Department of Mathematics
Winter 2024 Graduate Course Descriptions

****MATH 501 | AIM Student Seminar | Alben, S. | Fri 1:00 PM – 2:00 PM; Fri 3:00 PM – 4:00 PM**

At least two 300 or above level math courses, and Graduate standing; Qualified undergraduates with permission of instructor only. (1). May be repeated for a maximum of 6 credits. Offered mandatory credit/no credit.

MATH 501 is an introductory and overview seminar course in the methods and applications of modern mathematics. The seminar has two key components: (1) participation in the Applied and Interdisciplinary Math Research Seminar; and (2) preparatory and post-seminar discussions based on these presentations. Topics vary by term.

No book for this course.

****MATH 506/IOE | Analysis for Finance | Bayraktar, E. | TR 10:00 AM – 11:30 AM**

Math 526. Graduate students or permission of instructor. (3). (BS). May not be repeated for credit.

The aim of this course is to teach the probabilistic techniques and concepts from the theory of stochastic processes required to understand the widely used financial models. In particular concepts such as martingales, stochastic integration/calculus, which are essential in computing the prices of derivative contracts, will be discussed. The specific topics include: Brownian motion (Gaussian distributions and processes, equivalent definitions of Brownian motion, invariance principle and Monte Carlo, scaling and time inversion, properties of paths, Markov property and reflection principle, applications to pricing, hedging and risk management, Brownian martingales), martingales in continuous time, stochastic integration (including It\^{o}'s formula), stochastic differential equations (including Feynman-Kac formula), change of measure (including Girsanov's theorem and change of numeraire), and, time permitting, stochastic. control (including Merton problem). Applications from various areas of Finance (including, pricing of derivatives, risk management, etc) are used to illustrate the theory.

****MATH 521 | Life Contingencies II | Natarajan, R. | TR 10:00 AM - 11:30 AM**

MATH 520 with a grade of C- or higher. (Prerequisites enforced at registration.) (3). (BS). May not be repeated for credit.

This course extends the single decrement and single life ideas of MATH 520 to multi-decrement and multiple-life applications directly related to life insurance. The sequence 520-521 covers the Part 4A examination of the Casualty Actuarial Society and covers the syllabus of the Course 150 examination of the Society of Actuaries. Concepts and Calculation are emphasized over proof.

****MATH 524 | Loss Models II | Young, V. | TR 8:30 AM – 10:00 AM**

STATS 426 and MATH 523. (Prerequisites enforced at registration.) (3). (BS). May not be repeated for credit.

Risk management is of major concern to all financial institutions, especially casualty insurance companies. This course is relevant for students in insurance and provides background for the professional examination in Short-Term Actuarial Modeling offered by the Society of Actuaries (Exam STAM). Students should have a basic knowledge of common probability distributions (Poisson, exponential, gamma, binomial, etc.) and have at least Junior standing.

Content: Frequentist and Bayesian estimation of probability distributions, model selection, credibility, simulation, and other topics in casualty insurance.

Textbook: *Loss Models: From Data to Decisions*, by Stuart A. Klugman, 9781118315323

****MATH 525/STATS | Probability Theory | TBD | TR 10:00 AM – 11:30 AM; TR 1:00 PM – 2:30 PM**

MATH 451, MATH 425/STATS 425 would be helpful. (3). (BS). May not be repeated for credit.

****MATH 526/STATS | Discrete State Stochastic Processes | Kara, A. | TR 10:00 AM – 11:30 AM; TR 1:00 PM – 2:30 PM**

MATH 525 or STATS 525 or EECS 501. (3). (BS). May not be repeated for credit.

This is a course on the theory and applications of stochastic processes on discrete state spaces. Some specific topics include:
(1) Markov chains – Markov property, recurrence and transience, stationarity, ergodicity, coupling, exit probabilities and expected exit times;
(2) Markov decision processes - optimal control, Banach fixed point theorem;
(3) Exponential distribution and Poisson processes– memoryless property, thinning and superposition, compound Poisson processes;
(4) Markov chains in continuous time – generators and Kolmogorov equations, embedded Markov chains, stationary distributions and limit theorems, exit probabilities and expected exit times, Markov queues;
(5) Martingales– conditional expectations, gambling (trading) with martingales, optional sampling, applications to the computation of exit probabilities and expected exit times, martingale convergence.

