

Introduction to Quantum Devices and Quantum Engineering

EEL 5934 Section #xxxx

Class Periods: Tue 10:30am – 11:30am; Thu 10:30am – 12:35pm

Location: Classroom location

Academic Term: Fall 2020

Instructor:

Name: Philip Feng
Email Address: feng@ece.ufl.edu
Office Phone Number: (352) 294-6320
Office Hours: TBD

Teaching Assistant/Peer Mentor/Supervised Teaching Student:

Please contact through the Canvas website

- **Dr. Jaesung Lee:** jaesung.lee@ufl.edu
- **Dr. Yanan Wang:** yanan.wang@ufl.edu

Course Description

This course will provide both physics and engineering fundamentals of emerging quantum information science and technologies (QIST), and focus on quantum hardware – from fundamental building blocks for encoding quantum information (qubits) to state-of-the-art quantum devices, circuits, and systems, help the students develop a comprehensive knowledge base to understand the key principles, milestone demonstrations, promises and potential applications of QIST, and today's main challenges and opportunities in quantum devices and hardware engineering.

Course Pre-Requisites / Co-Requisites

EEE3396c, basic knowledge of solid-state physics and quantum mechanics would be a plus.

Course Objectives

The main objective of this course is to expose the graduate students to the forefronts of QIST and prepare them for the second quantum revolution. In order to achieve this overarching goal, the course will be developed from the following modules.

- **Physics Foundation:** The course will start with reviewing the history of the first quantum revolution and recapping the fundamentals in solid-state physics and quantum mechanics.
- **Quantum Computing:** By comparing with the development of classical computers, the basic concepts of quantum computers and overall architecture will be introduced. The hardware implementation of quantum bits (qubits) will be discussed in detail.
- **Quantum Communication:** By reviewing the major milestones, quantum key distribution, quantum cryptography, and quantum network will be introduced.
- **Quantum Sensing:** Practicing a similar protocol, quantum sensing will be introduced, by reviewing the key demonstrations, below nanoscale or uncertainty principle limit.
- **Quantum Simulation:** In this module, we will review how simulation is widely used and take quantum materials design and IBM-Q online experience as examples to show how quantum simulation works.
- **Perspectives and Future Applications of QIST:** The course will be concluded with a discussion session on the future development and potential applications of QIST.

Materials and Supply Fees

NA

Required Textbooks and Software

- No Textbook. It will be based on latest materials and research articles assembled by the instructor.

Recommended Materials

- **Quantum Computing Devices: Principles, Designs & Analysis**

Authors: Goong Chen, David Church, Berthold-Georg Englert, Carsten Henkel, Bernd Rohwedder, Marlan O. Scully, Suhail Zubairy

Publisher: Chapman and Hall/CRC; 1 Edition (2007)

<https://www.amazon.com/Quantum-Computing-Devices-Principles-Mathematics/dp/1584886811>

- **National Academies 2019 Report - Quantum Computing: Progress & Prospects**

Editors: Emily Grumbling & Mark Horowitz

The National Academies Press (2019).

Free PDF Download:

<https://www.nap.edu/catalog/25196/quantum-computing-progress-and-prospects>

Course Schedule

	Module	Topics	Description
Week 1	Physics Foundation	History of First Quantum Revolution	<ul style="list-style-type: none">• Reviewing the history of the first quantum revolution• Recapping the fundamentals in solid-state physics and quantum mechanics
Week 2	Physics Foundation	Impact of First Quantum Revolution	<ul style="list-style-type: none">• Demonstrating how quantum mechanics leads to the major technologies breakthroughs• Case study with lasers and transistors
Week 3	Quantum Computing	Introduction to Quantum Computing	<ul style="list-style-type: none">• Introducing the basic concepts of quantum computing• Comparing with classical computing
Week 4	Quantum Computing	Key Milestones in Quantum Computing	<ul style="list-style-type: none">• Reviewing the development of quantum computing• Deriving roadmap and figures of merit (FoM)
Week 5	Quantum Computing	Building Blocks of Quantum Computer (I)	<ul style="list-style-type: none">• Introducing hardware implementation based on atoms/ions/molecules, superconducting junctions
Week 6	Quantum Computing	Building Blocks of Quantum Computer (II)	<ul style="list-style-type: none">• Introducing hardware implementation based on quantum dots, solid-state defect centers, topological insulators, and others
Week 7	Quantum Computing	Quantum Computing Algorithm, Compiling and Architecture	<ul style="list-style-type: none">• Introducing the overall architecture of quantum computer and the concept of error correction
Week 8	Midterm Exam		

