DOCTORAL PROGRAMS IN COMPUTATIONAL SCIENCE AND ENGINEERING

Computational Science and Engineering (*https://catalog.mit.edu/interdisciplinary/graduate-programs/computational-science-engineering*)

Doctor of Philosophy in Computational Science and Engineering

Program Requirements

Core Subjects		
18.335[J]	Introduction to Numerical Methods	12
CSE.900	Doctoral Seminar in Computational Science and Engineering	3
Core Area of Study		48
Choose four 12-unit subjects from the core CSE areas in the table below. [1]		
Computational Concentration [1]		**24**
Unrestricted Electives		**24**
Choose 24 units of additional graduate-level subjects in any field.		
Thesis Research		**168-288**
Total Units		**279-399**

Note: Students in this program can choose to receive the Doctor of Philosophy or the Doctor of Science in the chosen field of specialization. Students receiving veterans benefits must select the degree they wish to receive prior to program certification with the Veterans Administration.

[1] *A program of study comprising subjects in the selected core areas and the computational concentration must be developed in consultation with the student's doctoral thesis committee and approved by the CCSE graduate officer.*

Core Area Subjects		
Computational Modeling		
1.545[J]	Atomistic Modeling and Simulation of Materials and Structures [1]	12
1.723	Computational Methods for Flow in Porous Media [1]	12
2.29	Numerical Fluid Mechanics [1]	12
3.320	Atomistic Computer Modeling of Materials [1]	12
4.450[J]	Computational Structural Design and Optimization [1]	
9.660	Computational Cognitive Science [1]	12
10.637[J]	Computational Chemistry [1]	12
12.521	Computational Geophysical Modeling [1]	12
12.850	Computational Ocean Modeling [1]	12
16.225[J]	Computational Mechanics of Materials [1]	12
18.369[J]	Mathematical Methods in Nanophotonics [1]	12
18.417	Introduction to Computational Molecular Biology [1]	12
22.315	Applied Computational Fluid Dynamics and Heat Transfer [1]	12
Discretization and Numerical Methods for Partial Differential Equations		
2.098	Introduction to Finite Element Methods	12
6.7300[J]	Introduction to Modeling and Simulation	12
6.8410	Shape Analysis	12
16.920[J]	Numerical Methods for Partial Differential Equations [1]	12
16.930	Advanced Topics in Numerical Methods for Partial Differential Equations	12
18.336[J]	Fast Methods for Partial Differential and Integral Equations [1]	12
22.15	Essential Numerical Methods	6
High-Performance Computing, Software Engineering, and/or Algorithms [2]		
6.5060	Algorithm Engineering [1]	12
6.5210[J]	Advanced Algorithms [1]	12
6.5220[J]	Randomized Algorithms	12
6.5250[J]	Distributed Algorithms	12
6.5320	Geometric Computing	12
18.337[J]	Parallel Computing and Scientific Machine Learning [1]	12
18.435[J]	Quantum Computation	12
Inference, Statistical Computing, and Data-Driven Modeling		
2.156	Artificial Intelligence and Machine Learning for Engineering Design	12
6.7800	Inference and Information [1]	12
6.7810	Algorithms for Inference	12
6.7830	Bayesian Modeling and Inference	12
6.7900	Machine Learning [1]	12
6.C51	Modeling with Machine Learning: from Algorithms to Applications	6
And one of the following 6-unit co-requisites:		
1.C51	Machine Learning for Sustainable Systems	