****551 | INTRODUCTION TO REAL ANALYSIS | Burns, D. | TR 11:30 AM – 1:00 PM**

TBD

MATH 555 | Introduction to Complex Variables | Miller, P. | TR 10:00 AM – 11:30 AM

MATH 451 or equivalent experience with abstract mathematics. (3). (BS). May not be repeated for credit.

This course covers the algebra of complex numbers; differentiation of complex functions; Cauchy-Riemann equations; contour integration, Cauchy's theorem, and Cauchy's integral formula; real harmonic functions; infinite series of complex numbers and functions, power series and radius of convergence; exponential, trigonometric, and hyperbolic functions and their mapping properties; fractional linear transformations; multi-valued analytic functions, branch points, and Riemann surfaces; Taylor and Laurent series; singularities of analytic functions, residues, and the residue theorem; applications to root-finding and the elegant evaluation of definite integrals; boundary-value problems for harmonic functions; Riemann mapping theorem; analytic continuation; conformal mapping of polygons; the Schwarz-Christoffel formula; applications to fluid dynamics including flow around a circular cylinder, flow in a corner and about point vortices, force exerted by a flow on an airfoil and the Kutta-Joukowski theorem.

Required Textbook: **Complex Analysis with Applications**, R. A. Silverman, Dover Publications, Mineola, NY, 1984. Optional textbook: **Applied Complex Variables**, John W. Dettman, Dover Publications, Mineola, NY, 1984.

****MATH 557 Applied Asymptotic Analysis Miller, P. TR 1:00 PM – 2:30 PM**
MATH 217, 419, or 420; MATH 451; and MATH 555 or 596. (3). (BS). May not be repeated for credit.

This course covers the theory and applications of divergent series and related approximations. The Laplace method, steepest descent method, and stationary phase method for asymptotic expansions of integrals will be developed and applied to study topics such as the properties of weakly viscous shock waves and the behavior of special functions. Expansion techniques for solutions of linear differential equations in the complex plane with rational coefficients will be developed rigorously for regular and irregular singular points. Regular and singular perturbation theory for linear differential equations will be covered, and the Wenzel-Kramers-Brillouin (WKB) method will be developed and applied to study wave scattering and Bohr-Sommerfeld quantization rules for eigenvalues. Boundary layers and the technique of matched asymptotic expansions will be covered. Finally, the long-time behavior of weakly nonlinear oscillations will be studied by the Poincaré-Lindstedt method and the method of multiple scales. Similar techniques will then be applied to the problem of weakly nonlinear wave propagation, and the cubic nonlinear Schrödinger equation will derived as a universal model for the modulation of wave packets in weakly nonlinear systems.

Required Textbook: **Applied Asymptotic Analysis**, by Peter D. Miller, Graduate Studies in Mathematics volume 75, American Mathematical Society, 2006. ISBN 0-8218-4078-9

****Math 564 Topics in Mathematical Biology Forger, D. TR 10:00 AM - 11:30 AM**

Topic: Physiological Modeling and Prediction with Differential Equations and Machine Learning

Physiological systems are typically modeled by differential equations representing the state of their components, for example, Hodgkin and Huxley's mathematical description of the electrical activity of neurons. Black box methods using machine learning have recently had remarkable success in predicting physiological state in some settings, for example, in scoring sleep from wearables. This course will explore the differences between these two approaches and new techniques using both mechanistic differential equation models and machine learning. Topics include backpropagation methods for learning in artificial neuronal networks and biophysical neuronal networks, methods for filtering physiological signals (e.g., autoencoders) to serve as inputs to physiological models, machine learning methods to solve differential equations and learn dynamics, analysis of musical performance and new methods to study noise in biological systems. Final projects and teamwork will allow students to apply these techniques to their own choice of systems to study.

No textbook required

****MATH 566 Combinatorial Theory Fomin, S. TR 11:30 AM – 1:00 PM**
MATH 465 group theory and abstract linear algebra. (3). (BS). May not be repeated for credit.