Week 9	Quantum Communication	Introduction to Quantum Communication	<ul style="list-style-type: none"> • Introducing the basic concepts of quantum communication • Comparing with current optical communication
Week 10	Quantum Communication	Key Milestones in Quantum Communication	<ul style="list-style-type: none"> • Reviewing the development of quantum communication • Deriving roadmap and Figures of Merit (FoM)
Week 11	Quantum Communication	Quantum Network Architecture and Implementation	<ul style="list-style-type: none"> • Introducing the overall architecture of quantum network and communication protocols
Week 12	Quantum Sensing	Introduction to Quantum Sensing	<ul style="list-style-type: none"> • Introducing the concept of quantum sensing • Case study of optically detected magnetic resonance and quantum N/MEMS sensing
Week 13	Quantum Simulation	Introduction to Quantum Simulation	<ul style="list-style-type: none"> • Introducing the concept of quantum simulation and quantum materials design • Experiencing IBM-Q
Week 14	Perspectives and Future Applications	Perspectives and Future Applications of QIST	<ul style="list-style-type: none"> • Open discussion and project presentation
Week 15	Final Project and Report due		

Attendance Policy, Class Expectations, and Make-Up Policy

This class will be presented online using Zoom and requires access to a working webcam and stable internet connection. We prefer that students keep their cameras on during the class so that we can see you as we would during normal face-to-face classes. Studies show that if we can see each other's faces then we will have more engagement, more student success, and more faculty success. However, this is not a requirement. We understand if on certain days you can't have your camera on due to internet bandwidth limitations, other family members, health issues, etc.

Excused absences must be in compliance with university policies in the Graduate Catalog (<http://gradcatalog.ufl.edu/content.php?catoid=10&navoid=2020#attendance>) and require appropriate documentation.

Evaluation of Grades

****Assessment Guidance from the ECE Graduate Committee:** Course evaluation components should include:

1. At least one component that individually evaluates each student's understanding of course material and ability to apply concepts.
2. At least one evaluation activity that takes place in class.
3. When a project is involved, evaluation rubrics should be explicitly stated.
4. When team work is expected, individual student contribution verification method should be explicitly stated.

If an in-class exam is administered then 1 and 2 are fulfilled. In the case of a project, a project report that is graded per the stated evaluation rubrics and states which work was done by each student in the project team will address both 3 and 4.

Assignment	Total Points	Percentage of Final Grade
Homework Sets (5)	100 each	25%
Quizzes (5)	100 each	15%
Exam	100	30%
Final Project/Paper	100	30%
		100%

This course is co-listed with the graduate class EEL 4930. The homework portion of the graduate section will involve additional work and more advanced concepts with respect to the undergraduate section. The exams will also involve additional questions for the graduate section with respect to the undergraduate section.

Grading for the homework and projects are different from the undergraduate course. The graduate and undergraduate sections will be graded separately, for which the graduate section has additional problems and different weights for all problems.

Grading Policy

The following is given as an example only.

Percent	Grade	Grade Points
90.0 - 100.0	A	4.00
87.0 - 89.9	A-	3.67
84.0 - 86.9	B+	3.33
81.0 - 83.9	B	3.00
78.0 - 80.9	B-	2.67
75.0 - 79.9	C+	2.33
72.0 - 74.9	C	2.00
69.0 - 71.9	C-	1.67
66.0 - 68.9	D+	1.33
63.0 - 65.9	D	1.00
60.0 - 62.9	D-	0.67
0 - 59.9	E	0.00

More information on UF grading policy may be found at:

<http://gradcatalog.ufl.edu/content.php?catoid=10&navoid=2020#grades>

Students Requiring Accommodations

Students with disabilities who experience learning barriers and would like to request academic accommodations should connect with the disability Resource Center by visiting <https://disability.ufl.edu/students/get-started/>. It is important for students to share their accommodation letter with their instructor and discuss their access needs, as early as possible in the semester.

Course Evaluation

Students are expected to provide professional and respectful feedback on the quality of instruction in this course by completing course evaluations online via GatorEvals. Guidance on how to give feedback in a professional and respectful manner is available at <https://gatorevals.aa.ufl.edu/students/>. Students will be notified when the evaluation period opens, and can complete evaluations through the email they receive from GatorEvals, in their Canvas course menu under GatorEvals, or via <https://ufl.bluera.com/ufl/>. Summaries of course evaluation results are available to students at <https://gatorevals.aa.ufl.edu/public-results/>.

