MAJOR IN MATHEMATICS

The major in Mathematics is designed to meet two goals: to introduce some of the central ideas in a variety of areas of mathematics and statistics, and to develop problem-solving ability by teaching students to combine creative thinking with rigorous reasoning. Mathematics is a gateway to many career paths including statistics, teaching, consulting, business, engineering, finance, actuarial studies and applied mathematics. Students are strongly encouraged to consult with the department faculty on choosing courses appropriate to an individualized program of study.

REQUIREMENTS (9 courses plus colloquium)

The major in Mathematics consists of nine courses plus the colloquium requirement. Mathematics is highly cumulative, and students should plan a
route to completing the major that ensures the proper sequencing and prerequisites for all needed courses. Note that not all upper level courses are offered every year.

**Calculus (2 courses)**

- Mathematics 140 Calculus II
- Mathematics 150 or 151 Multivariable Calculus

**Applied/Discrete Mathematics/Statistics (1 course)**

- Mathematics 209 Differential Equations
- Mathematics 210 Mathematical Methods for Scientists (Same as Physics 210)
- Mathematics 200 Discrete Mathematics
- Statistics 201 Statistics and Data Analysis
- Statistics 231 Statistical Design of Experiments
- or a more advanced applied/discrete/statistics course with prior department approval

**Core Courses (3 courses)**

- Mathematics 250 Linear Algebra
- Mathematics 350 Real Analysis or Mathematics 351 Applied Real Analysis
- Mathematics 355 Abstract Algebra

**Completion (3 courses plus colloquium)**

- Two electives from courses numbered 300 and above, or STAT 231
- One Senior Seminar: Any course numbered between 400 and 479, taken in the senior year.

Participation in the Department Colloquium, in which all senior majors present a talk on a mathematical or statistical topic of their choice. Each major must attend at least 20 colloquia, and up to 5 attendances may be counted in their junior year. Students engaged in study away may petition the department in advance to count up to 5 suitable colloquia attendances from their study away program.

**ADVANCED PLACEMENT**

Students who come to Williams with advanced placement will be moved up in the Mathematics major, and should consult with faculty to be placed in the best class reflecting their experience and background. A student who places out of a course substitutes another course of equal or higher level in Mathematics or Statistics to complete the nine course major. Students should select courses best suited to their preparation and goals, and consult with the department faculty concerning appropriate courses and placement. The department reserves the right to refuse registration in any course for which the student is overqualified.

For Example, a student starting in MATH 130 might take MATH 130 and 140 the first year, MATH 150 and MATH 200 the second year, MATH 250 and MATH 350 the third year, MATH 355 and a senior seminar the fourth year, plus the two required electives some time. Students are encouraged to consult freely with any math faculty about course selection and anything else.

**CALCULUS PLACEMENT**

**Recommended placement for students who have taken an Advanced Placement Examination in Calculus (AB or BC) is:**

- BC 1, 2 or AB 2, 3 Math 140
- AB 4 or 5 Math 150
- BC 3, 4 or 5 Math 151

Consult with department faculty for any Calculus or Statistics placement questions. Students who have had calculus in high school, whether or not they took the Advanced Placement Examination, are barred from 130 unless they obtain permission from the instructor.

**NOTES**

**Substitutions, Study Abroad, and Transfer Credit:** In some cases, and with prior permission of the Mathematics and Statistics Department, appropriate courses from other institutions or a course from another Williams department may be substituted for electives. Programs like the “Budapest Semester in Mathematics” are recommended for majors who wish to focus on mathematics away. The department, though, normally
accommodates students who select other study away programs. The department offers its core courses in both the fall and the spring to allow students to spend more easily a semester away.

**Double Counting:** No course may count towards two different majors.

**Early Senior Seminar:** The senior seminar is designed and intended to be taken during the senior year. Students who have made significant progress towards the major may request to fulfill this requirement with a senior seminar taken during their junior year. Such requests should be submitted to the department chair, and should include a plan for completing the major and the rationale for taking their senior seminar as a Junior.

**Planning Courses:** Core courses Mathematics 350/351 and 355, are normally offered every year. Most other 300-level topics are offered in alternate years. Topology, Complex Analysis, and second courses in real analysis and abstract algebra are normally offered at least every other year.

Each 400-level topic is normally offered every two to four years. Students should check with the department before planning far into the future.

**Course Admission:** Courses are normally open to all students meeting the prerequisites, subject to any course caps. Students with questions about the level at which courses are conducted are invited to consult department faculty.

**FAQ**

Students MUST contact departments/programs BEFORE assuming study away credit will be granted toward the major or concentration.

**Can your department or program typically pre-approve courses for major/concentration credit?**

Yes, in many cases, though students should be sure to contact the department.

**What criteria will typically be used/required to determine whether a student may receive major/concentration credit for a course taken while on study away?**

Course title and description, and complete syllabus including readings/assignments.

**Does your department/program place restrictions on the number of major/concentration credits that a student might earn through study away?**

No.

**Does your department/program place restrictions on the types of courses that can be awarded credit towards your major?**

Yes. They have to be approved MATH/STAT courses.

**Are there specific major requirements that cannot be fulfilled while on study away?**

Yes. Colloquium requirement, Senior Seminar requirement.

**Are there specific major requirements in your department/program that students should be particularly aware of when weighing study away options? (Some examples might include a required course that is always taught in one semester, laboratory requirements.)**

Yes. The highly cumulative structure of the major.

**Give examples in which students thought or assumed that courses taken away would count toward the major or concentration and then learned they wouldn’t:**

None to date.

**THE DEGREE WITH HONORS IN MATHEMATICS**

The degree with honors in Mathematics is awarded to the student who has demonstrated outstanding intellectual achievement in a program of study which extends beyond the requirements of the major. The principal considerations for recommending a student for the degree with honors will be: Mastery of core material and skills, breadth and, particularly, depth of knowledge beyond the core material, ability to pursue independent study of mathematics or statistics, originality in methods of investigation, and, where appropriate, creativity in research.

An honors program normally consists of two semesters (MATH/STAT 493 and 494) and a winter study (WSP 031) of independent research, culminating in a thesis and a presentation. Under certain circumstances, the honors work can consist of coordinated study involving a one semester (MATH/STAT 493 or 494) and a winter study (WSP 030) of independent research, culminating in a “minithesis” and a presentation. At least one semester should be in addition to the major requirements, and thesis courses do not count as 400-level senior seminars.

An honors program in actuarial studies requires significant achievement on four appropriate examinations of the Society of Actuaries.

Highest honors will be reserved for the rare student who has displayed exceptional ability, achievement or originality. Such a student usually will have written a thesis, or pursued actuarial honors and written a mini-thesis. An outstanding student who writes a mini-thesis, or pursues actuarial honors and writes a paper, might also be considered. In all cases, the award of honors and highest honors is the decision of the Department.

**APPLIED MATHEMATICS TRACK**

Students interested in applied mathematics, engineering, or other sciences should consider:

Mathematics 140 Calculus II
Mathematics 150 or 151 Multivariable Calculus
Statistics 201 Statistics and Data Analysis
Mathematics 250 Linear Algebra
Mathematics 351 Applied Real Analysis
Mathematics 355 Abstract Algebra
Some programming or numerical analysis (e.g. MATH 361, 318T, or anything if you’ve had CSCI 134)
MATH 309 or Post-core Differential Equations/Numerical Methods
Senior seminar (e.g. Math Ecology MATH 410T or Mathematical Modeling MATH 433)

Other recommended courses: complex analysis, discrete mathematics (e.g. combinatorics or graph theory), operations research, optimization, probability, statistics, appropriate courses in Biology, Chemistry, Computer Science, Economics, Neuroscience, Physics, etc.

Williams has exchange and joint programs with good engineering schools. Interested students should consult the section on engineering near the beginning of the Bulletin and the Williams pre-engineering advisor for further information.

GRADUATE SCHOOL TRACK
Students interested in continuing their study of mathematics in graduate school should consider:

Mathematics 140 Calculus II
Mathematics 150 or 151 Multivariable Calculus
Mathematics 250 Linear Algebra
Mathematics 350 Real Analysis
Mathematics 355 Abstract Algebra
Complex Analysis
Topology
Some second semester analysis
Some second semester algebra
Some post-core geometry
Thesis

[With prior permission, in unusual circumstances, senior seminar can be waived in favor of harder post-core electives.]

Students headed for graduate school generally take more than this relatively small number of courses required for a liberal arts major. Reading knowledge of a foreign language (French, German, or Russian) can be helpful.

Students interested in studying statistics in graduate school should take STAT 201, 346, 360, a 400 level statistics course and MATH 350/351 and 341 in addition to their other math requirements.

OTHER CAREER PATHS
Other Graduate and Professional Schools: An increasing number of graduate and professional schools require mathematics and statistics as a prerequisite to admission or to attaining their degree. Students interested in graduate or professional training in business, medicine, economics, or psychology are advised to find out the requirements in those fields early in their college careers.

Statistics and Actuarial Science: Students interested in statistics or actuarial science should consider Mathematics 341, Statistics courses, and Economics 255. Additionally, students should consider taking some number of the actuarial exams given by the Society of Actuaries, which can constitute part of an honors program in actuarial studies (see section on honors above).

Teaching: Students interested in teaching mathematics at the elementary or secondary school level should consider courses on teaching, number theory, geometry, statistics, and practice as a tutor or teaching assistant. Winter study courses that provide a teaching practicum are also highly recommended. Consult the Program in Teaching (Professor Susan Engel) and the Office of Career Counseling.

Business and Finance: Students interested in careers in business or finance should consider Mathematics 333 and Statistics courses. Since
these courses address different needs, students should consult with the instructors to determine which seem to be most appropriate for individuals.

There are three types of 300-level courses. There are the core courses: Real Analysis, MATH 350/351, and Abstract Algebra Math 355. There are the “precore” courses, which do not have the core courses as prerequisites and have numbers 300-349. Finally, there are those courses that have an Abstract Algebra or Real Analysis prerequisite, which are numbered 360-399.