This course is an introduction to algebraic and enumerative combinatorics at the beginning graduate level. Topics include: fundamentals of algebraic graph theory; applications of linear algebra to enumeration of matchings, tilings, and spanning trees; combinatorics of electric networks; partially ordered sets; integer partitions and Young tableaux.

****MATH 567 Introduction to Coding Theory Gadish, N. TR 2:30 PM - 4:00PM**
One of MATH 217, 419, 420. (3). (BS). May not be repeated for credit.

This course introduces information theory, covering the concepts of entropy, Shannon's theorem, and channel capacity. We will further discuss noiseless coding and data compression. Our main tool will be linear algebra; thus, we will review these tools and introduce the relevant abstract algebra, finite fields, and polynomials over finite fields. Basic examples of codes we cover include Golay, Hamming, BCH, Reed-Muller, and Reed-Solomon codes. We will further discuss linear codes and cyclic codes and give fundamental asymptotic bounds on coding efficiency.

Required Textbook: **Introduction to Coding and Information Theory**, by S. Roman, ISBN: 978-0387947044

****MATH 571 Numerical Linear Algebra Viswanath, D. TR 8:30 AM – 10:00 AM**
MATH 214, 217, 417, 419, or 420; and one of MATH 450, 451, or 454 or permission from the instructor.. (3). (BS). May not be repeated for credit.

This class is about solving linear systems numerically, finding eigenvalues and singular values, and solving linear least squares problems. We will discuss condition numbers, numerical stability, QR factorization, Cholesky, SVD, and the QR algorithm as well as iterative methods (GMRES, Arnoldi, Conjugate Gradients, Lanczos). The following applications are included: KKT conditions, convergence of the perceptron, and back propagation networks. The homework assignments will use either Python or Matlab, with the choice left to the student.

Required Textbook: **Numerical Linear Algebra**, by Lloyd N. Trefethen and David Bau; ISBN-13: 978-0898713619

****MATH 572 Numerical Methods for Differential Equations Krasny, R. TR 11:30 AM – 1:00PM**
MATH 214, 217, 417, 419, or 420; and one of MATH 450, 451, or 454. (3). (BS). May not be repeated for credit.

Computer simulation is routinely used in science and engineering, and increasingly also in other fields such as finance and medicine. Accurate and efficient computer simulations can be challenging; using a faster computer is no guarantee of success; sometimes a better algorithm is needed. Math 572 is an introduction to numerical methods for differential equations. The course focuses on finite-difference schemes for initial value problems involving ordinary and partial differential equations. Theory and practical computing issues will be covered.

No textbook required

****MATH 574 Financial Mathematics II Ekren, I. TR 1:00 PM – 2:30 PM**
MATH 526 and MATH 573. (Prerequisites enforced at registration.) Although MATH 506 is not a prerequisite for MATH 574, it is strongly recommended that either these courses are taken in parallel, or MATH 506 precedes MATH 574. (3). (BS). May not be repeated for credit.

This is a continuation of Math 573. This course discusses Mathematical Theory of Continuous-time Finance. The course starts with the general Theory of Asset Pricing and Hedging in continuous time and then proceeds to specific problems of Mathematical Modeling in Continuous-time Finance. These problems include pricing and hedging of (basic and exotic) Derivatives in Equity, Foreign Exchange, Fixed Income and Credit Risk markets. In addition, this course discusses Optimal Investment in Continuous time (Merton's problem), High-frequency Trading (Optimal Execution), and Risk Management (e.g. Credit Value Adjustment).

Required Textbook: **Arbitrage Theory in Continuous Time** by Tomas Björk, fourth edition, published by Oxford University Press in 2020 (ISBN: 978-0198851615)

****MATH 575 Introduction to Theory of Numbers I Lagarias, J. MWF 12:00 PM – 1:00 PM**

MATH 451 and 420 or permission of instructor (Some background in abstract algebra – basics of groups, rings, fields – will be helpful). (1 - 3). (BS). May not be repeated for credit.