University Honesty Policy

UF students are bound by The Honor Pledge which states, “We, the members of the University of Florida community, pledge to hold ourselves and our peers to the highest standards of honor and integrity by abiding by the Honor Code. On all work submitted for credit by students at the University of Florida, the following pledge is either required or implied: “On my honor, I have neither given nor received unauthorized aid in doing this assignment.” The Honor Code (<https://sccr.dso.ufl.edu/policies/student-honor-code-student-conduct-code/>) specifies a number of behaviors that are in violation of this code and the possible sanctions. Furthermore, you are obligated to report any condition that facilitates academic misconduct to appropriate personnel. If you have any questions or concerns, please consult with the instructor or TAs in this class.

Commitment to a Safe and Inclusive Learning Environment

The Herbert Wertheim College of Engineering values broad diversity within our community and is committed to individual and group empowerment, inclusion, and the elimination of discrimination. It is expected that every person in this class will treat one another with dignity and respect regardless of gender, sexuality, disability, age, socioeconomic status, ethnicity, race, and culture.

If you feel like your performance in class is being impacted by discrimination or harassment of any kind, please contact your instructor or any of the following:

- Your academic advisor or Graduate Program Coordinator
- Robin Bielling, Director of Human Resources, 352-392-0903, rbielling@eng.ufl.edu
- Curtis Taylor, Associate Dean of Student Affairs, 352-392-2177, taylor@eng.ufl.edu
- Toshikazu Nishida, Associate Dean of Academic Affairs, 352-392-0943, nishida@eng.ufl.edu

Software Use

All faculty, staff, and students of the University are required and expected to obey the laws and legal agreements governing software use. Failure to do so can lead to monetary damages and/or criminal penalties for the individual violator. Because such violations are also against University policies and rules, disciplinary action will be taken as appropriate. We, the members of the University of Florida community, pledge to uphold ourselves and our peers to the highest standards of honesty and integrity.

Student Privacy

There are federal laws protecting your privacy with regards to grades earned in courses and on individual assignments. For more information, please see: <https://registrar.ufl.edu/ferpa.html>

Campus Resources:

Health and Wellness

U Matter, We Care:

Your well-being is important to the University of Florida. The U Matter, We Care initiative is committed to creating a culture of care on our campus by encouraging members of our community to look out for one another and to reach out for help if a member of our community is in need. If you or a friend is in distress, please contact umatter@ufl.edu so that the U Matter, We Care Team can reach out to the student in distress. A nighttime and weekend crisis counselor is available by phone at 352-392-1575. The U Matter, We Care Team can help connect students to the many other helping resources available including, but not limited to, Victim Advocates, Housing staff, and the Counseling and Wellness Center. Please remember that asking for help is a sign of strength. In case of emergency, call 9-1-1.

Counseling and Wellness Center: <http://www.counseling.ufl.edu/cwc>, and 392-1575; and the University Police Department: 392-1111 or 9-1-1 for emergencies.

Sexual Discrimination, Harassment, Assault, or Violence

If you or a friend has been subjected to sexual discrimination, sexual harassment, sexual assault, or violence contact the **Office of Title IX Compliance**, located at Yon Hall Room 427, 1908 Stadium Road, (352) 273-1094, title-ix@ufl.edu

Sexual Assault Recovery Services (SARS)

Student Health Care Center, 392-1161.

University Police Department at 392-1111 (or 9-1-1 for emergencies), or <http://www.police.ufl.edu/>.

Academic Resources

E-learning technical support, 352-392-4357 (select option 2) or e-mail to Learning-support@ufl.edu.
<https://lss.at.ufl.edu/help.shtml>.

Career Resource Center, Reitz Union, 392-1601. Career assistance and counseling. <https://www.crc.ufl.edu/>.

Library Support, <http://cms.uflib.ufl.edu/ask>. Various ways to receive assistance with respect to using the libraries or finding resources.

Teaching Center, Broward Hall, 392-2010 or 392-6420. General study skills and tutoring.
<https://teachingcenter.ufl.edu/>.

Writing Studio, 302 Tigert Hall, 846-1138. Help brainstorming, formatting, and writing papers.
<https://writing.ufl.edu/writing-studio/>.

Student Complaints Campus: <https://care.dso.ufl.edu>.

On-Line Students Complaints: <http://www.distance.ufl.edu/student-complaint-process>.