**MATH 102  (F)  Foundations in Quantitative Skills**

This course will strengthen a student's foundation in quantitative reasoning in preparation for the science curriculum and QFR requirements. The material will be at the college algebra/precalculus level, and covered in a tutorial format with students working in small groups with the professor. Access to this course is limited to placement by a quantitative skills counselor.

**Requirements/Evaluation:** homework, presentations during the tutorial meetings, and projects

**Prerequisites:** access to the course is limited to placement by a quantitative skills counselor

**Enrollment Limit:** 10

**Enrollment Preferences:** students who need most help with the quantitative reasoning

**Expected Class Size:** 10

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3)

Fall 2019

TUT Section: T1    TBA    Mihai Stoiciu

**MATH 110  (F)  Logic and Likelihood  (QFR)**

How best can we reason in the face of uncertainty? We will begin with an examination of rationality and the reasoning process including a survey of formal logic. Starting with uncertainty from a psychological and philosophical viewpoint, we will move to a careful theory of likelihood and how to reason with probabilistic models. The course will conclude with a consideration of observation and information, how to test hypotheses, and how we update our beliefs to incorporate new evidence.

**Requirements/Evaluation:** homework, essays, presentations, exams, and participation

**Prerequisites:** none

**Enrollment Limit:** 25

**Enrollment Preferences:** first-year students

**Expected Class Size:** 25

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** This course will be covering formal logic and probability theory at sufficient depth to place this course on level with other QFR designated courses.

Not offered current academic year

**MATH 113  (S)  The Beauty of Numbers  (QFR)**

Have you ever wondered what keeps your credit card information safe everytime you buy something online? Number theory! Number Theory is one of the oldest branches of mathematics. In this course, we will discover the beauty and usefulness of numbers, from ancient Greece to modern cryptography. We will look for patterns, make conjectures, and learn how to prove these conjectures. Starting with nothing more than basic high school algebra, we will develop the logic and critical thinking skills required to realize and prove mathematical results. Topics to be covered include the meaning and content of proof, prime numbers, divisibility, rationality, modular arithmetic, Fermat's Last Theorem, the Golden ratio, Fibonacci numbers, coding theory, and unique factorization.

**Requirements/Evaluation:** projects, homework assignments, and exams
**Prerequisites:** MATH 102 (or demonstrated proficiency on a diagnostic test) or permission of instructor

**Enrollment Limit:** 25

**Expected Class Size:** 25

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

Spring 2020

LEC Section: 01  TR 9:55 am - 11:10 am  Allison Pacelli

**MATH 130 (F)(S) Calculus I (QFR)**

Calculus permits the computation of velocities and other instantaneous rates of change by a limiting process called differentiation. The same process also solves "max-min" problems: how to maximize profit or minimize pollution. A second limiting process, called integration, permits the computation of areas and accumulations of income or medicines. The Fundamental Theorem of Calculus provides a useful and surprising link between the two processes. Subtopics include trigonometry, exponential growth, and logarithms.

**Requirements/Evaluation:** exams, homework and quizzes

**Prerequisites:** MATH 102 (or demonstrated proficiency on a diagnostic test); this is an introductory course for students who have not seen calculus before

**Enrollment Limit:** 50

**Enrollment Preferences:** professor's discretion

**Expected Class Size:** 30

**Grading:** yes pass/fail option, yes fifth course option

**Unit Notes:** students who have previously taken a calculus course may not enroll in MATH 130 without the permission of instructor

**Distributions:** (D3) (QFR)

Fall 2019

LEC Section: 01  MWF 11:00 am - 11:50 am  Allison Pacelli

LEC Section: 02  MWF 12:00 pm - 12:50 pm  Allison Pacelli

Spring 2020

LEC Section: 01  MWF 9:00 am - 9:50 am  Eva Goedhart

**MATH 140 (F)(S) Calculus II (QFR)**

Mastery of calculus requires understanding how integration computes areas and business profit and acquiring a stock of techniques. Further methods solve equations involving derivatives ("differential equations") for population growth or pollution levels. Exponential and logarithmic functions and trigonometric and inverse functions play an important role. This course is the right starting point for students who have seen derivatives, but not necessarily integrals, before.

**Requirements/Evaluation:** homework, quizzes, and/or exams

**Prerequisites:** MATH 130 or equivalent; students who have received the equivalent of advanced placement of AB 4, BC 3 or higher may not enroll in MATH 140 without the permission of instructor

**Enrollment Limit:** 50

**Expected Class Size:** 30

**Grading:** yes pass/fail option, yes fifth course option

**Unit Notes:** students who have higher advanced placement must enroll in MATH 150 or above

**Distributions:** (D3) (QFR)

Fall 2019
MATH 150 (F)(S) Multivariable Calculus (QFR)
Applications of calculus in mathematics, science, economics, psychology, the social sciences, involve several variables. This course extends calculus to several variables: vectors, partial derivatives, multiple integrals. There is also a unit on infinite series, sometimes with applications to differential equations.

Requirements/Evaluation: homework, quizzes, and/or exams
Prerequisites: MATH 140 or equivalent, such as satisfactory performance on an Advanced Placement Examination
Enrollment Limit: 50
Expected Class Size: 50
Grading: yes pass/fail option, yes fifth course option
Unit Notes: students with the equivalent of advanced placement of AB 4 or above should enroll in MATH 150, students with a BC 3 or higher should enroll in Math 151 when it is being offered, and Math 150 otherwise.
Distributions: (D3) (QFR)

Fall 2019
LEC Section: 01 MWF 9:00 am - 9:50 am Julie C. Blackwood
LEC Section: 02 MWF 10:00 am - 10:50 am Julie C. Blackwood
LEC Section: 03 MWF 11:00 am - 11:50 am Julie C. Blackwood

Spring 2020
LEC Section: 01 MWF 10:00 am - 10:50 am Steven J. Miller
LEC Section: 02 MWF 11:00 am - 11:50 am Steven J. Miller

MATH 151 (F) Multivariable Calculus (QFR)
Applications of calculus in mathematics, science, economics, psychology, the social sciences, involve several variables. The goal of the course is Stokes Theorem, a deep and profound generalization of the Fundamental Theorem of Calculus. The difference between this course and MATH 150 is that MATH 150 covers infinite series instead of Stokes Theorem. Students with the equivalent of BC 3 or higher should enroll in MATH 151, as well as students who have taken the equivalent of an integral calculus and who have already been exposed to infinite series. For further clarification as to whether MATH 150 or MATH 151 is appropriate, please consult a member of the math/stat department.

Requirements/Evaluation: homework, quizzes, and/or exams
Prerequisites: AP BC 3 or higher or integral calculus with infinite series
Enrollment Limit: 50
Expected Class Size: 50
Grading: yes pass/fail option, yes fifth course option
Unit Notes: MATH 151 satisfies any MATH 150 prerequisite; credit will not be given for both MATH 150 and MATH 151
Distributions: (D3) (QFR)

Fall 2019
LEC Section: 01 MWF 9:00 am - 9:50 am Colin C. Adams
LEC Section: 02 MWF 10:00 am - 10:50 am Colin C. Adams
LEC Section: 03 MWF 11:00 am - 11:50 am Colin C. Adams
MATH 200  (F)(S) Discrete Mathematics  (QFR)
Course Description: In contrast to calculus, which is the study of continuous processes, this course examines the structure and properties of finite sets. Topics to be covered include mathematical logic, elementary number theory, mathematical induction, set theory, functions, relations, elementary combinatorics and probability, graphs and trees, and algorithms. Emphasis will be given on the methods and styles of mathematical proofs, in order to prepare the students for more advanced math courses.

Class Format: discussion
Requirements/Evaluation: homework and exams
Prerequisites: MATH 140 or MATH 130 with CSCI 134 or 135; or one year of high school calculus with permission of instructor; students who have taken a 300-level math course should obtain permission of the instructor before enrolling
Enrollment Limit: 40
Expected Class Size: 25
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)

Fall 2019
LEC Section: 01  TR 9:55 am - 11:10 am  Josh Carlson
LEC Section: 02  TR 11:20 am - 12:35 pm  Josh Carlson

Spring 2020
LEC Section: 01  MWF 10:00 am - 10:50 am  Lori A. Pedersen
LEC Section: 02  MWF 11:00 am - 11:50 am  Lori A. Pedersen

MATH 210  (S) Mathematical Methods for Scientists  (QFR)
Cross-listings: MATH 210  PHYS 210
Secondary Cross-listing
This course covers a variety of mathematical methods used in the sciences, focusing particularly on the solution of ordinary and partial differential equations. In addition to calling attention to certain special equations that arise frequently in the study of waves and diffusion, we develop general techniques such as looking for series solutions and, in the case of nonlinear equations, using phase portraits and linearizing around fixed points. We study some simple numerical techniques for solving differential equations. A series of optional sessions in Mathematica will be offered for students who are not already familiar with this computational tool.

Class Format: three hours per week
Requirements/Evaluation: several exams and on weekly problem sets, all of which have a substantial quantitative component
Prerequisites: MATH 150 or 151 and familiarity with Newtonian mechanics at the level of PHYS 131
Enrollment Limit: 50
Expected Class Size: 30
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
MATH 210 (D3) PHYS 210 (D3)

Spring 2020
LEC Section: 01  TR 9:55 am - 11:10 am  Daniel P. Aalberts, David R. Tucker-Smith

MATH 250  (F)(S) Linear Algebra  (QFR)
Many social, political, economic, biological, and physical phenomena can be described, at least approximately, by linear relations. In the study of systems of linear equations one may ask: When does a solution exist? When is it unique? How does one find it? How can one interpret it geometrically? This course develops the theoretical structure underlying answers to these and other questions and includes the study of matrices,
vector spaces, linear independence and bases, linear transformations, determinants and inner products. Course work is balanced between theoretical and computational, with attention to improving mathematical style and sophistication.

