**ENGINEERING MATHEMATICS (ENM)**

**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 or equivalent
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.

Course usually offered in spring term
Prerequisites: MATH 240 or equivalent along with sophomore standing in SEAS, or permission of the instructor(s)
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, basic programming
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
Prerequisites: Sophomores and Juniors only.
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
Prerequisites: Basic knowledge of a computer programming language; MATH 240, 241 and/or ENM 510 (or their equivalents) are highly recommended
Activity: Lecture
1.0 Course Unit

**ENM 503 Introduction to Probability and Statistics**

Course usually offered in fall term
Prerequisite: MATH 240 or equivalent
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
Prerequisites: MATH 240, MATH 241 or equivalent
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 or equivalent
Activity: Lecture
1.0 Course Unit

ENM 512 Nonlinear Dynamics and Chaos

One-term course offered either term
Prerequisites: Some Differential Equations and Senior or Master's standing in Engineering or permission of the instructor.
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.

Course usually offered in fall term
Prerequisites: Basic theory of ordinary and partial differential equations
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 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.
Course not offered every year
Prerequisites: MATH 240 or MATH 513 or ENM 240, MATH 430 or ENM 321 or ENM 503, programming in Python and MATLAB
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.
Course not offered every year
Prerequisites: Background in ordinary and partial differential equations; proficiency in a programming language such as MATLAB, C, or Fortran
Activity: Lecture
1.0 Course Unit