Course Change Request

New Course Proposal

Date Submitted: 10/29/19 9:11 am

Viewing: PHYS 334 : Introduction to Quantum Computation and Quantum Information

Last edit: 10/29/19 10:35 am

Changes proposed by: prubin

Are you completing this form on someone else's behalf?

No

In Workflow

1. **PHYS UG Committee**
2. **PHYS Chair**
3. **SC Curriculum Committee**
4. SC Associate Dean
5. Assoc Provost-Undergraduate
6. Registrar-Courses
7. Banner

Approval Path

1. 11/04/19 12:14 pm Philip Rubin (prubin): Approved for PHYS UG Committee
2. 11/04/19 12:35 pm Paul So (paso): Approved for PHYS Chair

Effective Term: Fall 2020

Subject Code: PHYS - Physics

Course Number: 334

Bundled Courses:

Is this course replacing another course? No

Equivalent Courses:

Catalog Title: Introduction to Quantum Computation and Quantum Information

Banner Title: Intro Quantum Comp and Info

Will section titles vary by semester? No

Credits: 3

Schedule Type: Lecture

Hours of Lecture or Seminar per week: 3

Repeatable: May be only taken once for credit, limited to 3 attempts (N3)

Max Allowable Credits: 3

Default Grade Mode: Undergraduate Regular

Recommended Prerequisite(s):

Recommended Corequisite(s):

Required Prerequisite(s) / Corequisite(s) (Updates only):

PHYS 260 or PHYS 270, and MATH 203 or PHYS 301

Registrar's Office Use Only - Required Prerequisite(s)/Corequisite(s):

And/Or	(	Course/Test Code	Min Grade/Score	Academic Level	)	Concurrency?

Registration Restrictions (Updates only):

Registrar's Office Use Only - Registration Restrictions:

Field(s) of Study:

Class(es):

Level(s):

Degree(s):

School(s):

Catalog Description:

Introduction to the basic components of quantum computing (qubit, quantum gates, and quantum circuits, entanglement, the non-cloning theorem, dense coding, and quantum teleportation, including physical implementation), as well as quantum algorithms, such as Deutsch-Josza, Bernstein-Varirani, Simon's, Shor's, and Grover's algorithms, and quantum error correction code. Quantum coding of these algorithms will be run on an IBMq.

Justification:

The National Quantum Initiative, signed into law in December 2018, mandated the creation of new research and educational programs to support the second quantum technological revolution. By harnessing quantum phenomena, it is possible to radically improve computing, sensing, and communications technology. Presently, there is a massive shortage of scientists and engineers with the appropriate expertise in quantum experiment and quantum theory. Numerous established companies and young technology startups are actively seeking to hire highly trained employees and most of those hires will be at the Bachelors and Masters degree levels. For the undergraduates, it will be important to have an understanding of quantum information whatever field of science, engineering, or mathematics they are coming from. From discussions with people in industry, this quantum information course is well-aligned with the basics of what students will need. As the required mathematics background is linear algebra (a standard STEM foundation course, available, as well, at the junior college level), this course is accessible to a broad range of math, science, and engineering majors.

Does this course cover material which crosses into another department? No

Learning Outcomes:

Attach Syllabus

phys334_new_syllabus.pdf

Additional Attachments

Staffing:

Tian, Zhao

Relationship to Existing Programs:

This course will be an elective for the Physics Bachelors degree program, and perhaps a requirement for the computational physics concentration. It may be added as an elective to other Bachelors degree programs in COS and Volgenau.

Relationship to Existing Courses:

This course is unique in the physics curriculum, completely independent of computational quantum mechanics, which involves computational methods on conventional computing platforms. It is designed to provide a foundation in quantum computing to students with backgrounds of only introductory physics and linear algebra or PHYS 301 (a mathematical methods course required of all physics majors that covers the necessary topics). The course is not currently required for any other courses.

