza. If the instructor feels the question and answer should be made available to all students, they will do so.

These exams will be available as a PDF on Brightspace at the stipulated time and date indicated on Brightspace. Submission of the exams will follow the same approach as homework assignments discussed above.

Exam Regrade Policy

If you believe an error was made in grading your exam, a request for a regrade must be filed with your professor within *one week* after the exam has been returned. No such requests will be honored after the one-week deadline has passed. Do not mark on the original exam.

Use of AI in this Class

You are not allowed to use any AI tool as a replacement/substitute for you writing your own code, solving homework or exam problems, or preparing parts of a final presentation. The purpose of the course activities are for you to build your skills in these areas. There is no true substitute for growing these skills except through intentional practice. Although AI tools (like large-language models) can potentially aid in this process over time, our focus here is on your direct skill development related to effectively communicating scientific concepts.

Teaching Philosophy

The content covered in this course is quite broad and can be challenging to learn due to how unfamiliar many concepts from quantum physics are to us. To deal with these unfamiliar concepts, we will discuss foundational experimental evidence to reinforce the outcomes of "weird" quantum effects where possible, and emphasize the intuition behind the mathematical tools we use to process and interpret results. Further, we will follow a careful, axiomatic development of the foundational formalism of quantization to build a solid understanding of how to develop a quantum description of a physical system. Although the lecture notes attempt to walk through the derivations in as detailed of a manner as possible, when learning quantum physics for the first time there is no substitute for working through the concepts on your own. As a result, the homework is absolutely essential in connecting concepts together and helping you take the next steps in understanding the course material.

How to Excel in this Class

Success will be fostered by active participation in class, by taking good notes and reviewing this material, and by considering how to apply this material in the solution to all homework problems. Working through these concepts yourself is absolutely essential to learning the content of this course, and so fully completing each homework assignment is incredibly important to your success in this course. You are strongly encouraged to start your homework early and to regularly attend office hours to maximize your performance on the assignments. In addition to this, reviewing the detailed homework solutions that are posted on Brightspace is also essential to make sure that you understand any mistakes in your homework solutions.

Class Attendance

Students are expected to attend all classes in person throughout the course of the semester. Engaging with the course lectures is extremely important to your overall success in the course.

If you miss class, you are still responsible for any material, information, handouts, announcements, etc. you may have missed.

In addition to this, there will periodically be short unannounced attendance quizzes throughout the semester that will contribute toward your final grade as extra credit or a dropped homework score. To receive the extra credit, you will need to be in attendance for 7 of the 10 attendance quizzes. Online students will receive this grade boost if they watch all lectures.

Class Schedule

While possible, class will be held at the published times in the published room. In line with the university's official academic calendar, we will not have class or assignments due during the Fall or Thanksgiving breaks.

Brightspace Page

You can access the course via Brightspace. It is strongly suggested that you explore and become familiar not only with the site navigation, but with content and resources available for this course. See the Help tab for resources.

Piazza Page

This term we will be using Piazza for class discussion. The system is highly catered to getting you help fast and efficiently from classmates and myself. Rather than emailing technical questions to the teaching staff, you are **required** to post your questions on Piazza. You may post questions privately to the instructor if you are concerned the question is too detailed to be shared with the entire class.

Find our class signup link at: https://piazza.com/purdue/fall2024/ece59500iqst

Academic Integrity

I take academic dishonesty very seriously and reserve the right to apply penalties as I see fit within my course. This includes penalties up to a grade of F in this course. I will file an official report with the Office of the Dean of Students in all cases of suspected academic dishonesty.

Purdue's 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."

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 integrity@purdue.edu or by calling 765-494-8778. While information may be submitted anonymously, the more information is submitted the greater the opportunity for the university to investigate the concern. More details are available on our course Brightspace under University Policies.

Course Evaluation

During the last two weeks of the semester, you will be provided with an opportunity to give feedback on this course and your instructor. Purdue uses an online course evaluation system. You will receive an official email from evaluation administrators with a link to the online evaluation site. You will have up to 10 days to complete this evaluation. Your participation is an integral part of this course, and your feedback is vital to improving education at Purdue University. I strongly urge you to participate in the evaluation system.

