

# APPLIED AND COMPUTATIONAL MATHEMATICS, MASTER OF SCIENCE

The Applied and Computational Mathematics program is devoted to the study and development of mathematical disciplines especially oriented to the complex problems of modern society. Our curriculum emphasizes several areas of applied mathematics which have been grouped into five focus areas: Applied Analysis, Information Technology and Computation, Operations Research, Probability and Statistics, and Simulation and Modeling.

A focus area is not required for this program. Students may choose to specialize in one of these areas, or tailor their courses to meet their individual needs.

## Admission Requirements

Applicants (degree seeking and special student) must meet the general requirements for admission to graduate study, as outlined in the Admission Requirements (<https://e-catalogue.jhu.edu/engineering/engineering-professionals/admission-requirements/>) section. The applicant's prior education must include the following prerequisites:

1. at least one mathematics course beyond multivariate calculus (such as advanced calculus, differential equations, or linear algebra); and
2. familiarity with at least one programming language (e.g., C, C++, FORTRAN, Java, Python, R, or MATLAB).

Applicants whose prior education does not include the prerequisites listed above may still be admitted under provisional status, followed by full admission once they have completed the missing prerequisites. Missing prerequisites may be completed with Johns Hopkins Engineering or, with approval, at another regionally accredited institution. In addition to these requirements, a detailed work résumé, statement of purpose, and transcripts from all college studies must be submitted. Admitted students typically have earned a grade point average of at least 3.0 on a 4.0 scale (B or above) in the latter half of their undergraduate studies. When reviewing an application, the candidate's academic and professional background will be considered.

## Program Requirements

Ten courses must be completed within five years. The curriculum consists of four core courses (including a two-term 700-level course sequence) and six electives. The six electives must include at least four courses from the Applied and Computational Mathematics (ACM) program (625.xxx) with at least two of the four ACM elective courses at the 700-level. At least one of two 700-level electives must not be on the list of core sequence courses (625.717/625.718, 625.721/625.722, and 625.725/625.726).

## Home-to-Hopkins

Home-to-Hopkins students are permitted to substitute Homewood Campus courses to help meet EP program course requirements. Students should work with their faculty advisor to develop a course plan that will satisfy the degree requirements.

Code	Title	Credits
<b>Core Courses</b>		
EN.625.603	Statistical Methods and Data Analysis	3
EN.625.601	Real Analysis	3
	or EN.625.609 Matrix Theory	
<b>Select one of the following sequences</b>		
EN.625.717 & EN.625.718	Advanced Differential Equations: Partial and Advanced Differential Equations: Nonlinear Differential Equations and Dynamical Systems <sup>1</sup>	6
EN.625.721 & EN.625.722	Probability and Stochastic Process I and Probability and Stochastic Process II	6
EN.625.725 & EN.625.726	Theory Of Statistics I and Theory of Statistics II	6

<sup>1</sup> courses may be taken in either order

An independent study (EN.625.800 Independent Study), research project (EN.625.801 Applied and Computational Mathematics Master's Research—EN.625.802 Applied and Computational Mathematics Master's Research), or thesis (EN.625.803 Applied and Computational Mathematics Master's Thesis—EN.625.804 Applied and Computational Mathematics Master's Thesis) may be substituted for one or two of the 700-level courses outside of the 700-level core sequence. The course 625.800 Independent Study may not be used towards the ACM M.S. if a student also wishes to count 625.801–802 or 625.803–804 towards the M.S. degree. Overall, given the requirements above, at least four 700- or 800-level ACM courses (625.xxx) must be completed. A student who has taken at least one semester of graduate statistics (outside of Applied and Computational Mathematics) may substitute another 625.xxx course for EN.625.603 Statistical Methods and Data Analysis with approval of the student's advisor. The prior statistics course must be calculus-based and must cover the same general topics as EN.625.603 Statistical Methods and Data Analysis. Focus areas are not required for this program. Only one C-range grade (C+, C, or C–) can count toward the master's degree. Course selections at the 800-level or outside of these core and focus area course lists are subject to advisor approval.

