ENM 240 Differential Equations and Linear Algebra
This course discusses the theory and application of linear algebra and differential equations. Emphasis is placed on building intuition for the underlying concepts and their applications in engineering practice along with tools for solving problems. We will also use computer simulations in MATLAB to augment this intuition.
One-term course offered either term
Prerequisite: MATH 114
Activity: Lecture
1.0 Course Unit

ENM 251 Analytical Methods for Engineering
This course introduces students to physical models and mathematical methods that are widely encountered in various branches of engineering. Illustrative examples are used to motivate mathematical topics including ordinary and partial differential equations, Fourier analysis, eigenvalue problems, and stability analysis. Analytical techniques that yield exact solutions to problems are developed when possible, but in many cases, numerical calculations are employed using programs such as Matlab and Maple. Students will learn the importance of mathematics in engineering.
Prerequisite: Sophomore standing in SEAS or permission of instructor(s)
Course usually offered in spring term
Prerequisite: MATH 240
Activity: Lecture
1.0 Course Unit

ENM 321 Engineering Statistics
This is a first course in applied statistics and probability for students in engineering. The course covers basic concepts of probability, discrete and continuous random variables, probability distributions, data description techniques, random samples, estimations, hypothesis testing, regression, and statistical quality control.
Course usually offered in fall term
Activity: Lecture
1.0 Course Unit

ENM 360 Introduction to Data-driven Modeling
From recognizing voice, text or images to designing more efficient airplane wings and discovering new drugs, machine learning is introducing a transformative set of tools in data analysis with increasing impact across engineering, sciences, and commercial applications. In this course, you will learn about principles and algorithms for extracting patterns from data and making effective automated predictions. We will cover concepts such as regression, classification, density estimation, feature extraction, sampling and probabilistic modeling, and provide a formal understanding of how, why, and when these methods work in the context of analyzing physical, biological, and engineering systems.
Course usually offered in fall term
Prerequisites: ENGR 105, MATH 240
Activity: Lecture
1.0 Course Unit

ENM 375 Biological Data Science I - Fundamentals of Biostatistics
The goal of this course is to equip bioengineering undergraduates with fundamental concepts in applied probability, exploratory data analysis and statistical inference. Students will learn statistical principles in the context of solving biomedical research problems.
Course usually offered in spring term
Activity: Lecture
1.0 Course Unit

ENM 502 Numerical Methods and Modeling
This course provides an advanced introduction to various numerical methods for solving systems of algebraic equations (linear and nonlinear) and differential equations (ordinary and partial). Techniques covered include Newton's method, implicit and explicit time stepping, and the finite difference and finite element methods. The MATLAB software package will be used to implement the various methods and execute representative calculations.
Course usually offered in spring term
Activity: Lecture
1.0 Course Unit

ENM 503 Introduction to Probability and Statistics
Introduction to combinatorics: the multiplication rule, the pigeonhole principle, permutations, combinations, binomial and multinomial coefficients, recurrence relations, methods of solving recurrence relations, permutations and combinations with repetitions, integer linear equation with unit coefficients, distributing balls into urns, inclusion-exclusion, an introduction to probability. Introduction to Probability: sets, sample sets, events, axioms of probability, simple results, equally likely outcomes, probability as a continuous set function and probability as a measure of belief, conditional probability, independent events, Bayes' formula, inverting probability trees. Random Variables: discrete and continuous, expected values, functions of random variables, variance.
Some Special Discrete Random Variables: Bernoulli, Binomial, Poisson, Geometric, Pascal (Negative Binomial) Hypergeometric and Poisson.
Course usually offered in fall term
Prerequisite: MATH 240
Activity: Lecture
1.0 Course Unit
**ENM 510 Foundations of Engineering Mathematics - I**
This is the first course of a two semester sequence, but each course is self-contained. Over the two semesters topics are drawn from various branches of applied mathematics that are relevant to engineering and applied science. These include: Linear Algebra and Vector Spaces, Hilbert spaces, Higher-Dimensional Calculus, Vector Analysis, Differential Geometry, Tensor Analysis, Optimization and Variational Calculus, Ordinary and Partial Differential Equations, Initial-Value and Boundary-Value Problems, Green's Functions, Special Functions, Fourier Analysis, Integral Transforms and Numerical Analysis. The fall course emphasizes the study of Hilbert spaces, ordinary and partial differential equations, the initial-value, boundary-value problem, and related topics.
Course usually offered in fall term
Prerequisite: MATH 240, 241
Activity: Lecture
1.0 Course Unit