Copyrighted Materials

See the University Policies and Statements section of Brightspace for guidance on Use of Copyrighted Materials. Effective learning environments provide opportunities for students to reflect, explore new ideas, post opinions openly, and have the freedom to change those opinions over time. Students and instructors are the authors of the works they create in the learning environment. As authors, they own the copyright in their works subject only to the university's right to use those works for educational purposes Students may not copy, reproduce, or post to any other outlet (e.g., YouTube, Facebook, or other open media sources or websites) any work in which they are not the sole or joint author or have not obtained the permission of the author(s).

Attendance Policy

This course follows the University Academic Regulations regarding class attendance, which state that students are expected to be present for every meeting of the classes in which they are enrolled. However, attendance will not be taken in class. When conflicts or absences can be anticipated, such as for many University-sponsored activities and religious observations, you should inform me of the situation as far in advance as possible. For unanticipated or emergency absences when advance notification to is not possible, contact, me as soon as possible by email or phone. For cases that fall under excused absence regulations, you or the your representative should contact or go to the Office of the Dean of Students (ODOS) website to complete appropriate forms for instructor notification. Under academic regulations, excused absences may be granted by ODOS for cases of grief/bereavement, military service, jury duty, parenting leave, or emergent medical care.

Nondiscrimination Statement

Purdue University is committed to maintaining a community that 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 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. A hyperlink to Purdue's full Nondiscrimination Policy Statement is included in our course Brightspace under University Policies and Statements.

Accessibility

Purdue University is committed to making learning experiences accessible. 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. You are also encouraged to contact the Disability Resource Center at: drc@purdue.edu or by phone: 765-494-1247.

Basic Needs Security

Any student who faces challenges securing their food or housing and believes this may affect their performance in the course is urged to contact the Dean of Students for support. There is no appointment needed and Student Support Services is available to serve students 8 a.m.-5 p.m. Monday through Friday.

Mental Health Statement

If you find yourself beginning to feel some stress, anxiety and/or feeling slightly overwhelmed, try Therapy Assistance Online (TAO), a new web and app-based mental health resource available courtesy of Purdue Counseling and Psychological Services (CAPS). TAO is available to students, faculty, and staff at any time.

If you need support and information about options and resources, please contact or see the Office of the Dean of Students. Call 765-494-1747. Hours of operation are M-F, 8 a.m.- 5 p.m.

If you find yourself struggling to find a healthy balance between academics, social life, stress, etc., sign up for free one-on-one virtual or in-person sessions with a Purdue Wellness Coach at RecWell. Student coaches can help you navigate through barriers and challenges toward your goals throughout the semester. Sign up is free and can be done on BoilerConnect.

If you're struggling and need mental health services: Purdue University is committed to advancing the mental health and well-being of its students. If you or someone you know is feeling overwhelmed, depressed, and/or in need of mental health support, services are available. For help, such individuals should contact Counseling and Psychological Services (CAPS) at 765-494-6995 during and after hours, on weekends and holidays, or by going to the CAPS office on the second floor of the Purdue University Student Health Center (PUSH) during business hours.

TaskHuman

TaskHuman offers 1:1 personalized guidance from LIVE specialists over video calls covering nearly 1000 aspects of your daily life such as anxiety, mindfulness, reducing stress, clean eating, time management, in-home workouts, relationship tensions, and so much more. Instantly discover and connect with the world's most comprehensive and enjoy 100% secure and confidential 1:1 sessions on the TaskHuman platform anytime, anywhere - whether you want to work out 1:1 through a personalized yoga session, work through heightened anxiety, or simply get guidance on time management.

Students have found great value in utilizing TaskHuman, celebrating real-world mental well-being wins all around the world. Since the launch of this program, Purdue Engineering students, staff, and faculty have made over 5,000 calls with an average user rating of 4.8/5!

Learn more here: https://engineering.purdue.edu/ECE/TaskHuman.

Emergency Preparation

In the event of a major campus emergency, course requirements, deadlines and grading percentages are subject to changes that may be necessitated by a revised semester calendar or other circumstances beyond the instructor's control. Relevant changes to this course will be posted onto the course website or can be obtained by contacting the instructors or TAs via email or phone. You are expected to read your @purdue.edu email on a frequent basis.

Disclaimer

This syllabus is subject to change. You will be notified of any changes as far in advance as possible via an announcement on Brightspace. Monitor your Purdue email daily for updates.