**Requirements/Evaluation:** homework and exams

**Prerequisites:** MATH 150/151 or MATH 200

**Enrollment Limit:** 45

**Expected Class Size:** 35

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

**Attributes:** COGS Related Courses

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Fall 2019

LEC Section: 01   TR 9:55 am - 11:10 am   Eva Goedhart

LEC Section: 02   TR 11:20 am - 12:35 pm   Eva Goedhart

Spring 2020

LEC Section: 01   TR 9:55 am - 11:10 am   Haydee M. A. Lindo

LEC Section: 02   TR 11:20 am - 12:35 pm   Haydee M. A. Lindo

**MATH 293 (F) Undergraduate Research Topics in Representation Theory** (QFR)

Central to the study of the representation theory of Lie algebras is the computation of weight multiplicities by using Kostant's weight multiplicity formula. This formula is an alternating sum over a finite group, and involves a partition function. In this tutorial, we will address questions regarding the number of terms contributing nontrivially to the sum and develop closed formulas for the value of the partition function. Techniques used include generating functions and counting arguments, which are at the heart of combinatorics and are accessible to undergraduate students.

**Class Format:** tutorial

**Requirements/Evaluation:** written assignments, oral presentations

**Prerequisites:** permission of instructor

**Enrollment Limit:** 10

**Enrollment Preferences:** programming experience, students with interests in the intersection of combinatorics and abstract algebra

**Expected Class Size:** 10

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

**Not offered current academic year**

**MATH 306 (S) Fractals and Chaos** (QFR)

Early in the course we introduce the notion of dynamical systems. Then we will develop the mathematics behind iterated function systems and study the notions of fractals and chaos. There will be a lot of computer experimentation with various programs and resources which the students are expected to use to learn and discover properties of fractals. The final topics will include dimension complex dynamics and the Mandelbrot set.

**Requirements/Evaluation:** homework, projects and exams

**Prerequisites:** MATH 250

**Enrollment Limit:** 30

**Expected Class Size:** 18

**Grading:** yes pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

**Not offered current academic year**

**MATH 307 (F) Computational Linear Algebra** (QFR)

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Linear algebra is of central importance in the quantitative sciences, including application areas such as image and signal processing, data mining, computational finance, structural biology, and much more. When the problems must be solved computationally, approximation, round-off errors, convergence, and efficiency matter, and traditional linear algebra techniques may fail to succeed. We will adopt linear algebra techniques on a large scale, implement them computationally, and apply them to core problems in scientific computing. Topics may include: systems of linear and nonlinear equations; approximation and statistical function estimation; optimization; interpolation; and Monte Carlo techniques. This course could also be considered a course in numerical analysis or computational science.

**Requirements/Evaluation:** quizzes/exams, problem sets, projects and activities

**Prerequisites:** MATH 250, some elementary computer programming experience is strongly recommended

**Enrollment Limit:** 30

**Enrollment Preferences:** Professor's discretion

**Expected Class Size:** 25

**Grading:** no pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

**Not offered current academic year**

**MATH 309 (S) Differential Equations (QFR)**

Ordinary differential equations (ODE) frequently arise as models of phenomena in the natural and social sciences. This course presents core ideas of ODE from an applied standpoint. Topics covered early in the course include numerical solutions, separation of variables, integrating factors, constant coefficient linear equations, and power series solutions. Later, we focus on nonlinear ODE, for which it is usually impossible to find analytical solutions. Tools from dynamical systems allows us to obtain some information about the behavior of the ODE without explicitly knowing the solution.

**Class Format:** discussion and interactive activities

**Requirements/Evaluation:** quizzes/exams, problem sets, activities

**Prerequisites:** MATH 150/151 and MATH 250

**Enrollment Limit:** 30

**Enrollment Preferences:** discretion of the instructor

**Expected Class Size:** 30

**Grading:** no pass/fail option, yes fifth course option

**Distributions:** (D3) (QFR)

Spring 2020

**LEC Section:** 01  MR 2:35 pm - 3:50 pm  Julie C. Blackwood

**MATH 310 (S) Mathematical Biology (QFR)**

**Cross-listings:** MATH 310  BIOL 210

**Primary Cross-listing**

This course will provide an introduction to the many ways in which mathematics can be used to understand, analyze, and predict biological dynamics. We will learn how to construct mathematical models that capture essential properties of biological processes while maintaining analytic tractability. Analytic techniques, such as stability and bifurcation analysis, will be introduced in the context of both continuous and discrete time models. Additionally, students will couple these analytic tools with numerical simulation to gain a more global picture of the biological dynamics. Possible biological applications include, but are not limited to, single and multi-species population dynamics, neural and biological oscillators, tumor cell growth, and infectious disease dynamics.

**Requirements/Evaluation:** problem sets, weekly meetings, final project and paper

**Prerequisites:** MATH 250, MATH 209 or 309, permission of instructor

**Enrollment Limit:** 10

**Enrollment Preferences:** if over-enrolled, will have students submit reasons for taking class; preference to those with interest in both subjects

**Expected Class Size:** 10
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
MATH 310 (D3) BIOL 210 (D3)

Quantitative/Formal Reasoning Notes: The course will introduce methods for developing and analyzing mathematical models.
Attributes: PHLH Methods in Public Health
Not offered current academic year

MATH 313 (F) Introduction to Number Theory (QFR)
The study of numbers dates back thousands of years, and is fundamental in mathematics. In this course, we will investigate both classical and modern questions about numbers. In particular, we will explore the integers, and examine issues involving primes, divisibility, and congruences. We will also look at the ideas of number and prime in more general settings, and consider fascinating questions that are simple to understand, but can be quite difficult to answer.
Requirements/Evaluation: performance on homework, projects, and examinations
Prerequisites: MATH 250 or permission of instructor
Enrollment Limit: 40
Expected Class Size: 25
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)
Not offered current academic year

MATH 314 (S) Cryptography (QFR)
An introduction to the techniques and practices used to keep secrets over non-secure lines of communication, including classical cryptosystems, the data encryption standard, the RSA algorithm, discrete logarithms, hash functions, and digital signatures. In addition to the specific material, there will also be an emphasis on strengthening mathematical problem solving skills, technical reading, and mathematical communication.
Requirements/Evaluation: exams, homework, and quizzes
Prerequisites: MATH 250
Enrollment Limit: 30
Enrollment Preferences: graduating seniors and Math majors
Expected Class Size: 30
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)
Quantitative/Formal Reasoning Notes: The course will contain mathematical proofs.

Spring 2020
LEC Section: 01 MWF 10:00 am - 10:50 am Eva Goedhart

MATH 316 (S) Protecting Information: Applications of Abstract Algebra and Quantum Physics (QFR)
Cross-listings: PHYS 316 MATH 316
Primary Cross-listing
Living in the information age, we find ourselves depending more and more on codes that protect messages against either noise or eavesdropping. This course examines some of the most important codes currently being used to protect information, including linear codes, which in addition to being mathematically elegant are the most practical codes for error correction, and the RSA public key cryptographic scheme, popular nowadays for internet applications. We also study the standard AES system as well as an increasingly popular cryptographic strategy based on elliptic curves. Looking ahead by a decade or more, we show how a quantum computer could crack the RSA scheme in short order, and how quantum cryptographic devices will achieve security through the inherent unpredictability of quantum events.
**MATH 317 (F) Introduction to Operations Research** (QFR)

In the first N math classes of your career, you can be misled as to what the world is truly like. How? You're given exact problems and told to find exact solutions. The real world is sadly far more complicated. Frequently we cannot exactly solve problems; moreover, the problems we try to solve are themselves merely approximations to the world! We are forced to develop techniques to approximate not just solutions, but even the statement of the problem. Additionally, we often need the solutions quickly. Operations Research, which was born as a discipline during the tumultuous events of World War II, deals with efficiently finding optimal solutions. In this course we build analytic and programming techniques to efficiently tackle many problems. We will review many algorithms from earlier in your mathematical or CS career, with special attention now given to analyzing their run-time and seeing how they can be improved. The culmination of the course is a development of linear programming and an exploration of what it can do and what are its limitations. For those wishing to take this as a Stats course, the final project must have a substantial stats component approved by the instructor.

**Prerequisites:** Linear Algebra (MATH 250) and one other 200-level or higher CSCI, MATH or STATS course.

**Requirements/Evaluation:** homework, exams, projects

**Enrollment Limit:** 40

**Enrollment Preferences:** Computer Science, Mathematics and Statistics majors

**Expected Class Size:** 25

**Grading:** yes pass/fail option, yes fifth course option

**Unit Notes:** http://web.williams.edu/Mathematics/sjmiller/public_html/317/

**Distributions:** (D3) (QFR)

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**MATH 318 (F) Numerical Problem Solving** (QFR)

In the last twenty years computers have profoundly changed the work in numerical mathematics (in areas from linear algebra and calculus to differential equations and probability). The main goal of this tutorial is to learn how to use computers to do quantitative science. We will explore concepts and ideas in mathematics and science using numerical methods and computer programming. We will use specialized software, including Mathematica and Matlab.

**Class Format:** tutorial

**Requirements/Evaluation:** evaluation will be based on homework, classwork, and exams

**Prerequisites:** MATH 150/151 and MATH 250 or permission of instructor

**Enrollment Limit:** 10

**Expected Class Size:** 10
Grading: no pass/fail option, no fifth course option

Distributions: (D3) (QFR)

Not offered current academic year

**MATH 319 (F) Integrative Bioinformatics, Genomics, and Proteomics Lab** (QFR)

**Cross-listings:** BIOL 319  CSCI 319  MATH 319  PHYS 319  CHEM 319

**Secondary Cross-listing**

What can computational biology teach us about cancer? In this capstone experience for the Genomics, Proteomics, and Bioinformatics program, computational analysis and wet-lab investigations will inform each other, as students majoring in biology, chemistry, computer science, mathematics/statistics, and physics contribute their own expertise to explore how ever-growing gene and protein data-sets can provide key insights into human disease. In this course, we will take advantage of one well-studied system, the highly conserved Ras-related family of proteins, which play a central role in numerous fundamental processes within the cell. The course will integrate bioinformatics and molecular biology, using database searching, alignments and pattern matching, phylogenetics, and recombinant DNA techniques to reconstruct the evolution of gene families by focusing on the gene duplication events and gene rearrangements that have occurred over the course of eukaryotic speciation. By utilizing high through-put approaches to investigate genes involved in the MAPK signal transduction pathway in human colon cancer cell lines, students will uncover regulatory mechanisms that are aberrantly altered by siRNA knockdown of putative regulatory components. This functional genomic strategy will be coupled with independent projects using phosphorylation-state specific antisera to test our hypotheses. Proteomic analysis will introduce the students to de novo structural prediction and threading algorithms, as well as data-mining approaches and Bayesian modeling of protein network dynamics in single cells. Flow cytometry and mass spectrometry will be used to study networks of interacting proteins in colon tumor cells.