## Courses

Code	Title	Credits
<b>Undergraduate-Level Courses</b>		
EN.625.108	Calculus I	0
EN.625.109	Calculus II	0
EN.625.201	General Applied Mathematics	3
EN.625.240	Introduction to Probability and Statistics	3
EN.625.250	Multivariable Calculus and Complex Analysis	3
EN.625.251	Introduction to Ordinary and Partial Differential Equations	3
EN.625.252	Linear Algebra and Its Applications	3
EN.625.260	Introduction to Signals and Systems	3

Students may take selected courses above as desired (e.g., as a refresher) or as required via provisional admissions status. Applicants whose prior education does not include the prerequisites listed under Admission Requirements may still be admitted under provisional status, followed by full admission once they have completed the missing prerequisites. These 100- and 200-level courses are not for graduate credit, and do not count toward the degree or certificate requirements.

Note that 625.250 fulfills a requirement for multivariable calculus (calculus III).

## Courses by Focus Areas

The focus areas offered represent related groups of courses that are relevant for students with interests in the selected areas. The focus areas are presented as an aid to students in planning their course schedules and are generally applicable to students seeking a master's degree; the more advanced courses within each focus area may also apply to the post-master's certificate. A Focus Area can be selected, but is not required for this program. They do not appear as official designations on a student's transcript or diploma.

Code	Title	Credits
<b>Focus Areas</b>		
Applied Analysis (p. 2)		
Information Technology and Computation (p. 2)		
Operations Research (p. 3)		
Probability and Statistics (p. 3)		
Simulation and Modeling (p. 4)		

### Applied Analysis

Code	Title	Credits
EN.625.601	Real Analysis	3
EN.625.602	Modern Algebra	3
EN.625.604	Ordinary Differential Equations	3
EN.625.609	Matrix Theory	3
EN.625.611	Computational Methods	3
EN.625.680	Cryptography	3
EN.625.685	Number Theory	3
EN.625.687	Applied Topology	3
EN.625.690	Computational Complexity and Approximation	3
EN.625.694	Introduction to Convexity	3
EN.625.703	Complex Analysis	3
EN.625.710	Fourier Analysis with Applications to Signal Processing and Differential Equations	3
EN.625.717	Advanced Differential Equations: Partial Differential Equations	3
EN.625.718	Advanced Differential Equations: Nonlinear Differential Equations and Dynamical Systems	3
EN.625.719	Advanced Differential Equations: Numerical Solutions to Ordinary and Partial Differential Equations	3
EN.625.728	Theory of Probability	3
EN.625.736	Combinatorial Optimization	3
EN.625.800	Independent Study	3
EN.625.801 & EN.625.802	Applied and Computational Mathematics Master's Research and Applied and Computational Mathematics Master's Research	6
EN.625.803 & EN.625.804	Applied and Computational Mathematics Master's Thesis and Applied and Computational Mathematics Master's Thesis	6

EN.625.805 & EN.625.806	Applied and Computational Mathematics Post-Master's Research and Applied and Computational Mathematics Post-Master's Research	6
EN.625.807 & EN.625.808	Applied and Computational Mathematics Post-Master's Thesis and Applied and Computational Mathematics Post-Master's Thesis	6

