Quantum Engineering

Degrees Offered

- Graduate Certificate in Quantum Engineering
- Master of Science (Non-Thesis)
- Master of Science (Thesis)

Program Requirements

Quantum Engineering is an interdisciplinary program that seeks to equip students for careers in emerging technologies based on quantum entanglement. It encompasses a wide range of disciplines that include physics, materials science, computer science, and mathematics, and is necessarily a collaborative effort among many Mines departments. Two Master's degrees and one Graduate certificate are offered.

For both degrees and the graduate certificate, Quantum Engineering has two "tracks" as summarized below. The Quantum Engineering Hardware (QEH) track will focus on experimental techniques relevant to quantum technology, while the Quantum Engineering Software (QES) track will focus on theory, algorithms and simulation. Students must choose a track to complete the program, but they may take courses from both tracks provided they meet the prerequisite requirements.

MS Degree Curriculum Requirements:

A Master of Science in Quantum Engineering will consist of 30 total credits. Students may choose a thesis or non-thesis option for this degree. For the thesis option, 9 credits out of the 30 are devoted to thesis research leading to an acceptable Master's thesis. Students choosing the non-thesis option will devote all 30 credits to coursework. Regardless of the option chosen, 9 of the coursework credits will be devoted to the required core classes for the chosen track.

Reflecting the interdisciplinary nature of the program, we strongly recommend to our students that at least 9 total credits of the MS degree coursework should come from courses in a department outside of the student's undergraduate major. The required core courses, if outside of the student's major, would count towards this recommendation. Our guiding philosophy is that the problem of building a quantum computer is a complex, interdisciplinary one which requires contributions from a vast array of subfields, and young scientists who appreciate this will likely have a far better perspective on the field than those who do not.

MS Non-Thesis Software Track

PHGN519	FUNDAMENTALS OF QUANTUM INFORMATION	3.0
CSCI581	QUANTUM PROGRAMMING	3.0
PHGN545	QUANTUM MANY-BODY PHYSICS	3.0
Electives		21.0
Total Semester Hrs		**30.0**

MS Non-Thesis Hardware Track

PHGN519	FUNDAMENTALS OF QUANTUM INFORMATION	3.0
PHGN435/535	INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY	3.0
EENG532	LOW TEMPERATURE MICROWAVE MEASUREMENTS FOR QUANTUM ENGINEERING	3.0
Electives		21.0
Total Semester Hrs		**30.0**

MS Thesis Software Track

PHGN519	FUNDAMENTALS OF QUANTUM INFORMATION	3.0
CSCI581	QUANTUM PROGRAMMING	3.0
PHGN545	QUANTUM MANY-BODY PHYSICS	3.0
Electives		12.0
PHGN707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	9.0
Total Semester Hrs		**30.0**

MS Thesis Hardware Track

PHGN519	FUNDAMENTALS OF QUANTUM INFORMATION	3.0
PHGN435/535	INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY	3.0
EENG/PHGN532	LOW TEMPERATURE MICROWAVE MEASUREMENTS FOR QUANTUM ENGINEERING	3.0
Electives		12.0
PHGN707	GRADUATE THESIS / DISSERTATION RESEARCH CREDIT	9.0
Total Semester Hrs		**30.0**

Coursework Details:

QES students will be required to take these courses in the following sequence:

In the Fall:

- PHGN519, Fundamentals of Quantum Information

In the Spring:

- CSCI581, Quantum Programming
- PHGN545, Quantum Many-Body Physics

QEH students will be required to take these courses in the following sequence:

In the Fall:

- PHGN519, Fundamentals of Quantum Information

In the Spring:

- PHGN435/PHGN535, Interdisciplinary Silicon Processing Laboratory
- PHGN532, Low Temperature Microwave Measurements for Quantum Applications

Approved Electives:

Physics Electives		
PHGN440	SOLID STATE PHYSICS	3.0
PHGN441	SOLID STATE PHYSICS APPLICATIONS AND PHENOMENA	3.0
PHGN466/566	MODERN OPTICAL ENGINEERING	3.0
PHGN480	LASER PHYSICS	3.0
PHGN520	QUANTUM MECHANICS I	3.0