**Class Format:** two afternoons of lab, with one hour of lecture, per week

**Requirements/Evaluation:** lab participation, several short homework assignments, one lab report, a programming project, and a grant proposal

**Prerequisites:** BIOL 202; students who have not taken BIOL 202 but have taken BIOL 101 and CSCI 315 or PHYS 315, may enroll with permission of instructor. No prior computer programming experience is required.

**Enrollment Limit:** 12

**Enrollment Preferences:** seniors, then juniors, then sophomores

**Expected Class Size:** 12

**Grading:** yes pass/fail option, yes fifth course option

**Unit Notes:** does not satisfy the distribution requirement for the Biology major

Distributions: (D3) (QFR)

**This course is cross-listed and the prefixes carry the following divisional credit:**

BIOL 319 (D3) CSCI 319 (D3) MATH 319 (D3) PHYS 319 (D3) CHEM 319 (D3)

**Attributes:** BIGP Core Courses  BIMO Interdepartmental Electives

Not offered current academic year

**MATH 321 (S) Knot Theory** (QFR)

Take a piece of string, tie a knot in it, and glue the ends together. The result is a knotted circle, known as a knot. For the last 100 years, mathematicians have studied knots, asking such questions as, "Given a nasty tangled knot, how do you tell if it can be untangled without cutting it open?" Some of the most interesting advances in knot theory have occurred in the last ten years. This course is an introduction to the theory of knots. Among other topics, we will cover methods of knot tabulation, surfaces applied to knots, polynomials associated to knots, and relationships between knot theory and chemistry and physics. In addition to learning the theory, we will look at open problems in the field.

**Requirements/Evaluation:** problem sets, midterms, a paper and a final exam

**Prerequisites:** MATH 250 or permission of instructor

**Enrollment Limit:** 30

**Expected Class Size:** 25

**Grading:** yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

Not offered current academic year
MATH 325  (F)  Set Theory  (QFR)

Set theory is the traditional foundational language for all of mathematics. We will be discussing the Zermelo-Fraenkel axioms, including the Axiom of Choice and the Continuum Hypothesis, basic independence results and, if time permits, incompleteness theorems. At one time, these issues tore at the foundations of mathematics. They are still vital for understanding the nature of mathematical truth.

Requirements/Evaluation:  exams and homework
Prerequisites:  MATH 250
Enrollment Limit:  30
Expected Class Size:  15
Grading:  yes pass/fail option,  yes fifth course option
Materials/Lab Fee:  textbook cost
Distributions:  (D3)  (QFR)

Fall 2019
LEC Section: 01    TR 9:55 am - 11:10 am    Thomas A. Garrity

MATH 328  (S)  Combinatorics  (QFR)

Combinatorics is a branch of mathematics that focuses on enumerating, examining, and investigating the existence of discrete mathematical structures with certain properties. This course provides an introduction to the fundamental structures and techniques in combinatorics including enumerative methods, generating functions, partition theory, the principle of inclusion and exclusion, and partially ordered sets.

Class Format: interactive activities and discussion
Requirements/Evaluation: quizzes/exams, homework, activities
Prerequisites: MATH 200 and MATH 250
Enrollment Limit:  30
Enrollment Preferences: discretion of the instructor
Expected Class Size:  25
Grading:  no pass/fail option,  no fifth course option
Distributions:  (D3)  (QFR)

Spring 2020
LEC Section: 01    MWF 11:00 am - 12:15 pm    Josh Carlson

MATH 329  (S)  Discrete Geometry  (QFR)

Discrete geometry is one of the oldest and most consistently vibrant areas of mathematics, stretching from the Platonic Solids of the ancient Greeks to the modern day applications of convex optimization and linear programming. In this tutorial we will learn about polygons and their higher-dimensional cousins, polyhedra and polytopes, and the various ways to describe, compute, and classify such objects. We will learn how these objects and ideas can be applied to other areas, from computation and optimization to studying areas of math like algebraic geometry. Throughout this course we will be engaging with mathematical work and literature from as old as 500 BCE and as recent as "posted to the internet yesterday."

Requirements/Evaluation: participation, problem sets, oral presentations, an oral exam, and a final project
Prerequisites: MATH 250 or permission of instructor
Enrollment Limit:  10
Enrollment Preferences: first-years and sophomores
Expected Class Size:  10
Grading:  no pass/fail option,  no fifth course option
Distributions:  (D3)  (QFR)
MATH 331  (F)  The little Questions  (QFR)

Using math competitions such as the Putnam Exam as a springboard, in this class we follow the dictum of the Ross Program and “think deeply of simple things”. The two main goals of this course are to prepare students for competitive math competitions, and to get a sense of the mathematical landscape encompassing elementary number theory, combinatorics, graph theory, and group theory (among others). While elementary frequently is not synonymous with easy, we will see many beautiful proofs and “a-ha” moments in the course of our investigations. Students will be encouraged to explore these topics at levels compatible with their backgrounds.

Requirements/Evaluation:  homework, classwork, and exams
Prerequisites:  MATH 250 or permission of instructor
Enrollment Limit:  30
Enrollment Preferences:  members or alternates of the Putnam team, Mathematics, Physics or Computer Science majors
Expected Class Size:  25
Grading:  yes pass/fail option,   yes fifth course option
Unit Notes:  http://web.williams.edu/Mathematics/sjmiller/public_html/331/
Distributions:  (D3)  (QFR)

MATH 334  (S)  Graph Theory  (QFR)

A graph is a collection of vertices, joined together by edges. In this course, we will study the sorts of structures that can be encoded in graphs, along with the properties of those graphs. We’ll learn about such classes of graphs as multi-partite, planar, and perfect graphs, and will see applications to such optimization problems as minimum colorings of graphs, maximum matchings in graphs, and network flows.

Requirements/Evaluation:  problem sets and exams
Prerequisites:  MATH 200 or MATH 250
Enrollment Limit:  35
Enrollment Preferences:  Math majors
Expected Class Size:  20
Grading:  yes pass/fail option,   yes fifth course option
Distributions:  (D3)  (QFR)

MATH 337  (F)  Electricity and Magnetism for Mathematicians  (QFR)

Maxwell’s equations are four simple formulas, linking electricity and magnetism, that are among the most profound equations ever discovered. These equations led to the prediction of radio waves, to the realization that a description of light is also contained in these equations and to the discovery of the special theory of relativity. In fact, almost all current descriptions of the fundamental laws of the universe are deep generalizations of Maxwell’s equations. Perhaps even more surprising is that these equations and their generalizations have led to some of the most important mathematical discoveries (where there is no obvious physics) of the last 25 years. For example, much of the math world was shocked at how these physics generalizations became one of the main tools in geometry from the 1980s until today. It seems that the mathematics behind Maxwell is endless. This will be an introduction to Maxwell’s equations, from the perspective of a mathematician.

Requirements/Evaluation:  performance on homework and exams
Prerequisites:  MATH 250; no physics background required
Enrollment Limit:  none
Enrollment Preferences:  none
Expected Class Size:  15
Grading:  yes pass/fail option,   yes fifth course option
Distributions:  (D3)  (QFR)
MATH 338  (F)  Intermediate Logic  (QFR)

Cross-listings: MATH 338  PHIL 338

Secondary Cross-listing

In this course, we will begin with an in-depth study of the theory of first-order logic. We will first get clear on the formal semantics of first-order logic and various ways of thinking about formal proof: natural deduction systems, semantic tableaux, axiomatic systems and sequent calculi. Our main goal will be to prove things about this logical system rather than to use this system to think about ordinary language arguments. In this way the goal of the course is significantly different from that of Logic and Language (PHIL 203). Students who have take PHIL 203 will have a good background for this class, but students who are generally comfortable with formal systems need not have taken PHIL 203. We will prove soundness and completeness, compactness, the Lowenheim-Skolem theorems, undecidability and other important results about first-order logic. As we go through these results, we will think about the philosophical implications of first-order logic. From there, we will look at extensions of and/or alternatives to first-order logic. Possible additional topics would include: modal logic, the theory of counterfactuals, alternative representations of conditionals, the use of logic in the foundations of arithmetic and Godel's Incompleteness theorems. Student interest will be taken into consideration in deciding what additional topics to cover.

Requirements/Evaluation: problem sets and exams
Prerequisites: some class in which student has studied formal reasoning
Enrollment Limit: 20
Enrollment Preferences: Philosophy majors; juniors and seniors
Expected Class Size: 15
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3)  (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
MATH 338 (D3) PHIL 338 (D2)

Quantative/Formal Reasoning Notes: This is a class in Formal Logic. PHIL 203 satisfies the QFR requirement. If anything, this class will be significantly more formal.

Fall 2019
SEM Section: 01    MR 1:10 pm - 2:25 pm     Keith E. McPartland

MATH 341  (F)(S)  Probability  (QFR)

Cross-listings: MATH 341  STAT 341

Primary Cross-listing

While probability began with a study of games, it has grown to become a discipline with numerous applications throughout mathematics and the sciences. Drawing on gaming examples for motivation, this course will present axiomatic and mathematical aspects of probability. Included will be discussions of random variables, expectation, independence, laws of large numbers, and the Central Limit Theorem. Many interesting and important applications will also be presented, potentially including some from coding theory, number theory and nuclear physics.

Requirements/Evaluation: homework, classwork, and exams
Prerequisites: MATH 250 or permission of the instructor
Enrollment Limit: 40
Expected Class Size: 20
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3)  (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
MATH 341 (D3) STAT 341 (D3)
MATH 350  (F)(S)  Real Analysis  (QFR)
Real analysis is the theory behind calculus. It is based on a precise understanding of the real numbers, elementary topology, and limits. Topologically, nice sets are either closed (contain their limit points) or open (complement closed). You also need limits to define continuity, derivatives, integrals, and to understand sequences of functions.