### Information Technology and Computation

Code	Title	Credits
EN.625.603	Statistical Methods and Data Analysis	3
EN.625.609	Matrix Theory	3
EN.625.611	Computational Methods	3
EN.625.615	Introduction to Optimization	3
EN.625.616	Optimization in Finance	3
EN.625.617	Intro to Enumerative Combinatorics	3
EN.625.618	Discrete Hybrid Optimization	3
EN.625.621	Modern Control Systems	3
EN.625.623	Introduction to Operations Research: Probabilistic Models	3
EN.625.624	Network Models and Analysis	3
EN.625.633	Monte Carlo Methods	3
EN.625.638	Foundations of Neural Networks	3
EN.625.661	Statistical Models and Regression	3
EN.625.665	Bayesian Statistics	3
EN.625.680	Cryptography	3
EN.625.685	Number Theory	3
EN.625.687	Applied Topology	3
EN.625.690	Computational Complexity and Approximation	3
EN.625.695	Time Series Analysis	3
EN.625.725	Theory Of Statistics I	3
EN.625.726	Theory of Statistics II	3
EN.625.734	Queuing Theory with Applications to Computer Science	3
EN.625.740	Data Mining	3
EN.625.742	Theory of Machine Learning	3
EN.625.743	Stochastic Optimization & Control	3
EN.625.744	Modeling, Simulation, and Monte Carlo	3
EN.625.800	Independent Study	3
EN.625.801 & EN.625.802	Applied and Computational Mathematics Master's Research and Applied and Computational Mathematics Master's Research	6
EN.625.803 & EN.625.804	Applied and Computational Mathematics Master's Thesis and Applied and Computational Mathematics Master's Thesis	6
EN.625.805 & EN.625.806	Applied and Computational Mathematics Post-Master's Research and Applied and Computational Mathematics Post-Master's Research	6

EN.625.807 Applied and Computational Mathematics Post- 6  
& EN.625.808 Master's Thesis  
and Applied and Computational Mathematics  
Post-Master's Thesis

EN.625.807 Applied and Computational Mathematics Post- 6  
& EN.625.808 Master's Thesis  
and Applied and Computational Mathematics  
Post-Master's Thesis

### Operations Research

Code	Title	Credits
EN.625.603	Statistical Methods and Data Analysis	3
EN.625.609	Matrix Theory	3
EN.625.615	Introduction to Optimization	3
EN.625.616	Optimization in Finance	3
EN.625.617	Intro to Enumerative Combinatorics	3
EN.625.618	Discrete Hybrid Optimization	3
EN.625.623	Introduction to Operations Research: Probabilistic Models	3
EN.625.624	Network Models and Analysis	3
EN.625.633	Monte Carlo Methods	3
EN.625.636	Graph Theory	3
EN.625.641	Mathematics of Finance	3
EN.625.642	Mathematics of Risk, Options, and Financial Derivatives	3
EN.625.661	Statistical Models and Regression	3
EN.625.662	Design and Analysis of Experiments	3
EN.625.663	Multivariate Statistics and Stochastic Analysis	3
EN.625.664	Computational Statistics	3
EN.625.665	Bayesian Statistics	3
EN.625.690	Computational Complexity and Approximation	3
EN.625.694	Introduction to Convexity	3
EN.625.695	Time Series Analysis	3
EN.625.714	Introductory Stochastic Differential Equations with Applications	3
EN.625.721	Probability and Stochastic Process I	3
EN.625.722	Probability and Stochastic Process II	3
EN.625.725	Theory Of Statistics I	3
EN.625.726	Theory of Statistics II	3
EN.625.734	Queuing Theory with Applications to Computer Science	3
EN.625.736	Combinatorial Optimization	3
EN.625.740	Data Mining	3
EN.625.741	Game Theory	3
EN.625.743	Stochastic Optimization & Control	3
EN.625.744	Modeling, Simulation, and Monte Carlo	3
EN.625.800	Independent Study	3
EN.625.801 & EN.625.802	Applied and Computational Mathematics Master's Research and Applied and Computational Mathematics Master's Research	6
EN.625.803 & EN.625.804	Applied and Computational Mathematics Master's Thesis and Applied and Computational Mathematics Master's Thesis	6
EN.625.805 & EN.625.806	Applied and Computational Mathematics Post-Master's Research and Applied and Computational Mathematics Post-Master's Research	6

