Course Change Request

New Course Proposal

Date Submitted: 11/01/19 9:43 am

Viewing: **PHYS 534 : Introduction to Quantum Computation and Quantum Information**

Last edit: 12/13/19 2:19 pm

Changes proposed by: jrosenb4

Programs referencing this course — SC-MS-PHAE: Applied and Engineering Physics, MS

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

No

Effective Term: Fall 2020

Subject Code: PHYS - Physics

Course Number: 534

Bundled Courses:

Is this course replacing another course? No

Equivalent Courses:

Catalog Title: Introduction to Quantum Computation and Quantum Information

Banner Title: Intro QISE

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: 9

Default Grade Mode: Graduate Regular

In Workflow

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

Approval Path

1. 12/04/19 2:52 pm Ernest Barreto (ebarreto): Approved for PHYS GR Committee
2. 12/06/19 2:45 pm Paul So (paso): Approved for PHYS Chair

Recommended Prerequisite(s):

Experience with programming. MATH 203 or PHYS 301. PHYS 160, 260; or 170, 270; or permission of instructor.

Recommended Corequisite(s):

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

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:

This course introduces science and engineering students to quantum computing code and quantum information using a linear algebra based approach. Prior experience with quantum mechanics is not required. Over the semester counterintuitive concepts, such as quantum entanglement and quantum teleportation, will be demystified. Basic quantum algorithms will be analyzed to understand quantum speedup over classical computing. Hands-on training in quantum circuit design and writing quantum code will be provided, culminating in running this code on simulators and quantum computers. Course content will include distinctions between classical and quantum computing, the qubit, quantum gates and circuits, and quantum algorithms for query, data base search, factorization, and error correction. State of the art and future prospects of quantum technology will also be discussed.

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 highly trained Bachelors and Masters-level employees who can help them make advances in quantum technologies. This is an interdisciplinary field that will draw students from physics, engineering (CS, ECE, and ME), computational and data sciences, chemistry, and mathematics. It is very helpful to have a course on quantum computing that can bring these students in and teach them the basics before they have had all of the coursework they need to take the more traditional quantum mechanics courses. This course has been taught twice (Fall 2018, Fall 2019) with 5 and 3 students respectively (total enrollment including the concurrent undergraduate course was 12 both years). This course will be a core course for the new Quantum Information Science and Engineering concentration within the Applied and Engineering Physics, MS. This is a program that we expect to thrive and bring in significant numbers of students in the coming years so these numbers are expected to grow with the Master's program.

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

Learning Outcomes:

• Understand the basic concepts underlying quantum computing
· Ability to write and execute quantum computing code on a quantum computer
· Understand common quantum algorithms and their advantages over classical algorithms
· Understand the state-of-the-art in quantum technology and future prospects

Attach Syllabus
QISsyllabus2019.pdf

Additional Attachments

Staffing:
Ming Tian
Erhai Zhao

Relationship to Existing Programs:
This course will be a core course for the new Quantum Information Science and Engineering concentration within the Applied and Engineering Physics, MS. This is a program that we expect to thrive and bring in significant numbers of students in the coming years. It will also be an elective for the Applied and Engineering Physics, MS standard emphasis, and the Physics PhD programs.

Relationship to Existing Courses:
This course is designed to provide a background in quantum computing without students needing more than introductory physics sequence and mathematics that includes matrices. The course is not currently a pre-requisite for any other courses.

Additional Comments:

Reviewer Comments

Key: 16574

PHYS 534
Introduction to Quantum Computation and Quantum Information

Instructors (possible): Ming Tian, Erhai Zhao

Location:

Office phone number:

Mason e-mail address:

Office hours:

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

Reference book: "Quantum Computing and Quantum Information" Nielsen & Chuang

1. Overview.
2. Review of quantum mechanics—two-state system, single qubit state and measurement.
3. Single photon as qubits and applications in quantum cryptography (BB84 protocol).
4. Two-qubit states. Tensor product. Entanglement, EPR pair and Bell's inequality.
5. Unitary transformation and single qubit gates, quantum circuit model.
6. Two-qubit gates. Tensor operators. Controlled-not, Swap, Universal set.
7. Three and more qubit states and gates. Quantum circuits.
8. Application: Teleportation, Dense coding, non-cloning theorem.
9. Decomposition of Toffoli and Fredkin gates
10. Getting to know IBM Q. Programming with Qiskit.
11. Deutsch's algorithm. Deutsch-Josza,
12. More query problems: Simon, Bernstein-Vazirani
13. Quantum Fourier transform
14. Integer factorization & period finding. Shor's algorithm for factoring large numbers
15. Search problem. Grover's algorithm. Grover diffusion and amplitude amplification.
16. Error correction
17. Physical realization: superconducting qubits and ion traps.
18. Advanced topics

Grades: Weekly homework (40%), midterm exam (30%), project (30%)

Course description:

The course will introduce basic components of quantum computing such as qubit, quantum gates, and quantum circuits, exploring the counterintuitive nature of qubit state such as entanglement, non-cloning theorem, the dense coding and quantum teleportation. Physical implementation will be discussed. The course will then focus on quantum algorithm including Deutsch-Josza, Bernstein-Varirani, Simon's, Shor's, and Grover's algorithms and quantum error correction code.

A hands–on project on programming quantum code for some of these algorithms, running them on IBMq, and presenting the results to the class will be required for this course.

Learning Outcomes:

By the end of this course students will:

- Understand the basic components of quantum computing and manipulate
- Understand the physical implementation of quantum computing technologies
- Use quantum algorithms to create a quantum code
- Develop a quantum code that can run on a quantum computer

Honor Code:

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 Honor Code: Student Members of the George Mason University community pledge not to cheat, plagiarize, steal, or lie in matters related to academic work.

Your work on your homework is your own, be sure that you turn in your own work. Discussion of the homework questions with peers is acceptable and expected. Giving or receiving assistance on exams will be considered a violation of the Honor Code. [See: http://academicintegrity.gmu.edu/honorcode]

Academic Accommodations:

If you are a student with a disability and you need academic accommodations, please see me ***and*** *contact the Office of Disability Resources at 703/993-2474. All academic accommodations must be arranged through that office.*