Class Format: discussion
Requirements/Evaluation: homework, classwork, and exams
Prerequisites: MATH 150 or MATH 151 and MATH 250, or permission of instructor
Enrollment Limit:  40
Expected Class Size:  30
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3)  (QFR)

MATH 351  (F)  Applied Real Analysis  (QFR)
Real analysis or the theory of calculus-derivatives, integrals, continuity, convergence--starts with a deeper understanding of real numbers and limits. Applications in the calculus of variations or "infinite-dimensional calculus" include geodesics, harmonic functions, minimal surfaces, Hamilton's action and Lagrange's equations, optimal economic strategies, nonEuclidean geometry, and general relativity.

Requirements/Evaluation: exams, homework and quizzes
Prerequisites: MATH 150 and MATH 250, or permission of instructor
Enrollment Limit: 50
Expected Class Size: 20
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3)  (QFR)
Quantative/Formal Reasoning Notes: Core mathematics major course with daily problem sets.

MATH 355  (F)(S)  Abstract Algebra  (QFR)
Algebra gives us tools to solve equations. The integers, the rationals, and the real numbers have special properties which make algebra work according to the circumstances. In this course, we generalize algebraic processes and the sets upon which they operate in order to better understand, theoretically, when equations can and cannot be solved. We define and study abstract algebraic structures such as groups, rings, and fields, as well as the concepts of factor group, quotient ring, homomorphism, isomorphism, and various types of field extensions. This course introduces students to abstract rigorous mathematics.

Requirements/Evaluation: problem sets and exams
Prerequisites: MATH 250 or permission of instructor
MATH 361  (F)(S)  Theory of Computation  (QFR)

Cross-listings:  CSCI 361  MATH 361

Secondary Cross-listing

This course introduces a formal framework for investigating both the computability and complexity of problems. We study several models of computation including finite automata, regular languages, context-free grammars, and Turing machines. These models provide a mathematical basis for the study of computability theory--the examination of what problems can be solved and what problems cannot be solved--and the study of complexity theory--the examination of how efficiently problems can be solved. Topics include the halting problem and the P versus NP problem.

Requirements/Evaluation:  problem sets, a midterm examination, and a final examination

Prerequisites:  CSCI 256 or both a 300-level MATH course and permission of instructor

Enrollment Limit:  30

Enrollment Preferences:  current or expected Computer Science majors

Expected Class Size:  30

Grading:  no pass/fail option,  no fifth course option

Distributions:  (D3)  (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:

CSCI 361 (D3) MATH 361 (D3)

Attributes:  COGS Interdepartmental Electives
MATH 374 (F) Topology (QFR)
Topology is the study of when one geometric object can be continuously deformed and twisted into another object. Determining when two objects are topologically the same is incredibly difficult and is still the subject of a tremendous amount of research, including recent work on the Poincaré Conjecture, one of the million-dollar millennium-prize problems. The main part of the course on point-set topology establishes a framework based on "open sets" for studying continuity and compactness in very general spaces. The second part on homotopy theory develops refined methods for determining when objects are the same. We will prove for example that you cannot twist a basketball into a doughnut.

Requirements/Evaluation: homework, tutorials, and exams
Prerequisites: MATH 350 or 351; not open to students who have taken MATH 323
Enrollment Limit: 30
Expected Class Size: 10
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)
Not offered current academic year

MATH 379 (F) Asymptotic Analysis in Differential Equations
Asymptotic Analysis is a fascinating subfield of differential equations in which interesting and unexpected phenomena can occur. Roughly speaking, the problem is this: Given a differential equation depending on a parameter epsilon, what happens to the solutions to the equation as we let epsilon go to 0? After an extensive survey of examples, we will cover asymptotic evaluation of integrals, such as stationary phase and Laplace's method, multiple scales, WKB approximations, averaging methods, matched asymptotic expansions, and boundary layers. If time permits, we will also discuss bifurcation theory and the Nash-Moser Inverse Function Theorem.

Class Format: lecture
Requirements/Evaluation: evaluation will be based primarily on homework and exams
Prerequisites: MATH 350 or MATH 351
Enrollment Limit: 25
Expected Class Size: 15
Grading: no pass/fail option, no fifth course option
Distributions: (D3)
Not offered current academic year

MATH 392 (F) Undergraduate Research Topics in Graph Theory (QFR)
Graph theory is a vibrant area of research with many applications to the social sciences, psychology, and economics. In this tutorial we focus on two topics of mathematical research in graph theory: evasion-pursuit games on graphs and domination theory. Students in this project-based tutorial will select among the presented topics, and will begin original research on an open problem in the field. Student assessment is based on problem sets, drafts of research project manuscript, and a final oral class presentation.

Requirements/Evaluation: homework assignments, oral presentations, and written project manuscript
Prerequisites: MATH 355 or permission of the instructor
Enrollment Limit: 10
Enrollment Preferences: programming experience, students with interests in the intersection of combinatorics and graph theory
Expected Class Size: 10
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)
Not offered current academic year
MATH 397  (F)  Independent Study: Mathematics
Directed 300-level independent study in Mathematics.
Prerequisites: permission of department
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3)

Fall 2019
IND Section: 01    TBA     Mihai  Stoiciu

MATH 398  (S)  Independent Study: Mathematics
Directed 300-level independent study in Mathematics.
Prerequisites: permission of department
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3)

Spring 2020
IND Section: 01    TBA     Mihai  Stoiciu

MATH 402  (S)  Measure Theory and Probability  (QFR)
The study of measure theory arose from the study of stochastic (probabilistic) systems. Applications of measure theory lie in biology, chemistry, physics as well as in economics. In this course, we develop the abstract concepts of measure theory and ground them in probability spaces. Included will be Lebesgue and Borel measures, measurable functions (random variables). Lebesgue integration, distributions, independence, convergence and limit theorems. This material provides good preparation for graduate studies in mathematics, statistics and economics.

Class Format: discussion
Requirements/Evaluation: performance on homework assignments and exams
Prerequisites: MATH 350 or MATH 351 or permission of instructor
Enrollment Limit: 40
Expected Class Size: 30
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3)  (QFR)
Not offered current academic year

MATH 403  (S)  Measure and Ergodic Theory  (QFR)
An introduction to measure theory and ergodic theory. Measure theory is a generalization of the notion of length and area, has been used in the study of stochastic (probabilistic) systems. The course covers the construction of Lebesgue and Borel measures, measurable functions, and Lebesgue integration. Ergodic theory studies the probabilistic behavior of dynamical systems as they evolve through time, and is based on measure theory. The course will cover basic notions, such as ergodic transformations, weak mixing, mixing, and Bernoulli transformations, and transformations admitting and not admitting an invariant measure. There will be an emphasis on specific examples such as group rotations, the binary odometer transformations, and rank-one constructions. The Ergodic Theorem will also be covered, and will be used to illustrate notions and theorems from measure theory.

Requirements/Evaluation: homework and exams
Prerequisites: MATH 350 or MATH 351 or permission of instructor
Enrollment Limit: 25
Enrollment Preferences: Mathematics majors
Expected Class Size: 15-20
MATH 404 (F) Random Matrix Theory  (QFR)

Initiated by research in multivariate statistics and nuclear physics, the study of random matrices is nowadays an active and exciting area of mathematics, with numerous applications to theoretical physics, number theory, functional analysis, optimal control, and finance. Random Matrix Theory provides understanding of various properties (most notably, statistics of eigenvalues) of matrices with random coefficients. This course will provide an introduction to the basic theory of random matrices, starting with a quick review of Linear Algebra and Probability Theory. We will continue with the study of Wigner matrices and prove the celebrated Wigner's Semicircle Law, which brings together important ideas from analysis and combinatorics. After this, we will turn our attention to Gaussian ensembles and investigate the Gaussian Orthogonal Ensemble (GOE) and the Gaussian Unitary Ensemble (GUE). The last lectures of the course will be dedicated to random Schrödinger operators and their spectral properties (in particular, the phenomenon called Anderson localization). Applications of Random Matrix Theory to theoretical physics, number theory, statistics, and finance will be discussed throughout the semester.

Requirements/Evaluation: homework assignments and exams

Prerequisites: experience with Real Analysis (MATH 350 or MATH 351) and with Probability (MATH 341 or STAT 201)

Enrollment Limit: 40

Enrollment Preferences: Mathematics and Statistics majors

Expected Class Size: 20

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

Quantitative/Formal Reasoning Notes: This course expands ideas in probability and statistics from random variables (1x1 random matrices) to nxn random matrices. The students will learn to model complex physical phenomena using random matrices and study them using rigorous mathematical tools and concepts.

Fall 2019

LEC Section: 01   TF 2:35 pm - 3:50 pm   Mihai Stoiciu

MATH 407 (F) Dance of the Primes  (QFR)

Prime numbers are the building blocks for all numbers and hence for most of mathematics. Though there are an infinite number of them, how they are spread out among the integers is still quite a mystery. Even more mysterious and surprising is that the current tools for investigating prime numbers involve the study of infinite series. Function theory tells us about the primes. We will be studying one of the most amazing functions known: the Riemann Zeta Function. Finding where this function is equal to zero is the Riemann Hypothesis and is one of the great, if not greatest, open problems in mathematics. Somehow where these zeros occur is linked to the distribution of primes. We will be concerned with why anyone would care about this conjecture. More crassly, why should solving the Riemann Hypothesis be worth one million dollars? (Which is what you will get if you solve it, beyond the eternal fame and glory.)

Requirements/Evaluation: exams and weekly homework assignments

Prerequisites: MATH 350 or MATH 351, and MATH 355

Enrollment Limit: 30

Enrollment Preferences: seniors

Expected Class Size: 10

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

Quantitative/Formal Reasoning Notes: It is a math course.