2.C51	Physical Systems Modeling and Design Using Machine Learning	
3.C51[J]	Machine Learning for Molecular Engineering	
6.C511	Modeling with Machine Learning for Computer Science	
7.C51	Machine Learning in Molecular and Cellular Biology	
22.C51	Modeling with Machine Learning: Nuclear Science and Engineering Applications	
SCM.C51	Machine Learning Applications for Supply Chain Management	
9.520[J]	Statistical Learning Theory and Applications	12
10.554[J]	Process Data Analytics	12
16.940	Numerical Methods for Stochastic Modeling and Inference [1]	12
IDS.131[J]	Statistics, Computation and Applications	12
Mathematical Foundations [3]		
6.7700[J]	Fundamentals of Probability [1]	12
18.1002	Real Analysis [1]	12
18.1011	Analysis and Manifolds [1]	12
18.1021	Introduction to Functional Analysis [1]	12
18.1031	Fourier Analysis: Theory and Applications [1]	12
18.125	Measure Theory and Analysis [1]	12
18.1521	Introduction to Partial Differential Equations [1]	12
18.3541	Nonlinear Dynamics: Continuum Systems [1]	12
18.4041[J]	Theory of Computation	12
18.655	Mathematical Statistics [1]	12
18.675	Theory of Probability [1]	12
Optimization Methods		
1.583[J]	Topology Optimization of Structures	12
6.7210[J]	Introduction to Mathematical Programming [1]	12
6.7220[J]	Nonlinear Optimization [1]	12
6.7230[J]	Algebraic Techniques and Semidefinite Optimization	12
6.7940	Dynamic Programming and Reinforcement Learning	12
6.C57[J]	Optimization Methods [1]	12
10.557	Mixed-integer and Nonconvex Optimization	12
15.083	Integer Optimization	12
15.C57[J]	Optimization Methods [1]	12
16.888[J]	Multidisciplinary Design Optimization	12

1 *Subject can be used for the qualification evaluation.*

2 *Harvard course COMPSCI 2050 High Performance Computing for Science and Engineering is also an approved subject in this area.*

3 *Students can also choose any 12-unit, letter-graded (not P/D/F), graduate-level Mathematics subject numbered 18.1* or higher not listed elsewhere in this approved subject list, though seminar and special tops subjects are generally not allowed.*

Programs Offered by CCSE in Conjunction with Select Departments in the Schools of Engineering and Science

Computational Science and Engineering (*https://catalog.mit.edu/interdisciplinary/graduate-programs/computational-science-engineering*)

The interdisciplinary doctoral program in Computational Science and Engineering (PhD in CSE + Engineering or Science (p. 4)) offers students the opportunity to specialize at the doctoral level in a computation-related field of their choice via computationally-oriented coursework and a doctoral thesis with a disciplinary focus related to one of eight participating host departments, namely, Aeronautics and Astronautics; Chemical Engineering; Civil and Environmental Engineering; Earth, Atmospheric and Planetary Sciences; Materials Science and Engineering; Mathematics; Mechanical Engineering; or Nuclear Science and Engineering.

Doctoral thesis fields associated with each department are as follows:

- **Aeronautics and Astronautics**
  - Aerospace Engineering and Computational Science
  - Computational Science and Engineering (available only to students who matriculate in 2023–2024 or earlier)
- **Chemical Engineering**
  - Chemical Engineering and Computation
- **Civil and Environmental Engineering**
  - Civil Engineering and Computation
  - Environmental Engineering and Computation
- **Materials Science and Engineering**
  - Computational Materials Science and Engineering
- **Mechanical Engineering**
  - Mechanical Engineering and Computation
- **Nuclear Science and Engineering**
  - Computational Nuclear Science and Engineering
  - Nuclear Engineering and Computation
- **Earth, Atmospheric and Planetary Sciences**
  - Computational Earth, Science and Planetary Sciences

- **Mathematics**
  - Mathematics and Computational Science

As with the standalone CSE PhD program, the emphasis of thesis research activities is the development of new computational methods and/or the innovative application of state-of-the-art computational techniques to important problems in engineering and science. In contrast to the standalone PhD program, however, this research is expected to have a strong disciplinary component of interest to the host department.

The interdisciplinary CSE PhD program is administered jointly by CCSE and the host departments. Students must submit an application to the CSE PhD program, indicating the department in which they wish to be hosted. To gain admission, CSE program applicants must receive approval from both the host department graduate admission committee and the CSE graduate admission committee. See the website for more information about the application process, requirements, and relevant deadlines (*https://cse.mit.edu/admissions*).