**ENM 511 Foundations of Engineering Mathematics - II**
This is the second course of a two semester sequence, but each course is self-contained. Over the two semesters topics are drawn from various branches of applied mathematics that are relevant to engineering and applied science. These include: Linear Algebra and Vector Spaces, Hilbert spaces, Higher-Dimensional Calculus, Vector Analysis, Differential Geometry, Tensor Analysis, Optimization and Variational Calculus, Ordinary and Partial Differential Equations, Initial-Value and Boundary-Value Problems, Green's Functions, Special Functions, Fourier Analysis, Integral Transforms and Numerical Analysis. The spring course emphasizes the study of Vector Analysis: space curves, Frenet-Serret formulae, vector theorems, reciprocal systems, co- and contra-variant components, orthogonal curvilinear systems. Matrix theory: Gauss-Jordan elimination, eigenvalues and eigenvectors, quadratic and canonical forms. Variational calculus: Euler-Lagrange equation. Tensor Analysis: Einstein summation, tensors of arbitrary order, dyads and polyads, outer and inner products, quotient law, metric tensor, Euclidean and Riemannian spaces, physical components, covariant differentiation, detailed evaluation of Christoffel symbols, Ricci's theorem, intrinsic differentiation, generalized acceleration, Geodesics. The spring course emphasizes the study of Vector Analysis: space curves, Frenet-Serret formulae, vector theorems, reciprocal systems, co- and contra-variant components, orthogonal curvilinear systems. Matrix theory: Gauss-Jordan elimination, eigenvalues and eigenvectors, quadratic and canonical forms. Variational calculus: Euler-Lagrange equation. Tensor Analysis: Einstein summation, tensors of arbitrary order, dyads and polyads, outer and inner products, quotient law, metric tensor, Euclidean and Riemannian spaces, physical components, covariant differentiation, detailed evaluation of Christoffel symbols, Ricci's theorem, intrinsic differentiation, generalized acceleration, Geodesics. Course usually offered in spring term
Prerequisite: ENM 510
Activity: Lecture
1.0 Course Unit

**ENM 512 Nonlinear Dynamics and Chaos**
One-term course offered either term
Activity: Lecture
1.0 Course Unit

**ENM 520 Principles and Techniques of Applied Math I**
This course is targeted to engineering PhD students in all areas. It will focus on the study of linear spaces (both finite and infinite dimensional) and of operators defined on such spaces. This course will also show students how powerful methods developed by the study of linear spaces can be used to systematically solve problems in engineering. The emphasis in this course will not be on abstract theory and proofs but on techniques that can be used to solve problems. Some examples of techniques that will be studied include Fourier series, Green's functions for ordinary and partial differential operators, eigenvalue problems for ordinary differential equations, singular value decomposition of matrices, etc. Prerequisite: Basic theory of ordinary and partial differential equations
Course usually offered in fall term
Activity: Lecture
1.0 Course Unit

**ENM 521 Principles and Techniques of Applied Math II**
This course is a continuation of ENM 520 (or equivalent) and deals with classical methods in applied mathematics. The topics to be covered include: Functions of a Complex Variable, Partial Differential Equations, Asymptotic and Perturbation Methods, and Convex Analysis and Variational Methods.
Course usually offered in spring term
Activity: Lecture
1.0 Course Unit
ENM 522 Numerical Methods for PDEs
The objective of the course is to provide training in fundamentals of numerical analysis at the PhD level. This course does not explore methods tailored to a specific physics subdomain. Instead, general ideas and systematic procedures for construction and analysis of numerical methods are introduced, which can be applied to diverse disciplines of computational science seeking numerical solution of complex differential equations. The course begins with the techniques for numerical differentiation/integration and solution of system of ODEs, which later is integrated into techniques for solution of PDEs of various types (hyperbolic, parabolic, and elliptic ones). Measures of stability and accuracy are presented, with emphasis on preserving symmetries of differential operators to preclude unphysical solution growth or decay. Spectral methods based on Sturm-Liouville eigenfunctions are covered. Utility and limitation of the widely used methods for computation of broadband phenomena are illustrated. Students will have first-hand experience writing their own computer programs, and also come to view critically the numerical output generated by a computer. Background on linear algebra and ordinary/partial differential equations at the level of ENM 510 and basic MATLAB experience. Undergraduates require instructor permission to enroll.
Taught by: George Ilhwan Park
Course offered spring; even-numbered years
Activity: Lecture
1.0 Course Unit

ENM 531 Data-driven Modeling and Probabilistic Scientific Computing
We will revisit classical scientific computing from a statistical learning viewpoint. In this new computing paradigm, differential equations, conservation laws, and data act as complementary agents in a predictive modeling pipeline. This course aims to explore the potential of modern machine learning as a unifying computational tool that enables learning models from experimental data, inferring solutions to differential equations, blending information from a hierarchy of models, quantifying uncertainty in computations, and efficiently optimizing complex engineering systems. Prerequisite: Programming in Python and MATLAB
Course not offered every year
Prerequisites: MATH 240, 513, 430 or ENM 240, 321, 503
Activity: Lecture
1.0 Course Unit

ENM 540 Topics In Computational Science and Engineering
This course is focused on techniques for numerical solutions of ordinary and partial differential equations. The content will include: algorithms and their analysis for ODEs; finite element analysis for elliptic, parabolic and hyperbolic PDEs; approximation theory and error estimates for FEM. Prerequisite: Background in ordinary and partial differential equations; proficiency in a programming language such as MATHLAB, C, Fortran
Course not offered every year
Activity: Lecture
1.0 Course Unit