Not offered current academic year
MATH 411 (S) Commutative Algebra (QFR)

Commutative Algebra is an essential area of mathematics that provides indispensable tools to many areas, including Number Theory and Algebraic Geometry. This course will introduce you to the fundamental concepts for the study of commutative rings, with a special focus on the notion of "prime ideals," and how they generalize the well-known notion of primality in the set of integers. Possible topics include Noetherian rings, primary decomposition, localizations and quotients, height, dimension, basic module theory, and the Krull Altitude Theorem.

Requirements/Evaluation: homework and exams
Prerequisites: MATH 355 or permission of instructor
Enrollment Limit: 30
Expected Class Size: 15
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)

Not offered current academic year

MATH 419 (S) Algebraic Number Theory (QFR)

We all know that integers can be factored into prime numbers and that this factorization is essentially unique. In more general settings, it often still makes sense to factor numbers into "primes," but the factorization is not necessarily unique! This surprising fact was the downfall of Lamé's attempted proof of Fermat's Last Theorem in 1847. Although a valid proof was not discovered until over 150 years later, this error gave rise to a new branch of mathematics: algebraic number theory. In this course, we will study factorization and other number-theoretic notions in more abstract algebraic settings, and we will see a beautiful interplay between groups, rings, and fields.

Requirements/Evaluation: homework assignments and exams
Prerequisites: MATH 355, or permission of instructor
Enrollment Limit: 25
Expected Class Size: 20
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)

Spring 2020
LEC Section: 01  TR 11:20 am - 12:35 pm  Allison Pacelli

MATH 420 (S) Analytic Number Theory (QFR)

How many primes are smaller than x? How many divisors does an integer n have? How many different numbers appear in the N x N multiplication table? Over the course of the past 150 years, tremendous progress has been made towards resolving these and similar questions in number theory, relying on tools and methods from analysis. The goal of this tutorial is to explain and motivate the ubiquitous appearance of analysis in modern number theory—a surprising fact, given that analysis is concerned with continuous functions, while number theory is concerned with discrete objects (integers, primes, divisors, etc). Topics to be covered include: asymptotic analysis, partial and Euler-Maclaurin summation, counting divisors and Dirichlet's hyperbola method, the randomness of prime factorization and the Erdos-Kac theorem, the partition function and the saddle point method, the prime number theorem and the Riemann zeta function, primes in arithmetic progressions and Dirichlet L-functions, the Goldbach conjecture and the circle method, gaps between primes, and other topics as time and interest allow.

Requirements/Evaluation: problem sets and presentations
Prerequisites: MATH 350 or MATH 351, MATH 372 (may be taken concurrently), familiarity with modular arithmetic
Enrollment Limit: 10
Enrollment Preferences: Mathematics majors
Expected Class Size: 10
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)

Not offered current academic year
MATH 421 (S) Quandles, Knots and Virtual Knots (QFR)

A quandle is an algebraic object that, like a group, has a "multiplication" of pairs of elements that satisfies certain axioms. But the quandle axioms are very different from the group axioms, and quandles turn out to be incredibly useful when considering the mathematical theory of knots. In this course, we will learn about this relatively new area of research (1982) and learn some knot theory and see how quandles apply to both classical knot theory and the relatively new area of virtual knot theory (1999).

Requirements/Evaluation: problem sets, tests, and a 3-page paper

Prerequisites: MATH 355

Enrollment Limit: 40

Enrollment Preferences: discretion of the instructor

Expected Class Size: 15

Grading: no pass/fail option, no fifth course option

Distributions: (D3) (QFR)

MATH 422 (F) Algebraic Topology (QFR)

Is a sphere really different from a torus? Can a sphere be continuously deformed to a point? Algebraic Topology concerns itself with the classification and study of topological spaces via algebraic methods. The key question is this: How do we really know when two spaces are different and in what senses can we claim they are the same? Our answer will use several algebraic tools such as groups and their normal subgroups. In this course we will develop several notions of "equality" starting with the existence of homeomorphisms between spaces. We will then explore several weakenings of this notion, such as homotopy equivalence, having isomorphic homology or fundamental groups, and having homeomorphic universal covers.

Requirements/Evaluation: homework and exams

Prerequisites: MATH 355 or permission of instructor

Enrollment Limit: 30

Enrollment Preferences: Math majors primarily, the juniors and seniors

Expected Class Size: 15

Grading: no pass/fail option, no fifth course option

Distributions: (D3) (QFR)

MATH 424 (F) Geometry, Surfaces and Billiards

Mathematical billiards is the study of a ball bouncing around in a table--a rectangle in the popular pub game, but any shape of table for us, including triangles and ellipses. The geometry of billiards is elegant, and is related to surfaces, fractals, and even continued fractions. We will study many types of billiards and surfaces, and take time to explore some beautiful examples and ideas.

Class Format: lecture

Requirements/Evaluation: based on work in class, problem sets, an exam and a project.

Prerequisites: MATH 350/351 and MATH 355

Enrollment Limit: 25

Expected Class Size: 15

Grading: yes pass/fail option, no fifth course option

Distributions: (D3)

MATH 426 (F) Differential Topology (QFR)

Differential topology marries the rubber-like deformations of topology with the computational exactness of calculus. This sub eld of mathematics asks
and answers questions like "Can you take an integral on the surface of doughnut?" and includes far-reaching applications in relativity and robotics. This tutorial will provide an elementary and intuitive introduction to differential topology. We will begin with the definition of a manifold and end with a generalized understanding of Stokes Theorem.

**Requirements/Evaluation:** weekly homework, weekly presentations, and final paper

**Prerequisites:** MATH 350 (students who have not taken MATH 250 may enroll only with permission of the instructor)

**Enrollment Limit:** 10

**Enrollment Preferences:** seniors, majors

**Expected Class Size:** 10

**Grading:** no pass/fail option, no fifth course option

**Distributions:** (D3) (QFR)

**Quantitative/Formal Reasoning Notes:** There will be weekly math problem sets.

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**Fall 2019**

TUT Section: T1    TBA     Haydee M. A. Lindo

**MATH 427  (S) Tiling Theory  (QFR)**

Since humans first used stones and bricks to tile the floors of their domiciles, tiling has been an area of interest. Practitioners include artists, engineers, designers, architects, crystallographers, scientists and mathematicians. This course will be an investigation into the mathematical theory of tiling. The course will focus on tilings of the plane, including topics such as the symmetry groups of tilings, the topology of tilings, the ergodic theory of tilings, the classification of tilings and the aperiodic Penrose tilings. We will also look at tilings in higher dimensions, including "knotted tilings".

**Requirements/Evaluation:** problem assignments, exams and a presentation/paper

**Prerequisites:** MATH 250 Linear Algebra and MATH 355 Abstract Algebra

**Enrollment Limit:** 30

**Enrollment Preferences:** senior majors, seniors, juniors, sophomores, first-year students (this is a senior seminar, one of which is required for all senior majors, so they have first preference)

**Expected Class Size:** 20

**Grading:** no pass/fail option, yes fifth course option

**Materials/Lab Fee:** cost of book which will be under $50

**Distributions:** (D3) (QFR)

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**Spring 2020**

LEC Section: 01    TR 9:55 am - 11:10 am     Colin C. Adams

**MATH 428  (S) Catching Robbers and Spreading Information  (QFR)**

Cops and robbers is a widely studied game played on graphs that has connections to searching algorithms on networks. The cop number of a graph is the smallest number of cops needed to guarantee that the cops can catch a robber in the graph. Similar combinatorial games such as "zero forcing" can be used to model the spread of information. The idea of "throttling" is to spread the information (or catch the robber) as efficiently as possible. This course will survey some of the main results about cops and robbers and the cop number. We will also explore recent research on throttling for cops and robbers, zero forcing, and other variants.

**Class Format:** interactive activities and discussion

**Requirements/Evaluation:** problem sets, investigation journal, final presentation

**Prerequisites:** MATH 200 and MATH 355

**Enrollment Limit:** 25

**Enrollment Preferences:** seniors

**Expected Class Size:** 20

**Grading:** yes pass/fail option, no fifth course option
MATH 431  (F)  Nonlinear Waves, Solitons  (QFR)
Waves arise in scientific and engineering disciplines such as acoustics, optics, fluid/solid mechanics, electromagnetism and quantum mechanics. Although linear waves are well understood, the study of nonlinear wave phenomena remains an active field of research and a source of inspiration and challenge for several areas of mathematics. We discuss traveling waves, shallow water models, wave steepening, solitons and blowup. Additional topics may include shocks, weak solutions and conservation laws.
Class Format: lecture
Requirements/Evaluation: problem sets, exams, and final project
Prerequisites: MATH 209/210 and MATH 350/351, or permission of the instructor
Enrollment Limit: 40
Expected Class Size: 15
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3)  (QFR)
Not offered current academic year

MATH 433  (F)  Mathematical Modeling  (QFR)
Mathematical modeling means (1) translating a real-life problem into a mathematical object, and (2) studying that object using mathematical techniques, and (3) interpreting the results in order to learn something about the real-life problem. Mathematical modeling is used in biology, economics, chemistry, geology, sociology, political science, art, and countless other fields. This is an advanced, seminar-style, course appropriate for students who have a strong enthusiasm for applied mathematics.
Class Format: discussion, research
Requirements/Evaluation: writing assignments, modeling activities, presentations, research project
Prerequisites: MATH 250, MATH 309 or similar, and some experience with computer programming (equivalent to CSCI 134 or MATH 307)
Enrollment Limit: 24
Expected Class Size: 20
Grading: no pass/fail option, no fifth course option
Distributions: (D3)  (QFR)
Not offered current academic year

MATH 434  (S)  Applied Dynamics and Optimal Control  (QFR)
We seek to understand how dynamical systems evolve, how that evolution depends on the various parameters of the system, and how we might manipulate those parameters to optimize an outcome. We will explore the language of dynamics by deepening our understanding of differential and difference equations, study parameter dependence and bifurcations, and explore optimal control through Pontryagin's maximum principle and Hamilton-Jacobi-Bellman equations. These tools have broad application in ecology, economics, finance, and engineering, and we will draw on basic models from these fields to motivate our study.
Requirements/Evaluation: exams and homework assignments
Prerequisites: MATH 209 or PHYS 210, and MATH 350 or 351, or permission of the instructor
Enrollment Limit: 40
Expected Class Size: 25
MATH 453 (F) Partial Differential Equations (QFR)
Partial differential equations (PDE) arise as mathematical models of phenomena in chemistry, ecology, economics, electromagnetics, fluid dynamics, neuroscience, thermodynamics, and more. We introduce PDE models and develop techniques for studying them. Topics include: derivation, classification, and physical interpretation of canonical PDE; solution techniques, including separation of variables, series solutions, integral transforms, and characteristics; and application to problems in the natural and social sciences.