This is a first course in number theory-sometimes called the higher arithmetic. The theory of numbers is unrivaled for the number and variety of its results and for the beauty and wealth of its demonstrations Topics covered will include divisibility and prime numbers, factorization and primality testing, RSA public key cryptography and DH key exchange, polynomial congruences, p-adic arithmetic, quadratic reciprocity, Jacobi reciprocity, reduction and equivalence of binary quadratic forms, arithmetic functions, Mobius inversion, Diophantine approximation, continued fractions.
Other topics will be covered as time permits.

Course based on: *An Introduction to Theory of Numbers*, by I. Niven, H. S. Zuckerman, and H. L. Montgomery (5th edition)

MATH 576 Algebraic Number Theory Snowden, A. TR 11:30 AM – 1:00 PM

MATH 575, 594, and Graduate standing

This course covers basic algebraic number theory, including rings of integers, extensions of prime ideals, unique factorization of prime ideals, finiteness of the ideal class group, the structure of the unit group, decomposition and inertia groups in relation to prime splitting, absolute values, localizations, and completions. Applications will be given to diophantine equations, recursive sequences, and computing Galois groups of polynomials.

No textbook required.

***MATH 582 Introduction to Set Theory Chen, R. TR 1:00PM – 2:30PM**

MATH 412 or 451 or equivalent experience with abstract mathematics. (3). (BS). May not be repeated for credit.

An introduction to axiomatic set theory, the foundations of mathematics, and the study of the infinite. We will cover topics including: the algebra of sets, the Zermelo-Fraenkel axioms of set theory, the encoding of mathematical objects as sets, induction, cardinals, ordinals, and the Axiom of Choice.

No textbook required.

****MATH 590 Introduction to Topology Blayac, P.L. MWF 12:00 PM – 1:00 PM**

MATH 451. (3). (BS). May not be repeated for credit. Rackham credit requires additional work.

This course is an introduction to point-set topology. We will cover topological spaces, continuous functions and homeomorphisms, the separation axioms, the quotient and product topology, compactness, connectedness, and metric spaces. We may also explore some topics in algebraic topology, time permitting.

Required Textbook: Topology, by James Munkres, ISBN: 978-0134689517

MATH 592 Introduction to Algebraic Topology Kriz, I. MWF 10:00 AM – 11:00 AM

Previous exposure to point-set topology and familiarity with abstract algebra will be assumed. MATH 591. (3). (BS). May not be repeated for credit.

This class is a first graduate-level introductory course into algebraic topology. The topics covered are the fundamental group and its applications to covering space theory and group theory, as well as singular homology groups and basic homological algebra. We will also look at how these groups are computed for CW-complexes, and their applications. Optional topics include geometric applications such as the Jordan Separation Theorem and the Invariance of Domain.

No textbook required. Suggested helpful texts are: May: A concise course in Algebraic Topology, and Munkres: Elements of Algebraic Topology, are freely available online.

MATH 594 Algebra II Mustata, M. TR 10:00 AM – 11:30 AM

Math 593 or instructor approval.

The course will cover an introduction to groups and fields. In the first part of the course we will discuss the basics of group theory, including group actions, the Sylow theorems, solvable and nilpotent groups, as well as an introduction to representations of finite groups. The second part of the course will be devoted to the study of field extensions and Galois theory.

No textbook required.

****MATH 597 Analysis II Hani, Z. MWF 11:00 AM – 12:00 PM**

MATH 395/451 and 590. (3). (BS). May not be repeated for credit.

This is a graduate course on real analysis and measure theory. We will develop the theory of Lebesgue measure and integration both abstractly and on Euclidean spaces. This is one of the basic courses for students beginning study towards the Ph.D. degree in mathematics. The approach is theoretical and rigorous and emphasizes abstract concepts and proofs.

Topics include: Lebesgue measure on R^d, Abstract measure spaces, measurable functions, Lebesgue integration, Introduction to L^p spaces, Signed and complex measures, Lebesgue differentiation theorem

****MATH 604 Complex Analysis Chelkak, D. MW 1:00 PM – 2:30 PM**

Prerequisites: first-year graduate analysis [complex and real]

This is a second course in one-dimensional complex analysis serving as a follow-up of MATH596 or similar. Topics will include:
- zeroes and growth of entire functions, holomorphic functions in the unit disc;
- potential theory: harmonic and subharmonic functions, capacity, harmonic measure;
- geometric function theory: univalent functions, extremal length, Loewner evolution;
- Beltrami equation and quasiconformal mappings;
- Riemann surfaces.

