ENGINEERING SCIENCES AND APPLIED MATHEMATICS

https://www.mccormick.northwestern.edu/applied-math/

Degree Types: PhD, MS

The programs in Engineering Science and Applied Mathematics (https://www.mccormick.northwestern.edu/applied-math/graduate) educate students in mathematical methods and their application to various scientific and engineering fields.

Our program emphasizes techniques associated with asymptotic analysis, bifurcation theory, dynamical systems, numerical analysis, ordinary and partial differential equations, singular perturbations, stability theory, and stochastic processes. These techniques are employed to address problems arising in science and engineering including fluid mechanics, microbiology, neurobiology, ecology, geophysics, materials, diffusion processes, fiber optics, interfacial phenomena, pattern formation, solid mechanics, solidification theory, wave phenomena, and social sciences.

Students are given broad-based training encompassing mathematical methods and fields of science or engineering where significant applications of mathematics are made.

Degrees Offered

- Engineering Sciences and Applied Mathematics MS (https://catalogs.northwestern.edu/tgs/engineering-sciences-applied-mathematics/engineering-sciences-applied-mathematics-ms)

Engineering Sciences and Applied Mathematics Courses

ES_APPM 311-1 Methods of Applied Mathematics (1 Unit)
Prerequisite: GEN_ENG 205-4, GEN_ENG 206-4, or MATH 250-0.

ES_APPM 311-2 Methods of Applied Mathematics (1 Unit)
Prerequisite: GEN_ENG 205-4, GEN_ENG 206-4, or MATH 250-0.

ES_APPM 312-0 Complex Variables (1 Unit)
Imaginary numbers and complex variables, analytic functions, calculus of complex functions, contour integration with application to transform inversion, conformal mapping.
Prerequisite: GEN_ENG 205-4, GEN_ENG 206-4, or MATH 250-0.

ES_APPM 322-0 Applied Dynamical Systems (1 Unit)
Example-oriented survey of nonlinear dynamical systems, including chaos. Combines numerical exploration of differential equations describing physical problems with analytic methods and geometric concepts. Applications to mechanical, fluid dynamical, electrical, chemical, and biological systems.
Prerequisites: ES_APPM 311-1 and ES_APPM 311-2 or equivalent or consent of instructor.

ES_APPM 345-0 Applied Linear Algebra (1 Unit)
Understanding and implementation of algorithms to calculate matrix decompositions such as eigenvalue/vector, LU, QR, and SVD decompositions. Applications include data-fitting, image analysis, and ranking algorithms.

ES_APPM 346-0 Modeling and Computation in Science & Engineering (1 Unit)
Advanced techniques for initial value problems, differential algebraic systems, bifurcations, chaos, and partial differential equations. Applications drawn from different physical areas.
Prerequisites: MATH 234-0, MATH 240-0, and MATH 250-0; or GEN_ENG 205-4 and PHYSICS 135-1, PHYSICS 135-2; or equivalent; familiarity with a programming language; or consent of instructor.

ES_APPM 370-1 Introduction to Computational Neuroscience (1 Unit)

ES_APPM 375-1 Quantitative Biology I: Experiments, Data, Models, and Analysis (1 Unit)
High-resolution, high-throughput, and dynamic imaging and sequencing data is the substrate of modern biology. The course consists of case-studies where we learn how to computational work with, analyze, and make sense of experimental dataset using fundamental principles of mathematics, statistics, and physics. No formal course prerequisites. Programming in python.

ES_APPM 375-2 Quantitative Biology II: Experiments, Data, Models, and Analysis (1 Unit)
High-resolution, high-throughput, and dynamic imaging and sequencing data is the substrate of modern biology. In this course we learn how to perform experiments, and computational work with, analyze, and make sense of experimental dataset using fundamental principles of mathematics, statistics, and physics. No formal course prerequisites. Programming in python.

ES_APPM 395-0 Special Topics (1 Unit)

ES_APPM 398-0 Introduction to Applied Math Research (0 Unit)
This is a seminar course where ESAM faculty present their current and planned research topics in applied mathematics.

ES_APPM 401-0 Options Pricing: Theory and Applications (1 Unit)
Consideration of ordinary and elementary partial differential equations models of problems in science and engineering, arising in various areas of application.
Prerequisites: Permission of instructor and department.