### Probability and Statistics

Code	Title	Credits
EN.625.603	Statistical Methods and Data Analysis	3
EN.625.617	Intro to Enumerative Combinatorics	3
EN.625.620	Mathematical Methods for Signal Processing	3
EN.625.623	Introduction to Operations Research: Probabilistic Models	3
EN.625.633	Monte Carlo Methods	3
EN.625.638	Foundations of Neural Networks	3
EN.625.641	Mathematics of Finance	3
EN.625.642	Mathematics of Risk, Options, and Financial Derivatives	3
EN.625.651	Mathematical Models in Healthcare	3
EN.625.661	Statistical Models and Regression	3
EN.625.662	Design and Analysis of Experiments	3
EN.625.663	Multivariate Statistics and Stochastic Analysis	3
EN.625.664	Computational Statistics	3
EN.625.665	Bayesian Statistics	3
EN.625.680	Cryptography	3
EN.625.690	Computational Complexity and Approximation	3
EN.625.692	Probabilistic Graphical Models	3
EN.625.695	Time Series Analysis	3
EN.625.710	Fourier Analysis with Applications to Signal Processing and Differential Equations	3
EN.625.714	Introductory Stochastic Differential Equations with Applications	3
EN.625.721	Probability and Stochastic Process I	3
EN.625.722	Probability and Stochastic Process II	3
EN.625.725	Theory Of Statistics I	3
EN.625.726	Theory of Statistics II	3
EN.625.728	Theory of Probability	3
EN.625.734	Queuing Theory with Applications to Computer Science	3
EN.625.740	Data Mining	3
EN.625.741	Game Theory	3
EN.625.742	Theory of Machine Learning	3
EN.625.743	Stochastic Optimization & Control	3
EN.625.744	Modeling, Simulation, and Monte Carlo	3
EN.625.800	Independent Study	3
EN.625.801 & EN.625.802	Applied and Computational Mathematics Master's Research and Applied and Computational Mathematics Master's Research	6
EN.625.803 & EN.625.804	Applied and Computational Mathematics Master's Thesis and Applied and Computational Mathematics Master's Thesis	6

EN.625.805 & EN.625.806	Applied and Computational Mathematics Post-Master's Research and Applied and Computational Mathematics Post-Master's Research	6	EN.625.801 & EN.625.802	Applied and Computational Mathematics Master's Research and Applied and Computational Mathematics Master's Research	6
EN.625.807 & EN.625.808	Applied and Computational Mathematics Post-Master's Thesis and Applied and Computational Mathematics Post-Master's Thesis	6	EN.625.803 & EN.625.804	Applied and Computational Mathematics Master's Thesis and Applied and Computational Mathematics Master's Thesis	6

### Simulation and Modeling

Code	Title	Credits
EN.625.603	Statistical Methods and Data Analysis	3
EN.625.604	Ordinary Differential Equations	3
EN.625.615	Introduction to Optimization	3
EN.625.616	Optimization in Finance	3
EN.625.618	Discrete Hybrid Optimization	3
EN.625.620	Mathematical Methods for Signal Processing	3
EN.625.621	Modern Control Systems	3
EN.625.623	Introduction to Operations Research: Probabilistic Models	3
EN.625.624	Network Models and Analysis	3
EN.625.633	Monte Carlo Methods	3
EN.625.638	Foundations of Neural Networks	3
EN.625.641	Mathematics of Finance	3
EN.625.642	Mathematics of Risk, Options, and Financial Derivatives	3
EN.625.651	Mathematical Models in Healthcare	3
EN.625.661	Statistical Models and Regression	3
EN.625.662	Design and Analysis of Experiments	3
EN.625.663	Multivariate Statistics and Stochastic Analysis	3
EN.625.664	Computational Statistics	3
EN.625.665	Bayesian Statistics	3
EN.625.690	Computational Complexity and Approximation	3
EN.625.695	Time Series Analysis	3
EN.625.714	Introductory Stochastic Differential Equations with Applications	3
EN.625.717	Advanced Differential Equations: Partial Differential Equations	3
EN.625.718	Advanced Differential Equations: Nonlinear Differential Equations and Dynamical Systems	3
EN.625.719	Advanced Differential Equations: Numerical Solutions to Ordinary and Partial Differential Equations	3
EN.625.721	Probability and Stochastic Process I	3
EN.625.722	Probability and Stochastic Process II	3
EN.625.725	Theory Of Statistics I	3
EN.625.726	Theory of Statistics II	3
EN.625.728	Theory of Probability	3
EN.625.740	Data Mining	3
EN.625.741	Game Theory	3
EN.625.743	Stochastic Optimization & Control	3
EN.625.744	Modeling, Simulation, and Monte Carlo	3
EN.625.800	Independent Study	3

