# Course Change Request

## New Course Proposal

Date Submitted: 08/13/25 12:35 am

## Viewing: QSE 570 : Quantum Computing System Design

### Last edit: 08/19/25 3:05 pm

Changes proposed by: kgaj

| | |
|---|---|
| **Programs referencing this course** | : Quantum Science and Engineering, MS |

### In Workflow

1. **SC Curriculum Committee**
2. SC Assistant Dean
3. Assoc Provost-Graduate
4. Registrar-Courses
5. Banner

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

No

**Effective Term:** Spring 2026

**Subject Code:** QSE - Quantum Science and Engineering **Course Number:** 570

**Bundled Courses:**

**Is this course replacing another course?** No

**Equivalent Courses:**

**Catalog Title:** Quantum Computing System Design

**Banner Title:** Quantum Computing Syst Design

**Will section titles vary by semester?** No

**Credits:** 3

**Schedule Type:** Lecture

**Hours of Lecture or Seminar per week:** 3

**Repeatable:** May only be taken once for credit (NR)
*GRADUATE ONLY*

**Default Grade Mode:** Graduate Regular

**Recommended Prerequisite(s):** QSE 500 and (QSE 501 or MATH 203) and (QSE 502 or CS 112), or equivalent

**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:**

Quantum computing is an emerging and promising technology that can be used to solve complex problems that are beyond the capability of classical computing. This course centers on quantum system-level optimization, guiding students through the end-to-end workflow—from designing quantum algorithms for specific applications, to synthesizing them into quantum circuits, and compiling those circuits for execution on quantum devices. The curriculum spans essential mathematical foundations, quantum logic gates, quantum machine learning, circuit optimization, noise modeling, and error mitigation techniques. Emphasizing hands-on programming and system integration, students will develop practical skills through team-based research projects and presentations. By the end of the course, students will gain a deep understanding of both theoretical concepts and practical system-level challenges in quantum computing, preparing them to contribute effectively to this rapidly evolving field.

**Justification:**

What: Create a new course.
Why: The field of quantum information science and technology (QIST) is experiencing rapid growth, creating more job openings. A critical area within QIST is quantum computing system design, which requires interdisciplinary expertise in algorithm development, hardware-software integration, and system-level optimization. To meet this demand, students must be equipped not only with foundational knowledge of quantum computing but also with practical experience in designing and implementing complete quantum systems.
This course addresses this need by offering a comprehensive, design-oriented learning experience. Students will gain hands-on exposure to the entire quantum computing stack—from algorithm formulation to circuit synthesis and device-level compilation—mirroring real-world quantum system development workflows. By bridging theoretical foundations with system-level practice, this course prepares students to contribute meaningfully to research and development efforts in the rapidly evolving QIST landscape.
The existing course, PHYS 534, overlaps to a limited extent with the fundamental contents of the proposed course. The proposed new course focuses more on quantum system design and optimization, considering a specific application. This approach should enable students to apply quantum technology to their own research and future professional activities.

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

**Learning Outcomes:**

**Will this course be scheduled as a cross-level cross listed section?** No

**Attach Syllabus** QSE_570_syllabus.pdf

**Additional Attachments**

**Have you reached out to the Libraries to determine whether there are adequate resources to support your course? If not, please email Meg Meiman, Associate University Librarian for Learning, Research, and Engagement at mmeiman2@gmu.edu.**

Yes

**Additional Comments:** This is a core course for the new MS in Quantum Science and Engineering.

**Reviewer Comments**

Key: 19073

# QSE 570: Quantum Computing System Design

**Instructor: Dr. Weiwen Jiang**
**ECE Department, College of Engineering and Computing**
**Email: wjiang8@gmu.edu**

**Semester and Year:** TBA

**Class Meeting Day(s) and Time(s):** TBA
**Modality:** Face-to-Face
**Class Location:** TBA

**Office Hours:** TBA
**Office Hours Location:** TBA

**Course Description:** Quantum computing is an emerging and promising technology that can be used to solve complex problems that are beyond the capability of classical computing. This course centers on quantum system-level optimization, guiding students through the end-to-end workflow—from designing quantum algorithms for specific applications, to synthesizing them into quantum circuits, and compiling those circuits for execution on quantum devices. The curriculum spans essential mathematical foundations, quantum logic gates, quantum machine learning, circuit optimization, noise modeling, and error mitigation techniques. Emphasizing hands-on programming and system integration, students will develop practical skills through team-based research projects and presentations. By the end of the course, students will gain a deep understanding of both theoretical concepts and practical system-level challenges in quantum computing, preparing them to contribute effectively to this rapidly evolving field.

**Recommended Prerequisites:** QSE 500 and (QSE 501 or MATH 203) and (QSE 502 or CS 112), or equivalent

**Course Outline**:

| Date | Topic |
|---|---|
| Week 1 | Course Information & Quantum Computing Fundamentals<br>a. Course requirements<br>b. Course overview<br>c. Fundamental linear algebra needed in quantum computing<br>d. From classical logic gates to quantum logic gates |
| Week 2 | Introduction to Quantum Computing<br>a. Qubit state and quantum gates<br>b. Quantum circuits and measurement<br>c. Quantum entanglement and quantum teleportation |