ES_APPM 411-1 Differential Equations of Mathematical Physics (1 Unit)

ES_APPM 411-2 Differential Equations of Mathematical Physics (1 Unit)
Integral equations in various scientific theories and their relation to perturbation, asymptotic, numerical, and integral transform methods.

**ES_APPM 411-3 Differential Equations of Mathematical Physics (1 Unit)**

**ES_APPM 412-0 Methods of Nonlinear Analysis (1 Unit)**

**ES_APPM 420-1 Asymptotic and Perturbation Methods in Applied Mathematics (1 Unit)**

**ES_APPM 420-2 Asymptotic and Perturbation Methods in Applied Mathematics (1 Unit)**

**ES_APPM 420-3 Asymptotic and Perturbation Methods in Applied Mathematics (1 Unit)**

**ES_APPM 421-1 Models in Applied Mathematics (1 Unit)**
Applications to illustrate typical problems and methods of applied mathematics. Mathematical formulation of models for phenomena in science and engineering, problem solution, and interpretation of results. Examples from solid and fluid mechanics, combustion, diffusion phenomena, chemical and nuclear reactors, and biological processes.

**ES_APPM 426-0 Theory of Flows With Small Inertia (1 Unit)**
Asymptotic methods for flows with small inertia: flows past bodies and matching procedures. Slowly varying flows: lubrication theory and Hele-Shaw flow; swimming of microorganisms and suspension of particles.

**ES_APPM 429-0 Hydrodynamic Stability Theory (1 Unit)**
Mathematical theory of hydrodynamic states; energy methods, linear theories, and nonlinear bifurcation theories. Convective, centrifugal, and shear flow instabilities. Instability of unsteady flows and systems having interfaces. Physical mechanisms and results of experiments.

**ES_APPM 430-0 Wave Propagation (1 Unit)**

**ES_APPM 440-0 Integral Equations & Applications (1 Unit)**

**ES_APPM 442-0 Stochastic Differential Equations (1 Unit)**
Brownian motion and Langevin’s equation. Ito and Stratonovich stochastic integrals. Stochastic calculus and Ito’s formula. SDEs and PDEs of Kolmogorov, Fokker-Planck, and Dynkin. Boundary conditions, exit times, exit distributions, stability. Asymptotic analysis of SDE, the Smoluchowski-Kramers approximation, and diffusion approximation to Markov chains. Applications.

**ES_APPM 444-0 High Performance Scientific Computing (1 Unit)**
Solving partial differential equations using high performance computing platforms. Basic C programming. Distributed computing using MPI. GPU programming using CUDA. Adaptation of algorithms for solving PDE’s to different architectures.

**ES_APPM 445-0 Iterative Methods for Elliptic Equations (1 Unit)**
Analysis and application of numerical methods for solving elliptic equations. Stationary iterative, multigrid, conjugate gradient, GMRES methods and preconditioners.

**ES_APPM 446-1 Numerical Solution of Partial Differential Equations (1 Unit)**

**ES_APPM 446-2 Numerical Solution of Partial Differential Equations (1 Unit)**

**ES_APPM 447-0 Boundary Integral Method (1 Unit)**

**ES_APPM 448-0 Numerical Methods for Random Processes (1 Unit)**
Analysis and implementation of numerical methods for random processes: random number generators, Monte Carlo methods, Markov chains, stochastic differential equations, and applications.

**ES_APPM 449-0 Numerical Methods for Moving Interfaces (1 Unit)**
Methods for simulating sharp interfaces. Marker particle, level set, fast marching, volume of fluid, and phase fields methods.

**ES_APPM 450-0 Selected Topics in Applied Mathematics (0.5-1 Unit)**
Topics selected from research of current interest in applied mathematics.

**ES_APPM 499-0 Projects (1 Unit)**
Special projects to be carried out under faculty direction. Permission of instructor and department required.

**ES_APPM 519-0 Responsible Conduct of Research Training (0 Unit)**

**ES_APPM 590-0 Research (1-4 Units)**
Independent investigation of selected problems pertaining to thesis or dissertation. May be repeated for credit.