Requirements/Evaluation: quizzes/exams, problem sets, projects and activities
Prerequisites: MATH 150-151; MATH 209 or MATH/PHYS 210 or MATH 309
Enrollment Limit: 30
Enrollment Preferences: Professor's discretion
Expected Class Size: 25
Grading: no pass/fail option, yes fifth course option
Distributions: (D3) (QFR)
Not offered current academic year

MATH 456 (F) Representation Theory (QFR)
Representation theory has applications in fields such as physics (via models for elementary particles), engineering (considering symmetries of structures), and even in voting theory (voting for committees in agreeable societies). This course will introduce the concepts and techniques of the representation theory of finite groups, and will focus on the representation theory of the symmetric group. We will undertake this study through a variety of perspectives, including general representation theory, combinatorial algorithms, and symmetric functions.

Class Format: lecture
Requirements/Evaluation: evaluation will be based primarily on homework, in class presentations, and exams
Prerequisites: MATH 355
Enrollment Limit: 40
Enrollment Preferences: junior and senior Math majors
Expected Class Size: 15
Grading: no pass/fail option, yes fifth course option
Distributions: (D3) (QFR)
Not offered current academic year

MATH 458 (S) Algebraic Combinatorics (QFR)
Algebraic combinatorics is a branch of mathematics at the intersection of combinatorics and algebra. On the one hand, we study combinatorial structures using algebraic techniques, while on the other we use combinatorial arguments and methods to solve problems in algebra. This course will focus on the study of symmetric functions, young tableaux, matroids, graph theory, and other related topics.

Requirements/Evaluation: homework assignments, proof portfolio, individual and group projects
Prerequisites: MATH 200 and MATH 355
Enrollment Limit: 25
Enrollment Preferences: seniors
Expected Class Size: 20
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)
Quantitative/Formal Reasoning Notes: Mathematics course in the area of algebraic combinatorics.
MATH 459 (S) Applied Partial Differential Equations (QFR)

Partial differential equations (PDE) arise as mathematical models of phenomena in chemistry, ecology, economics, electromagnetics, epidemiology, fluid dynamics, neuroscience, and much more. Furthermore, the study of partial differential equations connects with diverse branches of mathematics including analysis, geometry, algebra, and computation. Adopting an applied viewpoint, we develop techniques for studying PDE. We draw from a body of knowledge spanning classic work from the time of Isaac Newton right up to today's cutting edge applied mathematics research. This tutorial is appropriate as a second course in differential equations. In this tutorial, students will: build and utilize PDE-based models; determine the most appropriate tools to apply to a PDE; apply the aforementioned tools; be comfortable with open-ended scientific work; read applied mathematical literature; communicate applied mathematics clearly, precisely, and appropriately; collaborate effectively.

Requirements/Evaluation: participation, problem sets, oral presentations, oral exams, and a final project

Prerequisites: MATH 209 or MATH/PHYS 210 or MATH 309 or permission of instructor; students who have taken MATH 453 may not enroll in MATH 458 without permission of the instructor

Enrollment Limit: 10

Enrollment Preferences: students with an interest in applied mathematics, selected to create a diverse set of tutorial participants

Expected Class Size: 10

Grading: no pass/fail option, no fifth course option

Distributions: (D3) (QFR)

Quantative/Formal Reasoning Notes: This tutorial involves regular and substantial problem sets in which quantitative/formal reasoning skills are practiced and evaluated.

Not offered current academic year

MATH 466 (F) Advanced Applied Analysis (QFR)

This course further develops and explores topics and concepts from real analysis, with special emphasis on introducing students to subject matter and techniques that are useful for graduate study in mathematics or an allied field, as well as applications in industry. Topics include Benford's law of digit bias, random matrix theory, and Fourier analysis, and as time permits additional areas based on student interest from analytic number theory, generating functions and probabilistic methods. This will be an intense, fast paced class which will give a flavor for graduate school. In addition to standard homework problems, students will assist in writing both reviews for MathSciNet and referee reports for papers for journals, write programs to investigate and conjecture, and read classic and current research papers, and possibly apply these and related methods to real world problems.

Requirements/Evaluation: homework, exams, possible paper/presentation

Prerequisites: MATH 350 or MATH 351

Enrollment Limit: 40

Enrollment Preferences: discretion of the instructor

Expected Class Size: 30

Grading: yes pass/fail option, yes fifth course option

Distributions: (D3) (QFR)

Not offered current academic year

MATH 474 (S) Tropical Geometry (QFR)

This course offers an introduction to tropical geometry, a young subject that has already established deep connections between itself and pure and applied mathematics. We will study a rich variety of objects arising from polynomials over the min-plus semiring, where addition is defined as taking a minimum, and multiplication is defined as usual addition. We will learn how these polyhedral objects connect to other areas of mathematics like algebraic geometry, and how they can be applied to solve problems in scheduling theory, phylogenetics, and other diverse fields.

Requirements/Evaluation: participation, problem sets, quizzes, exams, and a final project

Prerequisites: MATH 355 or permission of instructor

Enrollment Limit: 25

Enrollment Preferences: senior Math majors
MATH 482 (F) Homological Algebra (QFR)

Though a relatively young subfield of mathematics, Homological Algebra has earned its place by supplying powerful tools to solve questions in the much older fields of Commutative Algebra, Algebraic Geometry and Representation Theory. This class will introduce theorems and tools of Homological Algebra, grounding its results in applications to polynomial rings and their quotients. We will focus on some early groundbreaking results and learn some of Homological Algebra's most-used constructions. Possible topics include tensor products, chain complexes, homology, Ext, Tor and Hilbert's Syzygy Theorem.

Requirements/Evaluation: homework and exams

Prerequisites: MATH 355

Enrollment Limit: 20

Enrollment Preferences: junior and senior math majors

Expected Class Size: 12

Grading: no pass/fail option, yes fifth course option

Unit Notes: this course is not a senior seminar, so it does not fulfill the senior seminar requirement for the Math major

Distributions: (D3) (QFR)

Fall 2019

LEC Section: 01 MR 2:35 pm - 3:50 pm Haydee M. A. Lindo

MATH 484 (S) Galois Theory (QFR)

Some equations--such as $x^5 - 1 = 0$--are easy to solve. Others--such as $x^5 - x - 1 = 0$--are very hard, if not impossible (using standard mathematical operations). Galois discovered a deep connection between field theory and group theory that led to a criterion for checking whether or not a given polynomial can be easily solved. His discovery also led to many other breakthroughs, for example proving the impossibility of squaring the circle or trisecting a typical angle using compass and straightedge. From these not-so-humble beginnings, Galois theory has become a fundamental concept in modern mathematics, from topology to number theory. In this course we will develop the theory and explore its applications to other areas of math.

Requirements/Evaluation: written homeworks, oral presentations, and exams

Prerequisites: MATH 355

Enrollment Limit: 15

Enrollment Preferences: discretion of the instructor

Expected Class Size: 10

Grading: no pass/fail option, yes fifth course option

Unit Notes: this course is not a senior seminar, so it does not fulfill the senior seminar requirement for the Math major

Distributions: (D3) (QFR)

Spring 2020

LEC Section: 01 TF 2:35 pm - 3:50 pm Andrew Bydlon

MATH 485 (F) Complex Analysis (QFR)

The calculus of complex-valued functions turns out to have unexpected simplicity and power. As an example of simplicity, every complex-differentiable function is automatically infinitely differentiable. As examples of power, the so-called residue calculus permits the computation of impossible integrals, and conformal mapping reduces physical problems on very general domains to problems on the round disc. The easiest proof of the Fundamental Theorem of Algebra, not to mention the first proof of the Prime Number Theorem, used complex analysis.
MATH 487  (S)  Computational Algebraic Geometry  (QFR)
Algebraic geometry is the study of shapes described by polynomial equations. It has been a major part of mathematics for at least the past two hundred years, and has influenced a tremendous amount of modern mathematics, ranging from number theory to robotics. In this course, we will develop the Ideal-Variety Correspondence that ties geometric shapes to abstract algebra, and will use computational tools to explore this theory in a very explicit way.

Requirements/Evaluation:  homework, exams, and final project
Prerequisites:  MATH 355
Enrollment Limit:  40
Enrollment Preferences:  instructor decision
Expected Class Size:  15
Grading:  no pass/fail option,     yes fifth course option
Unit Notes:  this course is not a senior seminar, so it does not fulfill the senior seminar requirement for the Math major
Distributions:  (D3)  (QFR)

MATH 493  (F)  Senior Honors Thesis: Mathematics
Mathematics senior honors thesis; this is part of a full-year thesis (493-494). Each student carries out an individual research project under the direction of a faculty member that culminates in a thesis. See description under The Degree with Honors in Mathematics.

Requirements/Evaluation:  yes pass/fail option,     yes fifth course option
Distributions:  (D3)

MATH 494  (S)  Senior Honors Thesis: Mathematics
Mathematics senior honors thesis; this is part of a full-year thesis (493-494). Each student carries out an individual research project under the direction of a faculty member that culminates in a thesis. See description under The Degree with Honors in Mathematics.