| | |
|---|---|
| Week 3 | Quantum Programming<br>a. IBM Qiskit and its components<br>b. Hands-on tutorial on implementing quantum gates and circuits<br>c. Implementation of Grover's algorithm |
| Week 4 | Quantum Learning System Design (1)<br>a. Differences between classical learning and quantum learning<br>b. Bottlenecks of classical learning<br>c. Challenges of quantum learning |
| Week 5 | Quantum Learning System Design (2)<br>a. Introduction to variational quantum circuits<br>b. Mapping of a classical neural network to a quantum circuit |
| Week 6 | Quantum Learning System Design (3)<br>a. Program the quantum learning circuit in Qiskit<br>b. Implementing the quantum learning circuit |
| Week 7 | Midterm exam & project announcements |
| Week 8 | Quantum Learning System Design (4)<br>a. Quantum-classical hybrid optimization algorithm |
| Week 9 | Quantum Circuit Optimization (1)<br>a. Properties of different types of physical qubits<br>b. Compilation of a logical circuit to physical qubits |
| Week 10 | Quantum Circuit Optimization (2)<br>a. Compilation optimization<br>b. OLSQ, an open-source compilation tool |
| Week 11 | Quantum Circuit Optimization (3)<br>a. Comparison of different data encoding methods<br>b. Optimization of data encoding circuit<br>c. Quantum circuit compression |
| Week 12 | Introduction to Quantum Noise<br>a. Introduction to the sources of noise<br>b. Coherent noise, incoherent noise, and readout noise |
| Week 13 | Quantum error mitigation<br>a. Zero-error noise extrapolation<br>b. Probabilistic error cancellation<br>c. Readout-error mitigation |
| Week 14 | Quantum error mitigation using Mitiq<br>a. Workflow of Mitiq<br>b. Integrating Mitiq in the designed quantum circuits |
| Exam Period | Course Project Demonstration |

**Course Learning Outcomes:**

There are three sessions in this course: (1) Introduction to quantum computing needed in system-level design, from week 1 to week 3; (2) Quantum system design and optimization, from week 4 to week 11; (3) Quantum error mitigation on hardware-software co-design, from week 12 to week 14.

The outcomes of session 1 are as follows:

- Ability to apply essential mathematical tools (e.g., linear algebra, unitary operations, tensor products) in the context of quantum system modeling.
- Conceptual understanding of how quantum gates and circuits serve as building blocks in quantum system design.
- Familiarity with quantum programming frameworks (e.g., Qiskit) and the ability to construct and simulate small-scale quantum circuits as components of larger systems.
- Preparation for higher-level tasks such as quantum algorithm synthesis, circuit optimization, and integration into full-stack quantum workflows.

The outcomes of session 2 are as follows:

- Developing the capability to implement quantum learning circuits on a hybrid classical-quantum computing platform.
- Capability to build quantum learning circuits for domain-specific applications.
- Understanding of the process of compiling logical quantum circuits to physical qubits.
- Understanding quantum circuit compression and devising various optimization algorithms to perform circuit optimization.

The expected outcomes of session 3 are as follows:

- Understanding of quantum noise models and their impact on quantum computing.
- Characterizing quantum noise using IBM Qiskit.
- Ability to optimize a quantum mitigation approach for noise-resilience quantum circuits.

**Homework and Midterm Labs:** There are 3 labs assigned to the students to practice basic skills of quantum circuit implementation using IBM Qiskit.

**Project:** Students will form teams to implement several open-topic projects, including quantum circuit design, quantum circuit optimization, quantum learning implementation, and quantum error mitigation. The course will be supported by the IBM Quantum Education program so that the students will have access to IBM quantum computers with priority or reservation. Each team will be assigned one project. At the end of the course, students will demonstrate the completed projects and deliver a comprehensive project/technical report.

**Grade Weights:**

- Homework assignments (3 take-home labs, 10% each) 30%
- Midterm exam 20%
- Research paper presentation 20%
- Project progress review (Presentation, Report) 10%
- Project report (Presentation, Report) 20%

**Grading Schema:**

| | | | |
|---|---|---|---|
| **A+** | TBA | **B** | TBA |
| **A** | TBA | **B-** | TBA |
| **A-** | TBA | **C** | TBA |
| **B+** | TBA | **F** | TBA |

**Grading-related Policies:**

- Missed Exams: TBA
- Late Submissions: TBA

**Textbook:**

- No formal textbook is required.

**Reference Literature:**

- Learn Quantum Computation using Qiskit, IBM Quantum (link1, link2)
- Introduction to Quantum Computing: From a Layperson to a Programmer in 30 Steps (link)
- Essential Mathematics for Quantum Computing (link)
- A Practical Guide to Quantum Machine Learning and Quantum Optimization: Hands-on Approach to Modern Quantum Algorithms (link)
- Machine Learning with Quantum Computers (link)
- Quantum Machine Learning: An Applied Approach (link)
- Programming Quantum Computers: Essential Algorithms and Code Samples (link)

## AI (Artificial Intelligence) Tools Policy:

The use of AI-based tools is permitted for purposes of learning, exploring ideas, and identifying credible references. Students may use such tools to clarify concepts, brainstorm topics, or locate scholarly sources. However, AI tools must not be used to generate complete solutions to assignments, assessments, or projects, nor may students present AI-generated text, code, or other output as their own original work. Copying, paraphrasing, or otherwise incorporating AI-generated materials without attribution constitutes academic dishonesty and will be treated as plagiarism under the University's Academic Standards. Students are responsible for critically evaluating and verifying any information obtained through AI tools, ensuring that their submissions reflect their own understanding, analysis, and synthesis of course material.

**Common Policies Affecting All Courses at George Mason University:**

Common policies affecting all courses at George Mason University, including

- Academic Standards
- Accommodations for Students with Disabilities
- FERPA and Use of GMU Email Addresses for Course Communication
- Title IX Resources and Required Reporting,

are available at
https://stearnscenter.gmu.edu/home/gmu-common-course-policies

You are strongly encouraged to get familiar with this additional information.