

# EE 396V – Quantum Information Hardware

Spring 2020

**Instructor:** Prof. Shyam Shankar; Office: EER 4.878; E-mail: [shyam.shankar@utexas.edu](mailto:shyam.shankar@utexas.edu).

Class hours: TTh 9:30 AM to 11:00 AM, EER 1.512

Office hours: EER 4.878, M 1:30 to 3:30 PM or by appointment in EER or MER.

**Teaching Assistant:** TBD

## Description:

This course will be an introduction to the hardware used for quantum information processing, from an applied physics perspective. The course covers the physical requirements for a hardware platform to process quantum information and describes various current hardware platforms such as superconducting quantum circuits, atomic systems, solid-state spins and optical photons.

## Objectives:

- Review key physical concepts underlying all hardware platforms used for storing and processing quantum information.
- Understand various hardware platforms that are currently being used for quantum information processing.
- Explore the developments needed for building future large-scale quantum machines. Applications of near-term quantum information hardware will also be introduced.

## Prerequisites:

Undergraduate-level Quantum mechanics, such as EE 334K, PHY 373 or equivalent is required. While not a formal pre-requisite, you will also benefit from having taken the course CS378 - Introduction to Quantum Information Science.

## Tentative course topics:

- Review of the quantum physics of spins and LC oscillators
- Necessary elements for quantum information processing: Quantum gates, measurement and coherence times
- Superconducting quantum circuits: the transmon qubit and circuit QED architecture
- Atomic systems: the neutral atom and trapped ion qubit
- Solid-state spins: the nitrogen-vacancy center in diamond and the phosphorus donor in silicon
- Optical photons: Computing and communicating with linear and nonlinear optics.
- Connecting distant quantum systems: remote entanglement, the modular quantum computing architecture and the quantum internet.
- Protecting against the loss of coherence: quantum error correction
- Near-term applications of noisy quantum machines

**Recommended references:**

Some useful books are

- *Exploring the Quantum*, by S. Haroche and J-M. Raimond
- *Quantum Computation and Quantum Information*, by M. A. Nielsen and I. L. Chuang

However, we will not follow any particular textbook closely. I will instead provide references to original journal articles and review articles throughout the course.

**Grading:**

30% Homework, 30 % Midterm, 40% Final.

Homework questions will be assigned throughout the class term, and will be due one to two weeks after being assigned.

Late homework will be accepted at instructor's discretion.

Discussion of homework questions is encouraged. Please be sure to submit your own independent homework solution.

Midterm exam date: TBD

Shortly before the spring semester begins, the registrar's office will announce the final exam dates and times according to the lecture time of each class at

<https://registrar.utexas.edu/students/exams>.

**Course notes:**

Course notes will be provided for most lectures. The web-based course management system "Canvas", available at <https://canvas.utexas.edu/> will be used to post course notes, homework assignments and solutions.

**Academic dishonesty:**

Plagiarism or any form of academic dishonesty (cheating includes, but is not limited to, copying another student's work, bringing notes into a test and copying material directly from a book, article or web site without including appropriate references, falsifying data, doing someone's work) is a violation of University rules and may return a grade of zero for each assignment in which it is detected or may incur even steeper penalties. For University policies see: <http://registrar.utexas.edu/catalogs/>

**Class Web sites and student privacy:**

Web-based, password-protected class sites are associated with all academic courses taught at The University. Syllabi, handouts, assignments and other resources are types of information that may be available within these sites. Site activities could include exchanging e-mail, engaging in class discussions and chats, and exchanging files. In addition, electronic class rosters will be a component of the sites. Students do not want their names included in these electronic class rosters must restrict their directory information in the Office of the Registrar, Main Building, Room 1.

