QUANTUM ENGINEERING - MINOR

A student graduating with a bachelor's degree from CU Boulder may also earn a minor in quantum engineering. Students earning a Bachelor of Science in Electrical Engineering or Electrical & Computer Engineering are eligible for this minor; however, they may not count the three required courses for the minor towards both their bachelor's degree and their minor.

The minor in quantum engineering provides training and a solid foundation in quantum technologies. Quantum technologies have applications in quantum-enhanced sensors, quantum communications, and quantum computing. The goal is to introduce students to the fundamentals of quantum theory and explore all of the major hardware platforms. This will allow graduates to easily adapt to the variety of technologies seen in industry. The skills obtained in this minor are important to students who expect to participate in real-world situations that increasingly involve quantum technologies.

Requirements

Prerequisites

Students admitted to the Quantum Engineering Minor must have a cumulative GPA of 2.700 or better.

There are three **prerequisites** for the quantum engineering minor.

1. **Programming**. ASEN 1320, ECEN 1310, CSCI 1300, APPM 3050, PHYS 2600 or similar.
2. **Calculus 2** (minimum). APPM 1360, MATH 2300 or similar.
3. **Linear Algebra**. MATH 3135, MATH 2130, MATH 2135, APPM 3310, CSCI 2820, APPM 2360 or similar.

Additionally, it is *recommended* that students have taken Calculus 3: APPM 2350, MATH 2400 or similar and probability: APPM 3570, STAT 3100, MATH 3510, ECEN 3810 or similar. Finally, PHYS 2130 is recommended as a preparatory subject for the minor. A grade of C- or better is required in all prerequisite courses.

Course Requirements

This minor requires a minimum of 18 credit hours.

A cumulative GPA of 2.000 or better is required for courses used to satisfy the requirements of this minor. Each individual course that is counted toward this minor must be passed with a grade of D- or better (note that a C- or better grade is required in all prerequisite courses).

Required Courses and Credits

Within the Quantum Engineering minor there is a theory and experimental track. It will consist of a set of required core courses and a selection of electives, as follows.

Code	Title	Credit Hours
Foundations Courses (to be taken by both Theory & Experimental Track students)		**6**
ECEN 4915	(ECEN 4914 Foundations of Quantum Engineering)	
ECEN 4925	Foundations of Quantum Hardware	
Track Course		**3**
Theory Track		
CSCI 3090	Introduction to Quantum Computing	
or PHYS 3090	Introduction to Quantum Computing	
Experimental Track (to be offered starting in 2023 or 2024)		
ECEN 4XXX Quantum Engineering Lab		
Electives [1]		**9**
ECEN 3250	Microelectronics	
ECEN 3400	Electromagnetic Fields and Waves	
ECEN 3410	Electromagnetic Waves and Transmission	
ECEN 4138	Control Systems Analysis	
ECEN 4553	Compiler Construction	
ECEN 4606	Undergraduate Optics Laboratory	
ECEN 4616	Optoelectronic System Design	
ECEN 4634	Microwave and RF Laboratory	
APPM 4490	Theory of Machine Learning	
APPM 4515	High-Dimensional Probability for Data Science	
PHYS 4340	Introduction to Solid State Physics	
PHYS 4230	Thermodynamics and Statistical Mechanics	
PHYS 4510	Optics	
PHYS 4430	Advanced Laboratory	
STAT 4250	Data Assimilation in High Dimensional Dynamical Systems	
STAT 4400	Advanced Statistical Modeling	
STAT 4100	Markov Processes, Queues, and Monte Carlo Simulations	
STAT 4610	Statistical Learning	
STAT 4540	Introduction to Time Series	
CHEN 4570	Instrumentation and Process Control	
CHEN 4521	Physical Chemistry for Engineers	
CHEN 4130	Chemical Engineering Laboratory	
CSCI 3656	Numerical Computation	
CSCI 3434	Theory of Computation	
CSCI 4555	Compiler Construction	
CSCI 4622	Machine Learning	
MCEN 4173	Finite Element Analysis	

[1] Listed electives are not required to relax their prerequisites to enable students to take the course. Students may also seek permission from the program director of the Quantum Engineering minor to apply an alternative course toward the minor. The decision will be at the discretion of the program director.