CS 4134 – Quantum Computation and Information Processing

Virginia Tech Department of Computer Science, Spring 2026

1 Basic information

Instructor: Sumeet Khatri

- Office: 2160H Torgersen Hall
- Email: skhatri@vt.edu
- Course website

Description: This course provides an introduction to quantum computation and information processing. After covering the basic mathematical tools of quantum information theory, we will cover topics in quantum computation such as universal gate sets, Shor's and Grover's algorithms, the phase-estimation algorithm, noise in quantum computing, and quantum error correction. We will also cover related topics in quantum information theory including entanglement measures, hypothesis testing, and the basic primitives of quantum communication, such as quantum teleportation and superdense coding.

Learning objectives: Upon successful completion of this course, a student will be able to do the following.

- Formulate examples of uniquely quantum-mechanical phenomena.
- Express quantum information concepts, such as quantum states (density operators), measurements, and quantum channels.
- Construct examples of quantum circuits and (universal) gate sets for quantum computation.
- Compute entanglement measures for quantum states.
- Formulate examples of quantum algorithms that (may or may not) have a known and provable advantage over classical algorithms.
- Express many of the known challenges in realizing large-scale quantum computers.

Timing and location: Tuesday and Thursday from 3:30pm to 4:45pm in 120 New Classroom Building.

Course prerequisites: (These topics will be refreshed, as needed, during the course.)

- Linear algebra (MATH 2114, 3144, 4144) (or equivalent).
- Basic knowledge of probability theory.

Teaching assistants:

- Ezekiel Cochran: ecochran@vt.edu
- Suraj Vishwanath: surajv@vt.edu
- Zorawar Gulati: zorawar@vt.edu
- Joshua Gao: joshuagao@vt.edu

Office hours:

- Sumeet Khatri: Thursdays from 11:30am–12:30pm via Zoom. (Zoom link shared on Canvas.)
- Ezekiel Cochran: Wednesdays 10am–11am, Torgersen 1070.
- Suraj Vishwanath: Tuesdays 11am–12pm, Torgersen 1070.
- Zorawar Gulati: Tuesdays and Thursdays, 8am–10:30am, Torgersen 1070; Fridays 2pm–5pm, Torgersen 1070.
- Joshua Gao: Mondays 2:30pm–5pm, Torgersen 1070.

2 Grading

The class will consist of midterm exams and small, weekly take-home assignments. Your final grade will be the maximum among the two grading schemes shown below.

There will be **five in-class written exams** throughout the semester. The **top four** will count towards the final grade.

Most midterm problems will come from a **problem bank** and the **assignment questions**, up to minor modifications. The problem bank can be found on the course website. You are encouraged to study the problem bank on your own time, and use the office hours as a resource to learn how to solve the problems.

You may collaborate with others on the assignments. Use of AI tools is not prohibited, but be prepared to explain your solutions and demonstrate your understanding to me on the board upon request at any time.

Exam schedule	
Exam 1	February 12, 2026
Exam 2	March 5, 2026
Exam 3	March 26, 2026
Exam 4	April 16, 2026
Exam 5	May 5, 2026

Final grade	**Scheme 1**	**Scheme 2**
Exams (top four)	80%	100%
Assignments	20%	0%

Percentage	93–100	90–93	87–90	83–87	80–83	77–80
Letter grade	A	A−	B+	B	B−	C+

Percentage	73–77	70–73	67–70	63–67	60–63	0–60
Letter grade	C	C−	D+	D	D−	F

3 Academic Accommodations

Virginia Tech welcomes students with disabilities into the University's educational programs. The University promotes efforts to provide equal access and a culture of inclusion without altering the essential elements of coursework. If you anticipate or experience academic barriers that may be due to disability, including but not limited to ADHD, chronic or temporary medical conditions, deaf or hard of hearing, learning disability, mental health, or vision impairment, please contact the Services for Students with Disabilities (SSD) office (540-231-3788, ssd@vt.edu, or visit ssd.vt.edu). If you have an SSD accommodation letter, please meet with me privately during office hours as early in the semester as possible to deliver your letter and discuss your accommodations. You must give me reasonable notice to implement your accommodations, which is generally 5 business days and 10 business days for final exams.

4 Academic Integrity

The Graduate Honor Code pledge that each member of the university community agrees to abide by states: "As a Hokie, I will conduct myself with honor and integrity at all times. I will not lie, cheat, or steal, nor will I accept the actions of those who do." Students enrolled in this course are responsible for abiding by the Honor Code. A student who has doubts about how the Honor Code applies to any assignment is responsible for obtaining specific guidance from the course instructor before submitting the assignment for evaluation. Ignorance of the rules does not exclude any member of the University community from requirements and expectations of the Honor Code. Specifically, the Honor Code applies in this class as follows.

You can consult the Reading Materials for the course. The instructor is available to provide any assistance that you may need. No other person or resource may give you answers to the assignment questions. You are allowed to work in small groups for assignments, but you must write the final solutions independently from your group.

5 Student Well-Being

Supporting your mental health and well-being is of high priority to me and Virginia Tech. If you are feeling overwhelmed academically, having trouble functioning, or are worried about a friend, please reach out to:

- **Cook Counseling**
  - 540-231-6557 to schedule an appointment and/or 24/7 crisis support
  - ucc.vt.edu for more information
- **Dean of Students Office**
  - 540 231-3787 for general advice
  - 540-231-6411 for after hours crisis
  - Refer a Student of Concern
  - dos.vt.edu for more information

- **Hokie Wellness**
  - hokiewellness.vt.edu for well-being education and prevention opportunities including financial wellness
- **Services for Students with Disabilities (SSD)**
  - 540-231-3788 or ssd.vt.edu for more information about accommodations and other disability-related supports
- **TimelyCare**
  - 12 free scheduled counseling sessions per academic year, unlimited on-demand mental health support 24/7, unlimited access to health coaching
  - Register for TimelyCare

For a full listing of campus resources, check out well-being.vt.edu.

Please also feel free to speak with me. I will make an effort to work with you; I care about you.

6 Outline of topics

Part I: Mathematics and phenomena of quantum (information) theory

- Basics of linear algebra, probability, and statistics
- Mathematical description of quantum objects: states, observables, unitaries (quantum gates)
- No-cloning theorem
- Entanglement
- Teleportation, superdense coding
- Hypothesis testing; state discrimination

Part II: Quantum circuits and algorithms

- Quantum circuits
- Universal gate sets
- Complexity classes
- The quantum Fourier transform
- Algorithms: Deutsch–Jozsa, Simon, Shor, Grover, phase estimation

Part III: Noise in quantum computing, error correction

- Modeling errors in quantum algorithms: quantum channels
- Quantifying errors in quantum algorithms: trace and diamond norm
- Correcting errors in quantum algorithms: exact and approximate error correction, stabilizer codes

7 Reading Materials

- Quantum Computation and Quantum Information, by Michael Nielsen and Isaac Chuang.
- An Introduction to Quantum Computing, by Phillip Kaye, Raymond Laflamme and Michele Mosca.
- Introduction to Classical and Quantum Computing, by Thomas G. Wong. *(Nice and gentle.)*
- Quantum Information: From Foundations to Quantum Technology Applications, by Dagmar Bruss and Gerd Leuchs (editors). *(Very broad in scope, discusses applications.)*
- The Theory of Quantum Information, by John Watrous.
- Classical and Quantum Computation, by A. Yu. Kitaev, A. H. Shen, M. N. Vyalyi. *(Quite advanced!)*
- Principles of Quantum Communication Theory: A Modern Approach, by Sumeet Khatri and Mark M. Wilde.