Course descriptions, Spring 2024

The following courses are tentatively being offered for the Fall 2023 semester. Descriptions have been given by some instructors; more may be added over time.

MATH 5103 Mathematical Models
Instructor: Nikola Petrov

Description: Since nonlinear ODEs do not satisfy the Superposition Principle, finding their general solution is difficult and often impossible. Because of this, one can instead try to describe the qualitative behavior of the solutions of the system.

In this class we will derive nonlinear ODEs occurring in some simple biological or mechanical problems, and will analyze the behavior of their solutions. We will develop some methods for studying their *bifurcations*, i.e., situations in which the solutions of the system change their qualitative behavior dramatically for a small change of some parameter. We will study the phase portraits of autonomous linear systems, some bifurcations occurring in such systems (saddle-node, transcritical, pitchfork, Hopf), presence or absence of certain types of asymptotic behavior of the solutions, limit cycles, hysteresis, Poincare maps, etc. We will also introduce some concepts related to highly iterated maps.

This course should be of interest to students of Mathematics, Physics, Chemistry, Biology, Engineering, and Economics.

MATH 5123 Fourier Transforms
Instructor: Tomasz Przebinda

- Text: Fourier Analysis, and introduction, by Elias Stein and Rami Shararchi, PrincetonUniversity Press
- .Course outline: Fourier Analysis was initiated by Joseph Fourier (a general in Napoleon'sarmy) in eighteen century in an attempt to solve a heat equation, but then evolved andgrew into a theory which found applications to Number Theory, Cryptography, QuantumComputing, Physics, Computer Engineering and may others. We shall study the details ofthe Fourier transform for functions defined on the real line, an Euclidean space and a finitecyclic group gaining sufficient background to understand applications to IsoperimetricInequality, Tomography and Magnetic Resonance Imagining.The material is contained in Chapters 1 - 7 of the text.

MATH 5163 Partial Differential Equations
Instructor: John Albert

MATH 5183 Advanced Numerical Analysis II
Instructor: Ying Wang

- Advanced Numerical Analysis II is the second course of a two- semester sequence (Math 5173/5183) of numerical analysis courses. But Math 5183 is a self-contained course, independent of Math 5173. It is designed for interested graduate students and well-prepared undergraduate students.
- Mathematical models for modern applied sciences and engineering often consist of ordinary and partial differential equations. In most cases these problems do not have a simple explicit solution and can only be solved numerically. The construction and the accuracy of the numerical computation become vitally important. This course will cover both the analytical and numerical aspects of the hyperbolic conservation laws, with emphasis on the numerical methods on the hyperbolic PDEs. We will discuss the derivation of conservation laws, weak solutions, viscosity solution, entropy condition, Riemann problem from the analytical standpoint. The numerical methods (e.g., first order upwind, second order upwind, Lax-Friedrich, Lax-Wendroff, ENO) will be introduced. We will start with linear scalar hyperbolic equations, system of linear hyperbolic equations, and move on to nonlinear scalar equations and systems, and develop numerical schemes for each class of equations. Applications involving hyperbolic conservation laws (e.g., traffic flow, shallow water equations) will be discussed. Students will have the opportunity to work on an individual research project during the course, and will present their results by the end of the semester.

MATH 5263 Issues and Problems in Math Pedagogy
Instructor: Milos Savic

In this course, I want to focus specifically on affectual aspects of RUME research. Affect is broadly defined as the beliefs, attitudes, values, and emotions of people as they engage or think about mathematics. We will read numerous papers with a focus on affect and its effect on what students/instructors report they do. Readings will be twice a week, with discussions both on Canvas and in person. There will also be a chance to start a RUME project by the end of the semester.

MATH 5363 Abstract Algebra II
Instructor: Travis Mandel

Galois theory, solvability. Modules over a principal ideal domain. Noetherian ideal theory. Group representations, semisimple rings. Classical groups.

MATH 5373 Abstract Linear Algebra
Instructor: Sepideh Stewart

Math 5373 is a slashlisted course with Math 4373. As the name suggests, this course is abstract and covers linear algebra definitions, theorems, and proofs.

The topics in this course are Finite dimensional vector spaces (e.g., span, linear independence, etc.), linear maps (e.g., null space and injectivity, fundamental theorem of linear maps), eigenvalues and eigenvectors (e.g., invariant subspaces, diagonalizable operators, minimal polynomials), inner product spaces (e.g., orthonormal bases) and operators on inner product spaces (e.g., self-adjoint and normal operators, matrix factorization).