(Depending on the background and interests of the enrolled students, some of these topics may receive more attention than the others and/or more topics be added if time permits.)

****MATH 623 | Computational Finance | Kim, D. | TR 8:30 AM – 10:00 AM**

"This course will focus on computational methods in mathematics and financial modeling. The students will learn how to use numerical algorithms to implement mathematical finance models and perform computations. There are three main parts:
1. lattice/tree method: binomial tree model and discretization of continuous models;
2. PDE method: many mathematical finance problems can be transferred to solving corresponding partial differential equations; we study how to derive the PDEs and standard numerical approach to solve such equations;
3. Monte Carlo method: this is a widely used method for computing expectations and integrals; we study the general idea and implementation of the MC method and several variance reduction techniques to improve the MC estimators."

****MATH 626/ STATS | Probability and Random Processes II | Rudelson, M. | TR 11:30 AM – 1:00 PM**

Advisory prerequisite: Math 625

The course will focus on discrete time Markov chains and ergodic theory. After covering the basics of Markov chain theory, we will concentrate on mixing in finite chains. Mixing time characterizes how fast a Markov chain approaches the stationary distribution. This theory has seen rapid progress in the last 20 years. Mixing in Markov chains plays a key role in many sampling and approximate counting algorithms in computer science.

Recommended Textbook: R. Durrett, *Probability: theory and examples*, fifth edition. Cambridge University Press, 2019. ISBN 978-1-108-47368-2

****MATH 628 | Machine Learning for Finance I | Nazari, A. | F 11:30 AM – 1:00 PM**

TBD

****MATH 632 | Algebraic Geometry II | Speyer, D. | TR 11:30 AM – 1:00 PM**

MATH 631 and Graduate standing. (3). (BS). May not be repeated for credit.

The theory of sheaves and sheaf cohomology on schemes. We'll aim to cover roughly chapters 14-19 of Vakil's textbook Foundations of Algebraic Geometry with an eye toward classical examples and geometric motivation.

Free Online Version Available

****MATH 635 | Differential Geometry | Uribe, A. | TR 1:00 PM – 2:30 PM**

591 or equivalent. Consent of instructor required. (3). (BS). May not be repeated for credit.

This is an introduction to Riemannian geometry. We will study the notions of connections, Riemannian metrics, geodesics, curvature, and Jacobi fields. We will cover the Hopf-Rinow and the Bonnet-Myers theorems. Then we will turn to complex manifolds and we will discuss some basic ideas in K˙ahler geometry. There will be approximately 6 homework assignments during the semester.

****MATH 636 | Topics in Differential Geometry | Bieri, L. | TR 10:00 AM – 11:30 AM**

Topic: The Mathematics of General Relativity Theory

Basic point set topology/manifold theory, real analysis

"Partial differential equations (PDE) on manifolds with rich geometrical features are studied in pure mathematics to unravel the structures of their solutions and the spaces they live in. PDE describe phenomena in the real world including physics, medicine, biology or economics. They have become essential to science, technology and to modern life.
In general relativity (GR) the Einstein equations describe the laws of the Universe. GR unifies space, time and gravitation. A spacetime in GR is a Lorentzian manifold where the metric solves the Einstein equations. They can be written as a system of nonlinear, second-order, hyperbolic PDE. The unknown is the metric. Typical physical questions are formulated as initial value problems for the Einstein equations under specific conditions. The solution will lay open the geometry of the resulting spacetime. Today, the methods of geometric analysis have proven to be most effective to investigate these structures. In this course, we introduce some of these methods which are universal and can be applied to other PDE outside GR.
First, we will introduce the spacetime as a solution of the Einstein equations. Then we will discuss topics from linear and nonlinear wave equations on flat and on curved backgrounds. Along the way, the role of curvature in GR will be given special attention. We will study the initial value problem in GR, and introduce the concept of black holes. In view of the latter, we shall prove Penrose's incompleteness theorem and study the extensions of this result by Hawking and Penrose. Those results are better known as the `singularity theorems'. The most important breakthrough along this way is certainly Christodoulou's result on the formation of black holes, showing that a closed trapped surface will form through the focusing of gravitational waves. Finally, we will address questions in modern research on gravitational waves and their geometric-analytic structures. These are produced during extreme events in our Universe like supernovae and when binary black holes merge. These waves were detected for the first time in 2015 by LIGO. This marks the beginning of a new era where we `decode' information transported by the spacetime itself from distant parts of the Universe. "

No required textbook.