Additional Comments:

Reviewer Comments

PHYS 334: Introduction to Quantum Computing

Term, Room

Instructor: Tian or Zhao

Office:

Phone:

E-mail:

Office Hours:

Website:

Notes:

Prerequisites: PHYS 260 or PHYS 270, and PHYS 301 or MATH 203

Textbook: Quantum Computing: A Gentle Introduction, E. Rieffel & W. Polak

Reference book: Quantum Computing and Quantum Information Nielsen & Chuang

Students must use your MasonLive e-mail account to receive important University information, including communications related to this class. Messages sent from a non-Mason address will not receive replies. All messages related to this course will be sent your MasonLive e-mail account.

OVERVIEW

The first part of the course introduces basic components of quantum computing, such as qubit, quantum gate, and quantum circuit. The counter-intuitive nature of qubit state—including entanglement, the no-cloning theorem, superdense coding, and quantum teleportation—are covered. Physical implementation is also discussed.

The second part of the course presents quantum algorithms, including Deutsch-Josza, Bernstein-Varirani, Simon, Shor, and Grover, as well as quantum error correction.

The last part of the course is a quantum code programming project based on the algorithms presented. The code must run on a quantum computer simulator available on line.

TOPICS

1. Overview, getting to know IBM Q
2. Quantum mechanics: two-state systems, a single qubit state, and measurement
3. Single photons as qubits, and applications in quantum cryptography (BB84 protocol)
4. Two-qubit states; tensor products; entanglement, EPR pair and Bell's inequality
5. Unitary transformation and single qubit gates; the quantum circuit model.
6. Two-qubit gates; tensor operators; Controlled-NOT, Swap, Universal set.
7. Three or more qubit states and gates; Quantum circuits.
8. Application: Teleportation, superdense coding, the no-cloning theorem.
9. Decomposition of Toffoli and Fredkin gates
10. Programming with Qiskit.
11. Deutsch's problem. Deutsch-Josza algorithm,
12. More query problems: Bernstein-Vazirani, Simon
13. Quantum Fourier transform, period finding, order finding
14. Shor's algorithm
15. Search problem. Grover's algorithm.
16. Error correction, surface code
17. Physical realization: superconducting qubits and ion traps.
18. Advanced topics

GRADING

Weekly homework (40%)

Assignments must be completed and submitted on-time. Lateness will reduce the grade 10% each day.

Mid-term exam (30%)

Must be taken on the scheduled date and time, the only exceptions are documented medical or legal emergencies.

End-of-term project (30%)

Projects must be completed and submitted on-time. Lateness will reduce the grade 10% each day.

Technology Policy

Cell phones, pagers, and other communicative devices are not allowed in this class. Please keep them stowed away and out of sight. Laptops or tablets (e.g., iPads) may be permitted for the purpose of taking notes or working on in-class assignments and projects only. Engaging in activities not related to the course (e.g., gaming, email, chat, etc.) will result in a significant deduction (10% for each violation) in your final grade.

Academic Integrity

It is expected that students adhere to the George Mason University Honor Code as it relates to integrity regarding coursework and grades. The Honor Code reads as follows:"To promote a stronger sense of mutual responsibility, respect, trust, and fairness among all members of the George Mason University community and with the desire for greater academic and personal achievement, we, the student members of the University Community have set forth this: Student members of the George Mason University community pledge not to cheat, plagiarize, steal and/or lie in matters related to academic work." More information about the Honor Code, including definitions of cheating, lying, and plagiarism, can be found at the Office of Academic Integrity website at http://oai.gmu.edu

Disability Accommodations

Disability Services at George Mason University is committed to providing equitable access to learning opportunities for all students by upholding the laws that ensure equal treatment of people with disabilities. If you are seeking accommodations for this class, please first visit http://ds.gmu.edu/ for detailed information about the Disability Services registration process. Then please discuss your approved accommodations with me. Disability Services is located in Student Union Building I (SUB I), Suite 2500. Email:ods@gmu.edu | Phone: (703) 993-2474