We cover up to 7 chapters of the new edition of the textbook by Sheldon Axler, *Linear Algebra Done Right*, 4th edition. A free pdf of the book will be available soon. The hard copy of the book will also be available for purchase.

The course is suitable for mathematics majors and also for physics and engineering students. Graduate students will benefit from taking this course, especially those who did not have a rigorous introduction to the first linear algebra course.

MATH 5383 Applied Modern Algebra
Instructor: Alan Roche

We'll explore some topics in cryptography (and related number theory) and coding theory.

MATH 5443 Introduction to Analysis II
Instructor: Javier Alejandro Chavez-Dominguez

This is the second part of the undergraduate course sequence in (Real) Mathematical Analysis. The approach is focused on proper proof-writing and becoming acquainted with the basic proof techniques used in analysis arguments. The main topics are:

- Integration of functions of a single variable.
- Series of real numbers.
- Sequences and series of functions, including uniform convergence.
- Differentiation of functions of more than one variable.

MATH 5463 Real Analysis II
Instructor: Keri Kornelson

MATH 5743 Intro to Math Statistics
Instructor: Christian Remling
The main focus is on estimators and their properties. The approach is abstract and theoretical, with an attempt to give coherent, reasonably complete arguments, but all heavy machinery (measure theory, for example) is avoided.

MATH 5763 Intro to Stochastic Processes
Instructor: Alex Grigo

This course will be mainly covering Markov process theory.
I plan to cover the basic classification of states for finite state Markov chains, the convergence theorem. Particular attention will be on how to estimate the rate of convergence to stationarity and simulation techniques such as coupling from the past, simulated annealing and Markov chain Monte Carlo.
The basic requirement for this course will be just a basic understanding of conditional probability (and some standard probability language), which I will briefly review at the beginning of the semester.
The textbook(s) will be available online as a pdf file through the library.

MATH 5793 Advanced Applied Statistics
Instructor: Wayne Stewart

MATH 5793 covers Advanced Statistics which is basically an introduction to multivariate statistics via the multivariate normal distribution. This is essentially an application of linear algebra and matrix methods. Topics such as tests for population mean differences, principal components, factor analysis and various clustering algorithms are typically covered. Throughout the course there is a heavy emphasis on R computing, package making and advanced techniques with functions and SHINY apps.

MATH 5863 Topology II
Instructor: Jing Tao

MATH 6343 Lie Theory II
Instructor: András Lorincz

Representation theory of semi-simple Lie algebras, Schur functors, invariants and representations of classical groups.

MATH 6393 Topics in Algebra (Literacy)
Instructor: Roi Docampo

MATH 6683 Differential Geometry II
Instructor: Michael Jablonski

Course content & Prerequisites
This is the second semester in the differential geometry sequence. The first semester was dedicated to manifold theory and this follow-up course will be dedicated to Riemannian geometry. It is strongly recommended to have taken a course in manifold theory before taking this one, otherwise the only requisites are the basic first year courses that all graduate students take.

Topics covered
I plan to cover Chapters 1-7, 9, and 10 from do Carmo along with some additional topics not in do Carmo. Depending on time, some topics from Chapters 11-13 will be discussed. These chapters will cover: Riemannian metrics, connections, geodesics, curvature, Jacobi fields, immersions, variations of energy, and comparison geometry. We will make extensive use of Lie groups for building examples, including homogeneous spaces and symmetric spaces.

Text(s)
Primary text: Riemannian Geometry, by Manfredo do Carmo.
Other texts worth consulting:
- Cheeger and Ebin, Comparison Theorems in Riemannian Geometry
- Gallot, Hulin, Lafontaine, Riemannian Geometry
- Spivak, A Comprehensive Introduction to Differential Geometry, volumes 1, 2, and 4 - Petersen, Riemannian Geometry
- Warner, Foundations of Differentiable Manifolds and Lie Groups.

MATH 6833 Topics in Topology (Literacy)
Instructors: Peter Patzt, Noel Brady, Murad Ozaydin

1) Patzt: An introduction to K-theory: We will start with vector bundles and topological K-theory. Depending on time and interest, we will also get into Algebraic K-theory.