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MATH 638 **Algebraic Groups** **Cotner, Sean** **TR 2:30 PM – 4:00 PM**

"The theory of algebraic groups naturally divides into the theory of abelian varieties and the theory of linear algebraic groups. We will explore the latter. These groups are ultimately describable by matrices, but in order to avoid case-by-case arguments it is useful to have a general abstract framework. Our goal is to study the structure theory of reductive groups, which will take considerable preparatory work.

A careful study of reductive groups over the real numbers clarifies the theory of Lie groups, over finite fields it leads to the construction of almost all finite simple groups, and over number fields it aids the study of modular forms and beyond. In order to accommodate all of this interesting mathematics, we will work throughout over an arbitrary field.

There is no required textbook; we will largely follow Brian Conrad's notes, available through his website. Other recommended resources are the books of Borel, Humphreys, and Springer (all called Linear Algebraic Groups), and the book of Platonov-Rapinchuk."

No required textbook.

****Math 654** **Intro Fluid Dynamics** **Alben, S.** **MW 1:00 PM – 2:30 PM**

Pre-requisites: Vector calculus. Complex analysis and differential equations at a senior undergraduate level (Math 450). Elementary physics (mechanics).

Course Description: The course is a broad introduction to fluid dynamics that uses classical applied mathematical tools to gain physical insight into fluid phenomena. No knowledge of fluid mechanics is assumed, but some upper-level undergraduate mathematics is (see pre-reqs).

Topics: Continua and conservation laws. Inviscid flow. Irrotational flow. Vorticity. Complex variable methods. Water waves. Airfoil theory and conformal transformations. Viscosity and the Navier-Stokes equations. The limit of zero Reynolds number. Boundary layers. Flow instabilities. Possible special topics: fluid-structure interactions and biological propulsion.

Required text: *Elementary Fluid Dynamics* by D. J. Acheson, Oxford University Press, 1990.

****MATH 658** **Topics in Ordinary Differential Equations** **Bloch, T.** **MW 10:00 AM – 11:30 AM**
Topic: Nonlinear Dynamics and Geometric Mechanics
A senior undergraduate or graduate course in differential equations. (3). (BS).

This course will discuss geometric aspects of the modern theory of ordinary differential equations and dynamical systems, with applications to various mechanical and physical systems. Topics will include: the qualitative theory of ODE's on manifolds, symplectic and Poisson geometry, nonlinear stability theory, Lagrangian and Hamiltonian mechanics, integrable systems, reduction and symmetries, mechanical systems with constraints and controls, and optimal control.

Optional Textbooks: *Nonholonomic Mechanics and Control* (2nd edition), by Anthony Bloch; 978-1-4939, *Mathematical Methods of Classical Mechanics*, by V. Arnold; 978-1-4757-1695-5

****MATH 669** **Topics in Combinatorial Theory** **Lam, T.** **TR 1:00 PM – 2:30 PM**
***Topic:* Symmetric Functions**

Good knowledge of linear algebra (3). (BS). May not be repeated for credit.

The theory of symmetric functions lies at the heart of algebraic combinatorics, with connections to representation theory, probability, and algebraic geometry. This course is an introduction to the theory of symmetric functions from the combinatorial point of view. We will introduce Schur functions, Young tableaux, and the Robinson-Schensted algorithm. We will discuss relations with representation theory of the symmetric group and with Schubert calculus on the Grassmannian. Towards the end of the class, we hope to discuss some variations, for example quasisymmetric functions, Stanley symmetric functions, plactic monoid, noncommutative symmetric functions, k-Schur functions, and so on.

No required textbook.