Once admitted, doctoral degree candidates are expected to complete the host department's degree requirements (including qualifying exam) with some deviations relating to coursework, thesis committee composition, and thesis submission that are specific to the CSE program and are discussed in more detail on the CSE website (*https://cse.mit.edu/programs/phd*). The most notable coursework requirement associated with this CSE degree is a course of study comprising five graduate subjects in CSE (below).

Computational Concentration Subjects

1.125	Architecting and Engineering Software Systems	12
1.545[J]	Atomistic Modeling and Simulation of Materials and Structures	12
1.583[J]	Topology Optimization of Structures	12
1.723	Computational Methods for Flow in Porous Media	12
2.098	Introduction to Finite Element Methods	12
2.156	Artificial Intelligence and Machine Learning for Engineering Design	12
2.168	Learning Machines	12
2.29	Numerical Fluid Mechanics	12
3.320	Atomistic Computer Modeling of Materials	12
4.450[J]	Computational Structural Design and Optimization	
6.7210[J]	Introduction to Mathematical Programming	12
6.7220[J]	Nonlinear Optimization	12
6.7230[J]	Algebraic Techniques and Semidefinite Optimization	12
6.7300[J]	Introduction to Modeling and Simulation	12
6.7810	Algorithms for Inference	12
6.7830	Bayesian Modeling and Inference	12
6.7900	Machine Learning [1]	12
6.7940	Dynamic Programming and Reinforcement Learning	12
6.8300	Advances in Computer Vision	12
6.8410	Shape Analysis	12
6.C51	Modeling with Machine Learning: from Algorithms to Applications [2]	6
9.520[J]	Statistical Learning Theory and Applications	12
9.660	Computational Cognitive Science	12
10.551	Systems Engineering [3]	9
10.552	Modern Control Design [3]	9
10.554[J]	Process Data Analytics	12
10.557	Mixed-integer and Nonconvex Optimization	12
10.637[J]	Computational Chemistry	12
12.515	Data and Models	12
12.521	Computational Geophysical Modeling	12
12.620[J]	Classical Mechanics: A Computational Approach	12
12.714	Computational Data Analysis	12
12.805	Data Analysis in Physical Oceanography	12
12.850	Computational Ocean Modeling	12
15.070[J]	Discrete Probability and Stochastic Processes	12
15.077[J]	Statistical Machine Learning and Data Science [1]	12
15.083	Integer Optimization	12
15.764[J]	The Theory of Operations Management	12
15.C57[J]	Optimization Methods	12
16.110	Flight Vehicle Aerodynamics	12
16.225[J]	Computational Mechanics of Materials	12
16.413[J]	Principles of Autonomy and Decision Making	12
16.888[J]	Multidisciplinary Design Optimization	12
16.920[J]	Numerical Methods for Partial Differential Equations	12
16.930	Advanced Topics in Numerical Methods for Partial Differential Equations	12

16.940	Numerical Methods for Stochastic Modeling and Inference	12
18.335[J]	Introduction to Numerical Methods	12
18.336[J]	Fast Methods for Partial Differential and Integral Equations	12
18.337[J]	Parallel Computing and Scientific Machine Learning	12
18.338	Eigenvalues of Random Matrices	12
18.369[J]	Mathematical Methods in Nanophotonics	12
18.435[J]	Quantum Computation	12
22.15	Essential Numerical Methods	6
22.212	Nuclear Reactor Analysis II	12
22.213	Nuclear Reactor Physics III	12
22.315	Applied Computational Fluid Dynamics and Heat Transfer	12
CSE.999	Experiential Learning in Computational Science and Engineering	
IDS.131[J]	Statistics, Computation and Applications	12

Note: Students may not use more than 12 units of credit from a "meets with undergraduate" subject to fulfill the CSE curriculum requirements

[1] *Credit can only be given for one of 6.7900, 15.077[J], or IDS.147[J].*

[2] *Students cannot receive credit without simultaneous completion of a 6-unit Common Ground disciplinary module. The two subjects together count as one 12-unit subject. See 6.C51 for more information.*

[3] *Students can receive credit for either 10.551 or 10.552 as a CSE concentration subject, but not both.*

[4] *Subject to Sloan bidding process.*