**Recommendations regarding emergency evacuation from the Office of Campus Safety and Security (<http://www.utexas.edu/safety/>):**

- Occupants of buildings on The University of Texas at Austin campus are required to evacuate buildings when a fire alarm is activated. Alarm activation or announcement requires exiting and assembling outside.
- Familiarize yourself with all exit doors of each classroom and building you may occupy. Remember that the nearest exit door may not be the one you used when entering the building.
- Students requiring assistance in evacuation shall inform their instructor in writing during the first week of class.
- In the event of an evacuation, follow the instruction of faculty or class instructors; exit in an orderly fashion and assemble outside.
- Do not re-enter a building unless given instructions by the following: Austin Fire Department, The University of Texas at Austin Police Department, or Fire Prevention Services office.
- Behavior Concerns Advice Line (BCAL): 512-232-5050
- Link to information regarding emergency evacuation routes and emergency procedures can be found at: [www.utexas.edu/emergency](http://www.utexas.edu/emergency)

**Student Rights and Responsibilities:**

- You have a right to a learning environment that supports mental and physical wellness.
- You have a right to respect.
- You have a right to be assessed and graded fairly.
- You have a right to freedom of opinion and expression.
- You have a right to privacy and confidentiality.
- You have a right to meaningful and equal participation, to self-organize groups to improve your learning environment.
- You have a right to learn in an environment that is welcoming to all people. No student shall be isolated, excluded or diminished in any way.

With these rights come responsibilities:

- You are responsible for taking care of yourself, managing your time, and communicating with the teaching team and with others if things start to feel out of control or overwhelming.
- You are responsible for acting in a way that is worthy of respect and always respectful of others.
- Your experience with this course is directly related to the quality of the energy that you bring to it, and your energy shapes the quality of your peers' experiences.
- You are responsible for creating an inclusive environment and for speaking up when someone is excluded.
- You are responsible for holding yourself accountable to these standards, holding each other to these standards, and holding the teaching team accountable as well.

## **Personal Pronoun Use**

Professional courtesy and sensitivity are especially important with respect to individuals and topics dealing with differences of race, culture, religion, politics, sexual orientation, gender, gender variance, and nationalities. Class rosters are provided to the instructor with the student's legal name, unless they have added a preferred name with the Gender and Sexuality Center. I will gladly honor your request to address you by a name that is different from what appears on the official roster, and by the gender pronouns you use (she/he/they/ze, etc). Please advise me of any changes early in the semester so that I may update my records.

## **Official Correspondence**

The University of Texas at Austin considers e-mail as an official mode of university correspondence: <https://cio.utexas.edu/policies/university-electronic-mail-student-notification-policy>. You are responsible for following course-related information on the Canvas site for the course.

## **University Honor Code**

“The core values of The University of Texas at Austin are learning, discovery, freedom, leadership, individual opportunity, and responsibility. Each member of the University is expected to uphold these values through integrity, honesty, fairness, and respect toward peers and community.” <http://www.utexas.edu/about/mission-and-values>.

## **Accommodations for religious holidays:**

A student who misses classes or other required activities, including examinations, for the observance of a religious holy day should inform the instructor as far in advance of the absence as possible so that arrangements can be made to complete an assignment within a reasonable period after the absence. A reasonable accommodation does not include substantial modification to academic standards, or adjustments of requirements essential to any program of instruction. Students and instructors who have questions or concerns about academic accommodations for religious observance or religious beliefs may contact the Office for Inclusion and Equity. The University does not maintain a list of religious holy days

## **Absence for Military Service**

In accordance with section 51.9111 of the Texas Education Code, a student is excused from attending classes or engaging in other required activities, including exams, if he or she is called to active military service of a reasonably brief duration. The maximum time for which the student may be excused has been defined by the Texas Higher Education Coordinating Board (THECB) as “no more than 25 percent of the total number of class meetings or the contact hour equivalent (not including the final examination period) for the specific course or courses in which the student is currently enrolled at the beginning of the period of active military service.” The student will be allowed a reasonable time after the absence to complete assignments and take exams. Policies affecting students who withdraw from the University for military service are given in the Withdrawal section.