MATH 675 **Analysis Theory Number** **Peluse, S.** **MW 1:00 PM – 2:30 PM**
Prerequisites: complex analysis (at least at the level of Math 596) and a course in elementary number theory (at least at the level of Math 575)

This is a first course in analytic number theory, focusing on multiplicative number theory and basic sieve theory. Topics covered include the distribution of prime numbers, the anatomy of integers, and the analytic theory of the Riemann zeta function and Dirichlet L-functions.

Optional Textbooks: **Multiplicative Number Theory I: Classical Theory,** by Montgomery and Vaughan (ISBN-13: 978-1107405820), **Introduction to Analytic and Probabilistic Number Theory**, by Tenenbaum (ISBN-13: 978-0821898543), **The Distribution of Prime Numbers**, by Koukoulopoulos (ISBN-13: 978-1470462857)

****MATH 697** **Topics in Topology** **Canary, R.** **MWF 2:00 PM – 3:00 PM**
Topic: Geometry and Dynamics of Hyperbolic Surfaces (and beyond)
The only prerequisite is the theory of covering spaces as discussed in Math 592.

The study of hyperbolic surfaces has is a fundamental motivation and basic expamle in a diverse array of mathematical subjects, including low-dimensional topology, Riemannian Geometry, hyperbolic dynamics, geometric group theory and algebraic geometry. We will begin with an elementary review of the fundamental results on hyperbolic surfaces with a view towards their generalizations elsewhere. Topics will include Teichmuller space, moduli space, collar lemmas, Patterson-Sullivan measures and ergodicity properties of geodesic flows. Depending on student interest we may also cover Teichmuller's existence and uniqueness theorems, the augmented Teichmuller space and the compactification of moduli space. In the final portion of the course we will, guided by student interests, explore some of the ways the ideas in this subject have propagated elsewhere in mathematics.

****MATH 710 Topics in Modern Analysis II Baik, J. TR 1:00 PM – 2:30 PM**
Topic: Random matrices
Complex Analysis and Probability (incl. martingales), e.g. MATH 596 & 625. *(3). (BS). May not be repeated for credit.*

"Random matrix theory is concerned with the behaviors of the eigenvalues from a randomly chosen matrix when the matrix size is large. Since the eigenvalues are complicated functions of the matrix entries, the eigenvalues are not necessarily independent, even if the entries of a matrix are independent random variables. Instead, the eigenvalues are strongly correlated, and they repel each other. These correlations between the eigenvalues turn out to be quite universal and describe the many complex models in probability and statistical physics as well, including random tilings and the zeros of the Riemann zeta function.
In this course, we will discuss some fundamental methods and ideas of random matrix theory. We will focus on some of the most basic random matrix models and study their properties. Along the way we discuss various topics in analysis and probability such as Stieltjes transform, moment method, Coulomb gases, potential theory of electric charges, orthogonal polynomials, method of steepest-descent, and Fredholm determinants. The students are assumed to be familiar with complex analysis and basic probability."

No required textbook.

****MATH 732 Topics in Algebraic Geometry II Stapleton, D. TR 1:00 PM – 2:30 PM**
Topic: Cubic Hypersurfaces

MATH 631-632 or equivalent. (3). (BS). May not be repeated for credit.

The goal of this course is an in-depth study of the geometry of cubic hypersurfaces. We will study many aspects of algebraic geometry through the lens of cubic hypersurfaces: rationality problems, Hodge theory and Torelli theorems, Fano varieties of lines and hyperK manifolds, and derived categories. The course will be example driven and will start with some general theory of cubic hypersurfaces, a study of their Fano varieties, and their moduli spaces. In the latter portion of the course we will carry out an in-depth study of cubics in dimensions 2, 3, and 4.

No required textbook.

****MATH 797 Advanced Topics in Topology Wilson, J. MWF 3:00 PM – 4:00 PM**
Topic: Methods in Algebraic Topology

Math 592 or equivalent

"We will study some general tools in algebraic topology: combinatorial methods with simplicial complexes, spectral sequences, and foundations of group (co)homology. As one application we will see how to use these tools to prove homological stability for a family of groups or spaces. This course will include a combination of lectures and small group work on guided worksheets."

No required textbook.