Requirements/Evaluation:  yes pass/fail option,     yes fifth course option
Distributions:  (D3)
MATH 497 (F) Independent Study: Mathematics
Directed 400-level independent study in Mathematics.
Prerequisites: permission of department
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3)

Fall 2019
IND Section: 01  TBA  Mihai Stoiciu

MATH 498 (S) Independent Study: Mathematics
Directed 400-level independent study in Mathematics.
Prerequisites: permission of department
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3)

Spring 2020
IND Section: 01  TBA  Mihai Stoiciu

MATH 499 (F)(S) Senior Colloquium
Mathematics senior colloquium. Meets every week for two hours both fall and spring. Senior majors must participate at least one hour a week. This colloquium is in addition to the regular four semester-courses taken by all students.
Class Format: colloquium
Grading: non-graded
Distributions: No divisional credit

Fall 2019
LEC Section: 01  MW 1:00 pm - 1:45 pm  Richard D. De Veaux
Spring 2020
LEC Section: 01  MW 1:00 pm - 1:45 pm  Richard D. De Veaux

Winter Study

MATH 11 (W) Narrative Structure Through Dungeons & Dragons
Dungeons & Dragons (5th edition) is a classic and ever-evolving tabletop role-playing game. One major component for the dungeon master is to develop and tell a story for the players to embark upon while simultaneously being willing to improvise based on player decisions. In this course, we will begin by learning the basics of the game and building a character. The students will then divide into groups and cycle through the role of dungeon master and player character to team build a narrative arc.
Requirements/Evaluation: DM execution and notes, player participation
Prerequisites: none
Enrollment Limit: 15
Enrollment Preferences: Mathematics majors and seniority
Grading: pass/fail only
Materials/Lab Fee: $10 and cost of books

Winter 2020
MATH 12 (W) The Mathematics of Lego Bricks
This course is a modification of six previous winter studies I have done on the Mathematics of LEGO bricks. Similar to those, we will use LEGO bricks as a motivator to talk about some good mathematics (combinatorics, algorithms, efficiency). We will partner with Williamstown Elementary and teach an Adventures in Learning course (where once a week for four weeks we visit the elementary school after the day ends to work with the kids). We will also submit a Lego Ideas Challenge, to try and create a set that Lego will then market and sell. Almost surely there will be a speed build challenge (college teams vs elementary school teams).

Requirements/Evaluation: final project or presentation
Prerequisites: none
Enrollment Limit: 30
Enrollment Preferences: discretion of the instructor
Grading: pass/fail only
Materials/Lab Fee: $45
Attributes: EXPE Experiential Education Courses

Winter 2020
LEC Section: 01 MWF 10:00 am - 11:50 am Steven J. Miller

MATH 13 (W) Reality Real Estate
Cross-listings: MATH 13 SPEC 13

Primary Cross-listing
Is the reality of real estate the way it looks on TV? Learn about buying and selling, real estate investments, mortgages, renovation, construction, and design. Class will meet Monday, Tuesday, and Wednesday afternoons. Students will learn about each of the topics above, and have the opportunity to do a final project on a real estate topic of their choice, from architecture to designing their dream home to proposing a successful real estate investment to on-site construction work. Guest lecture(s) by experts in the field. The instructor Allison Pacelli is a licensed MA real estate agent, and co-owner of a design and renovation business that renovates investment properties as well as clients’ homes.

Requirements/Evaluation: final project, equivalent to a 10-page paper
Prerequisites: none
Enrollment Limit: 15
Enrollment Preferences: questionnaire
Grading: pass/fail only
Materials/Lab Fee: $80 and cost of books
This course is cross-listed and the prefixes carry the following divisional credit:
MATH 13 SPEC 13

Winter 2020
LEC Section: 01 Cancelled

MATH 14 (W) Introductory Photography: People and Places
Cross-listings: SPEC 29 MATH 14

Primary Cross-listing
This is an introductory course in photography, both color and black & white photography, and using the digital camera. The main themes will be people and the landscape. No previous knowledge is assumed, but students are expected to have access to a 35 mm (or equivalent) digital camera, with manual override or aperture priority. The topics covered will include composition, exposure, camera use, direction and properties of light, and digital
imaging. Students will develop their eye through the study of the work of well-known photographers and the critical analysis of their own work. We will discuss the work of contemporary photographers such as Mary Ellen Mark, Joel Meyerowitz, Constantine Manos, and Eugene Richards. Students will be expected to spend a considerable amount of time practicing their own photography outside of class. There will be three required local half-day field trips. Students will also be introduced to Photoshop and Lightroom, and will work on their own images with these programs. In 2010 Adjunct Instructor Bio: Mr. Washburne joined the stable of photographic artists who are represented by the Sun to Moon gallery in Dallas. Since then he has worked exclusively as a fine art photographer concentrating on landscapes, abstracts and street shooting. He also published travel stories alongside his photography in both D Magazine and The Robb Report.

Requirements/Evaluation: class participation, an in-class quiz and a final project

Prerequisites: none

Enrollment Limit: 12

Enrollment Preferences: e-mail questionnaire

Grading: pass/fail only

Materials/Lab Fee: $35 and cost of books

This course is cross-listed and the prefixes carry the following divisional credit: SPEC 29 MATH 14

Winter 2020

LEC Section: 01   MTR 10:00 am - 11:50 am   Dick Washburne

MATH 15  (W) Exploring the Primes: A Crash Course in Analytic Number Theory

This will be a crash course in analytic number theory. Given our time constraints, our goal will be to obtain a big-picture view of the field by understanding the outline of proofs of the most important results in the field. Among other topics we'll discuss the Riemann zeta function, the Prime Number Theorem, the Riemann Hypothesis, Dirichlet's theorem on primes in arithmetic progressions, and Roth's theorem on arithmetic progressions. There will be no written problem sets, but students will be expected to present solutions to problems in class. Each student will also be expected to write up a class summary (in LaTeX) for one of our meetings.

Requirements/Evaluation: final project or presentation

Prerequisites: complex analysis or permission of instructor

Enrollment Limit: 10

Enrollment Preferences: interview with instructor

Grading: pass/fail only

Winter 2020

LEC Section: 01   MWF 1:00 pm - 2:50 pm   Leo Goldmakher

MATH 16  (W) Women and Minorities in Science

This course will be centered on learning about the achievements of women and minorities who have made significant contributions to science and the scientific community. We will discuss both historical and modern challenges faced by women and under-represented minorities in the sciences. Students will conduct an independent research project on a scientist of their choosing and lead a discussion based on that individual. Additional reading for this course will include the book Hidden Figures: The American Dream and the Untold Story of the Black Women Mathematicians Who Helped Win the Space Race, which was made into the 2016 film Hidden Figures.

Requirements/Evaluation: final project or presentation

Prerequisites: none

Enrollment Limit: 30

Enrollment Preferences: based on expressed interest

Grading: pass/fail only

Materials/Lab Fee: approximately $50 for books
**Winter 2020**

**LEC Section: 01    TR 10:00 am - 12:50 pm     Julie C. Blackwood**

**MATH 17  (W)  Tournament Bridge**

We'll study, prepare, and play in as many bridge tournaments in the area as possible, coupled with analysis, reading, and writing. Tournament play followed by analysis and the writing up of lessons learned is an essential part of the study of bridge. At this level, it is much more than a "game": it is an intense intellectual and academic activity. Tournament time (including days, nights, and weekends) averaging about 12 hours per week, other class time about 6 hours per week, homework 4 hours per week. Text: Larry Cohen https://www.larryco.com/bridge-learning-center  

Adjunct Instructor Bio: Frank Morgan is Atwell Professor of Mathematics, Emeritus, at Williams College and a Silver Life Master with the American Contract Bridge League.  

**Requirements/Evaluation:** participation in competition and write-ups (totaling more than 10 pages)  

**Prerequisites:** knowing how to play bridge  

**Enrollment Limit:** 15  

**Enrollment Preferences:** bridge playing knowledge and experience  

**Grading:**    pass/fail only  

**Materials/Lab Fee:** $200  

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**Winter 2020**

**LEC Section: 01    M-F 10:00 am - 11:50 am     Frank Morgan**

**MATH 20  (W)  Humor Writing**

**Cross-listings:** ENGL 20  MATH 20  

**Primary Cross-listing**

What is humor? The dichotomy inherent in the pursuit of comedic intent while confronting the transient nature of adversity can ratchet up the devolving psyche's penchant for explication to a catastrophic threshold, thwarting the existential impulse and pushing the natural proclivity for causative norms beyond the possibility of pre-situational adaptation. Do you know what that means? If so, this is not the course for you. No, we will write funny stuff, day in and day out. Or at the very least, we will think it's funny. Stories, essays, plays, fiction, nonfiction, we'll try a little of each. And we'll read some humor, too. Is laughter the body's attempt to eject excess phlegm? Why did Plato write dialogues instead of monologues? Who backed into my car in the Sawyer parking lot on the afternoon of March 2, 2019? These are just a few of the questions we will not explore in this course. No, we won't have time because we will be busy writing. (But if you know the answer to the third question, there's a $10 reward.) Plan to meet 6 hours a week, and to spend at least 20 hours a week on the course. No slackers need apply. Produce or become produce. We will put on a reading/performance at the end of winter study.  

**Requirements/Evaluation:** at least 10 pages of writing and a final performance  

**Prerequisites:** none  

**Enrollment Limit:** 15  

**Enrollment Preferences:** based on writing samples  

**Grading:**    pass/fail only  

**Materials/Lab Fee:** approximately $50 for books  

This course is cross-listed and the prefixes carry the following divisional credit:  

ENGL 20 MATH 20  

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**Winter 2020**

**LEC Section: 01    M-F 10:00 am - 11:50 am     Colin C. Adams**

**MATH 30  (W)  Senior Project: Mathematics**

To be taken by candidates for honors in Mathematics other than by thesis route.  

**Class Format:** honors project
MATH 31 (W) Senior Thesis: Mathematics
To be taken by students registered for Mathematics 493-494.
Class Format: thesis
Grading: pass/fail only

MATH 99 (W) Independent Study: Mathematics
Open to upperclass students. Students interested in doing an independent project (99) during Winter Study must make prior arrangements with a faculty sponsor. The student and professor then complete the independent study proposal form available online. The deadline is typically in late September. Proposals are reviewed by the pertinent department and the Winter Study Committee. Students will be notified if their proposal is approved prior to the Winter Study registration period.
Class Format: independent study
Grading: pass/fail only