## **Campus Carry**

“The University of Texas at Austin is committed to providing a safe environment for students, employees, university affiliates, and visitors, and to respecting the right of individuals who are licensed to carry a handgun as permitted by Texas state law.” For more information, please see <http://campuscarry.utexas.edu/students>.

## **Safety Information**

If you have concerns about the safety or behavior of students, TAs, Professors, or others, call the Behavioral Concerns Advice Line at 512-232-5050. Your call can be anonymous.

## **Students with Disabilities**

UT provides upon request appropriate academic accommodations for qualified students with disabilities. Disabilities range from visual, hearing, and movement impairments to ADHD, psychological disorders (e.g. depression and bipolar disorder), and chronic health conditions (e.g. diabetes and cancer). These also include temporary disabilities such as broken bones and recovery from surgery. Services for Students with Disabilities is available at 512-471-6259 [voice], 866-329-3986 [video], [ssd@uts.cc.utexas.edu](mailto:ssd@uts.cc.utexas.edu), or <http://ddce.utexas.edu/disability>.

## **Mental Health Counseling**

College can be stressful and sometimes we need a little help. Luckily, we have a wealth of resources and dedicated people ready to assist you, and treatment does work. The Counseling and Mental Health Center (CMHC) provides counseling, psychiatric, consultation, and prevention services that facilitate student academic and life goals and enhance their personal growth and well-being. CMHC counselors are available Monday-Friday 8am-5pm 5th floor of the Student Services Building (SSB) in person and by phone (512-471-3515).

Alternatively, you can talk to Ms. Jeni Wade, LCSW right here in the College of Engineering. Ms. Wade is our Care Counselor and she can be reached at 512-471-8396. She has office hours in EER 2.848 for drop-ins.

If you are experiencing a mental health crisis (e.g. depression or anxiety), please call the Mental Health Center Crisis line at 512-471-CALL(2255). Call even if you aren't sure you're in a full-blown crisis, but sincerely need help. Staff are there to help you.

A wonderful resource is the MindBody Lab, a self-paced environment designed to help UT students explore various resources for improving their emotional and physical health. The Lab currently features audio and video instruction on a variety of topics, including sleep issues; food and body image; health and well-being; relaxation and meditation. Most of the material is experiential, enabling students to follow along and practice the skills as they are being discussed. MindBody Labs are located in SSB 5th floor, SAC 2.106 and NUR 3.156D.

## **Title IX Reporting**

Title IX is a federal law that protects against sex and gender-based discrimination, sexual harassment, sexual assault, sexual misconduct, dating/domestic violence and stalking at federally funded educational institutions. UT Austin is committed to fostering a learning and working environment free from discrimination in all its forms where all students, faculty, and staff can learn, work, and thrive. When sexual misconduct occurs in our community, the university can:

1. Intervene to prevent harmful behavior from continuing or escalating.
2. Provide support and remedies to students and employees who have experienced harm or have become involved in a Title IX investigation.
3. Investigate and discipline violations of the university's relevant policies.

Faculty members and certain staff members are considered "Responsible Employees" or "Mandatory Reporters," which means that they are required to report violations of Title IX to the Title IX Coordinator at UT Austin. **I am a Responsible Employee and must report any Title IX related incidents** that are disclosed in writing, discussion, or one-on-one. Before talking with me, or with any faculty or staff member about a Title IX related incident, be sure to ask whether they are a responsible employee. If you want to speak with someone for support or remedies without making an official report to the university, email [advocate@austin.utexas.edu](mailto:advocate@austin.utexas.edu). For more info about reporting options and resources, visit <https://titleix.utexas.edu/campus-resources> or contact the Title IX Office at [titleix@austin.utexas.edu](mailto:titleix@austin.utexas.edu).

## **References**

This course syllabus uses wording suggested by Prof. Mary Steinhardt and the Faculty Innovation Center (<https://facultyinnovate.utexas.edu/effective-syllabus>) at UT Austin.