EN.625.801 & EN.625.802	Applied and Computational Mathematics Master's Research and Applied and Computational Mathematics Master's Research	6
EN.625.803 & EN.625.804	Applied and Computational Mathematics Master's Thesis and Applied and Computational Mathematics Master's Thesis	6
EN.625.805 & EN.625.806	Applied and Computational Mathematics Post-Master's Research and Applied and Computational Mathematics Post-Master's Research	6
EN.625.807 & EN.625.808	Applied and Computational Mathematics Post-Master's Thesis and Applied and Computational Mathematics Post-Master's Thesis	6

### Electives

Two electives may be from the Applied and Computational Mathematics (ACM) program or from another graduate program provided the courses have significant mathematical content. The following is a list of approved non-ACM electives. Electives from outside of this list must be approved by an advisor. Courses that contain significant mathematical content from outside of this list may also be taken as electives subject to approval by the student's advisor.

Code	Title	Credits
EN.525.605	Intermediate Electromagnetics	3
EN.525.614	Probability & Stochastic Processes for Engineers	3
EN.525.616	Communication Systems Engineering	3
EN.525.627	Digital Signal Processing	3
EN.525.645	Modern Navigation Systems	3
EN.525.661	UAV Systems and Control	3
EN.525.665	Machine Perception	3
EN.525.707	Error Control Coding	3
EN.525.721	Advanced Digital Signal Processing	3
EN.525.724	Introduction to Pattern Recognition	3
EN.525.762	Introduction to Wavelets	3
EN.525.770	Intelligent Algorithms	3
EN.525.776	Information Theory	3
EN.525.780	Multidimensional Digital Signal Processing	3
EN.535.621	Intermediate Fluid Dynamics	3
EN.535.735	Computational Fluid Dynamics	3
EN.535.742	Applied Machine Learning for Mechanical Engineers	3
EN.555.627	Stochastic Processes and Applications to Finance	3
EN.555.642	Investment Science	3
EN.555.644	Introduction to Financial Derivatives	3
EN.555.645	Interest Rate and Credit Derivatives	3
EN.555.646	Financial Risk Management and Measurement	3
EN.555.647	Quantitative Portfolio Theory & Performance Analysis	3
EN.555.648	Financial Engineering and Structured Products	3
EN.575.608	Optimization Methods for Public Decision Making	3
EN.575.704	Applied Statistical Analysis and Design of Experiments for Environmental Applications	3

EN.585.719	Sparse Representations in Computer Vision and Machine Learning	3
EN.605.621	Foundations of Algorithms	3
EN.605.622	Computational Signal Processing	3
EN.605.626	Image Processing	3
EN.605.633	Social Media Analytics	3
EN.605.645	Artificial Intelligence	3
EN.605.646	Natural Language Processing	3
EN.605.647	Neural Networks	3
EN.605.649	Introduction to Machine Learning	3
EN.605.662	Data Visualization	3
EN.605.671	Principles of Data Communications Networks	3
EN.605.716	Modeling and Simulation of Complex Systems	3
EN.605.728	Quantum Computation	3
EN.605.729	Formal Methods	3
EN.605.755	Systems Biology	3
EN.615.641	Mathematical Methods for Physics and Engineering	3
EN.615.765	Chaos and Its Applications	3
EN.615.769	Physics of Remote Sensing	3
EN.615.775	Physics of Climate	3
EN.685.621	Algorithms for Data Science	3
EN.685.648	Data Science	3
EN.695.615	Cyber Physical Systems Security	3
EN.695.641	Cryptology	3
EN.705.741	Reinforcement Learning	3

*Please refer to the course schedule ([ep.jhu.edu/schedule](http://ep.jhu.edu/schedule) (<http://ep.jhu.edu/schedule/>)) published each term for exact dates, times, locations, fees, and instructors.*