Quantum Computation

3 credits

Bulletin Description: Quantum Bits (Qubits), Single and Multiple Qubit Gates, Quantum Circuits, Quantum Computation, Quantum Algorithms, Quantum Computers
Prereq. Phys 252.

Instructor: Andrei Kryjevski, South Engineering 318D
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Meetings: Tue Th 12:30-13:45   **Office Hours:**   W 14:00-16:00
               South Engineering 221   (or by arrangement)

Course Description: Students will master the foundations of quantum computation and quantum information, including underlying physical concepts and practical applications. Topics covered include Quantum Bits (Qubits), Single and Multiple Qubit Gates, Quantum Circuits, Quantum Computation, Quantum Algorithms, and Quantum Computers. Sstudents will also gain experience with programming and executing quantum algorithms, such as Fourier Transform, Grover's, Shor's Algorithms using, *e.g.*, IBM Quantum Experience platform.

Course Learning Outcomes: Students will have knowledge of the foundations of quantum computation and quantum information, including underlying physical concepts of quantum mechanics. They will have working knowledge of quantum algorithms. Students will be able to program and execute quantum algorithms on the (publicly) available quantum processors. Graduate students will be able to program and execute advanced quantum algorithms, such as Fourier Transform, Grover's, Shor's Algorithms.

Student Responsibilities: Complete assignments on time. Come prepared for discussion. Ask questions and give feedback.

This course has no single textbook: attending lectures and taking notes is encouraged.
Literature:
1. T. G. Wong, **Introduction to Classical and Quantum Computing**, Rooted Grove (2022), **free** e-book:
`https://www.thomaswong.net/introduction-to-classical-and-quantum-computing-1e4p.pdf`
2. M. A. Nielsen, and I. L. Chuang, **Quantum Computation and Quantum Information**, Cambridge University Press, 2010

Major Topics:
• **Classical Information and Computation:** Bits, Boolean Algebra, Gates, Error Correction
• **Basic Concepts of Quantum Mechanics:** The Stern-Gerlach Experiment, Spin-1/2 Systems, Quantum Mechanics Postulates
• **Quantum Bits – Qubits:** Superposition, Bloch Sphere, Measurements, Single Qubit Gates, Gates as Matrices, Quantum Circuits, Physical Realization of Qubits

- **Multiple Qubits:** Entanglement, Multiple Qubit Gates, Quantum Adders, Decoherence, Quantum Error Correction
- **Quantum Programming:** IBM Quantum Experience
- **Entanglement and Quantum Protocols:** Entangled States, Bell Inequalities, Quantum Teleportation, Quantum Key Distribution
- **Quantum Algorithms:** Grover's Algorithm, Quantum Fourier Transform, Shor's Factoring Algorithm
- **Quantum Information:** Quantum Information Processing

Course Schedule:
Weeks 1-2 - Classical Information and Computation
Weeks 3-4 - Introduction to Quantum Mechanics
Weeks 5-9 - Properties of Qubits, Quantum Gates, **Exam 1**
Weeks 11-13 - Quantum Programming, Quantum Protocols,
Weeks 14-16 - Quantum Algorithms, Quantum Information
Weeks 17 - **Final Exam**

Evaluation: weekly homework assignments (50%); 2 exams (midterm 20%, final 30%); graduate students will be assigned a written project worth 5% of the grade; for graduate students homework and exams will be rescaled to contribute 95% of the grade.

Homework and Lateness: Group discussion of homework is strongly encouraged, but written solutions must be your own. Late work will be accepted with a 20% penalty/day until next class.

Grading:
Undergraduates: A: 90-100%, B: 75-89.9%, C: 60-74.9%, D: 50-59.9%, F: < 50%
Graduate Students: A: 90-100%, B: 70-89.9%, C: 60-69.9%, D: 50-59.9%, F: < 50%

- *The academic community is operated on the basis of honesty, integrity, and fair play. NDSU Policy 335: Code of Academic Responsibility and Conduct applies to cases in which cheating, plagiarism, or other academic misconduct have occurred in an instructional context. Students found guilty of academic misconduct are subject to penalties, up to and possibly including suspension and/or expulsion. Student academic misconduct records are maintained by the Office of Registration and Records. Informational resources about academic honesty for students and instructional staff members can be found at* `www.ndsu.edu/academichonesty`.

- *Any students with disabilities who need accommodations in this course are invited to share these concerns or requests with the instructor and contact the Disability Services Office as soon as possible.*

- *Veterans and student service members with special circumstances or who are activated are encouraged to notify the instructor as soon as possible and are encouraged to provide Activation Orders.*

- *Your personally identifiable information and educational records as they relate to this course are subject to FERPA.*