PHGN521	QUANTUM MECHANICS II	3.0
PHGN530	STATISTICAL MECHANICS	3.0
PHGN550	NANOSCALE PHYSICS AND TECHNOLOGY	3.0
PHGN585	NONLINEAR OPTICS	3.0
Computer Science Electives		
CSCI542	SIMULATION	3.0
CSCI563	PARALLEL COMPUTING FOR SCIENTISTS AND ENGINEERS	3.0
CSCI564	ADVANCED COMPUTER ARCHITECTURE	3.0
CSCI571	ARTIFICIAL INTELLIGENCE	3.0
CSCI474	INTRODUCTION TO CRYPTOGRAPHY	3.0
CSCI575	ADVANCED MACHINE LEARNING	3.0
CSCI580	ADVANCED HIGH PERFORMANCE COMPUTING	3.0
Electrical Engineering Electives		
EENG509	SPARSE SIGNAL PROCESSING	3.0
EENG417/517	MODERN CONTROL DESIGN	3.0
EENG526	ADVANCED ELECTROMAGNETICS	3.0
EENG528	COMPUTATIONAL ELECTROMAGNETICS	3.0
EENG529	ACTIVE RF & MICROWAVE DEVICES	3.0
EENG530	PASSIVE RF & MICROWAVE DEVICES	3.0
EENG617	INTELLIGENT CONTROL SYSTEMS	3.0
EENG618	NONLINEAR AND ADAPTIVE CONTROL	3.0
Metallurgy and Material Engineering Electives		
MTGN456	ELECTRON MICROSCOPY	2.0
Materials Science Electives		
MLGN593	BONDING, STRUCTURE, AND CRYSTALLOGRAPHY	3.0
Applied Mathematics and Statistics Electives		
MATH408	COMPUTATIONAL METHODS FOR DIFFERENTIAL EQUATIONS	3.0
MATH436	ADVANCED STATISTICAL MODELING	3.0
MATH438	STOCHASTIC MODELS	3.0
MATH510	ORDINARY DIFFERENTIAL EQUATIONS AND DYNAMICAL SYSTEMS	3.0
MATH551	COMPUTATIONAL LINEAR ALGEBRA	3.0
Humanities, Arts, and Social Sciences Electives		
HASS423	ADVANCED SCIENCE COMMUNICATION	3.0

Mines' Combined Undergraduate / Graduate Degree Program:

Students enrolled in Mines' combined undergraduate/graduate program may double count up to six credits of graduate coursework to fulfill requirements of both their undergraduate and graduate degree programs. These courses must have been passed with "B-" or better, not be substitutes for required coursework, and meet all other University, Department, and Program requirements for graduate credit.

Students are advised to consult with their undergraduate and graduate advisors for appropriate courses to double count upon admission to the combined program.

Graduate Certificate Curriculum Requirements:

The certificate option consists of three of the four new courses, plus one additional elective chosen from the above list, for a total of 12 credits.

Graduate Certificate, Software Track

PHGN519	FUNDAMENTALS OF QUANTUM INFORMATION	3.0
CSCI581	QUANTUM PROGRAMMING	3.0
PHGN545	QUANTUM MANY-BODY PHYSICS	3.0
Elective		3.0
Total Semester Hrs		**12.0**

Graduate Certificate, Hardware Track

PHGN519	FUNDAMENTALS OF QUANTUM INFORMATION	3.0
PHGN435/535	INTERDISCIPLINARY MICROELECTRONICS PROCESSING LABORATORY	3.0
EENG/PHGN532	LOW TEMPERATURE MICROWAVE MEASUREMENTS FOR QUANTUM ENGINEERING	3.0
Elective		3.0
Total Semester Hrs		**12.0**

Program Director

Eliot Kapit, Associate Professor, Physics

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Lincoln Carr, Professor

Serena Eley, Assistant Professor

Zhexuan Gong, Assistant Professor

Eliot Kapit, Associate Professor

Kyle Leach, Associate Professor

Meenakshi Singh, Assistant Professor

Affiliated Faculty

Matt Beard, Joint Appointment, NREL and Chemistry

Justin Johnson, Joint Appointment, NREL and Physics

Adele Tamboli, Joint Appointment, NREL and Physics