ROBOTICS - DOCTOR OF PHILOSOPHY (PHD)

The doctoral program in robotics provides advanced training and study in robotics-related topics consistent with the program focus on autonomy and AI, field robotics, human-robot interaction, smart materials, security, controls and estimation, bio-inspired systems and advanced manufacturing. The program prepares students for careers in local and national industry, government, national labs, academic research laboratories and university faculty positions.

The program provides a strong foundation in mathematics and engineering, while also allowing flexibility to select courses across departments to achieve the breadth and depth required for research advances beyond the state of the art. Students will achieve their educational goals through a combination of cross-disciplinary coursework and research under the supervision of one or more of the program's faculty members.

For more information, see the Robotics (https://www.colorado.edu/program/robotics/academics/)website.

Required Courses and Credits

The degree requires a minimum of 30 credit hours of coursework in courses numbered 5000 or above, with a minimum GPA of 3.00, plus 30 hours of dissertation credit. More coursework may be required at the faculty advisor's discretion. All courses listed on the Application for Admission to Candidacy must have grades of B- or better. For policies concerning academic probation, refer to the Graduate School rules in the University Catalog. A maximum of 21 credit hours of graduate coursework may be transferred from another accredited institution, assuming the courses meet program and Graduate School standards. All courses taken in a master's degree program at CU Boulder may be applied toward the doctoral degree at the university, provided they are at the 5000 level or above and meet doctoral standards.

The PhD in Robotics provides a flexible curriculum that provides depth of study across the disciplines from departments and programs hosted in CEAS, including Architectural Engineering (AREN), Aerospace Engineering (ASEN), Biomedical Engineering (BMEN), Chemical Engineering (CHEN), Civil Engineering (CVEN), Computer Science (CSCI), Electrical, Computing and Energy Engineering (ECEN), Electrical Engineering (EEEN), Engineering Management (EMEN), Environmental Engineering (EVEN), Mechanical Engineering (MCEN) or ATLAS. Of the 30 credit hours of coursework required, at least 18 credit hours will be specifically in designated robotics (ROBO) courses, with the remaining credit hours obtained, as needed, from other STEM fields. Of the 18 credit hours of robotics coursework required, one core course is required: ROBO 5000 Introduction to Robotics, which provides a foundation for advanced study. This allows for maximum flexibility for students to tailor coursework for a variety of post-graduate career goals. Additionally, the Robotics Graduate Program will provide guidance on recommended courses in the basic concentration areas but each student and advisor are required to develop a course plan and submit to the graduate committee for approval.

Preliminary Examination

Every student desiring to pursue the PhD degree must pass a preliminary examination. As a part of this evaluation, students must pass a multiple subject area oral examination to test fundamental robotics competency. Subject areas are based on the tracks within the robotics program and selected by the student. Overall performance in the required examinations will determine pass/fail status.

Comprehensive Examination

After passing the preliminary examination, students continue their coursework and prepare a written dissertation prospectus. When ready, they take an oral comprehensive examination covering the graduate coursework and the dissertation prospectus. The oral examination is based primarily on a written proposal for the dissertation research provided by the student to committee members in advance. This examination is conducted before the student's doctoral committee of five or more graduate faculty members chosen by the student and approved by the program and the Graduate School.

PhD Dissertation

A minimum of 30 dissertation credit hours are required for the PhD degree. Up to 10 credit hours may be taken in any given semester. Students must write a dissertation based on original research conducted under the supervision of a graduate faculty member. The dissertation must fulfill all Graduate School requirements. After the dissertation is completed, an oral final examination on the dissertation and related topics is conducted by the student's doctoral committee of at least five members. The approved dissertation must be submitted to the program and the Graduate School.

Time Limit

All requirements for the Robotics PhD must be completed within six years of admission to the PhD program. A waiver from the Graduate Committee is required for each semester beyond this limit.

Course Requirements

A minimum of 18 credit hours is required (3 core plus 15 robotics electives).

Code	Title	Credit Hours
Core Course Requirement		
ROBO 5000	Introduction to Robotics	3
Robotics Electives		**15**
Robotics Courses in Computer Science		
CSCI 5254	Convex Optimization and Its Applications	3
CSCI 5302	Advanced Robotics	3
CSCI 5322	Algorithmic Human-Robot Interaction	3
CSCI 5622	Machine Learning	3
CSCI 5922	Neural Networks and Deep Learning	3
Robotics Courses In Aerospace Engineering Sciences		
ASEN 5014	Linear Control Systems	3
ASEN 5044	Statistical Estimation for Dynamical Systems	3
ASEN 5067	Microavionics: Introduction to PIC Microcontrollers for Aerospace Systems	3
ASEN 5254	Algorithmic Motion Planning	3
ASEN 5264	Decision Making under Uncertainty	3
ASEN 6024	Nonlinear Control Systems	3
ASEN 6044	Advanced State Estimation	3
ASEN 6519	Special Topics (Hybrid Systems)	3
Robotics Courses in Mechanical Engineering		

MCEN 5115	Mechatronics and Robotics I	3
MCEN/ECEN 5138	Feedback Control	3
MCEN 5155	Automated Mechanical Design Synthesis	3
MCEN 5157	Modeling of Human Movement	3
MCEN 5173	Finite Element Analysis	3
MCEN 5195	Bioinspired Robotics	3
MCEN 5228	Special Topics in Mechanical Engineering (Advanced Dynamics)	3
MCEN 5228	Special Topics in Mechanical Engineering (Industrial Automation)	3
MCEN 5293	Mechanics of Soft Matter	3
MCEN/ECEN 5448	Linear Systems	3
MCEN 5636	Micro-Electro-Mechanical Systems 1	3
MCEN 6228	Special Topics in Mechanical Engineering (Robust Multivariable Control)	3
Robotics Courses in Electronical Engineering		
ECEN 5008	Special Topics (Game Theory)	3
ECEN/MCEN 5138	Control Systems Analysis	3
ECEN/MCEN 5448	Advanced Linear Systems	3
ECEN 5458	Sampled Data and Digital Control Systems	3
ECEN 5478	Online Convex Optimization and Learning	3
ECEN 5638	Control Systems Laboratory	3
ECEN 5738	Theory of Nonlinear Systems	3
Robotics Courses in Atlas		
ATLS/CSCI 5616	Introduction to Virtual Reality	3
Technical Electives		**12**

Courses in STEM fields will be considered, provided they are related to the research goals of the student.

Learning Outcomes

Upon completing the program, students will:

- Possess a deep knowledge of their specific research area that includes a thorough understanding of the fundamental science and mathematics that underlies their research.
- Be well-versed in the current state of knowledge of their area as described in the literature as well as the fundamental questions that are of critical importance to the field.
- Communicate effectively (orally and written) about their research area to roboticists within and outside of their focus area.
- Independently plan, perform, analyze and report high quality research in robotics.
- Be experts in a set of modern research tools used in performance of research.