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 taken at Williams 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)
- or Mathematics 210 Mathematical Methods for Scientists (Same as Physics 210)
- or Mathematics 200 Discrete Mathematics
- or Statistics 201 Statistics and Data Analysis
- Mathematics 309 Differential Equations
- 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 mathematics or statistics electives from courses numbered 300 and above
- One Senior Seminar: Any mathematics or statistics course numbered between 400 and 479, taken in the junior or 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 (reduced to 15 during the Academic Year 2020-2021), 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.

Pass/Fail policies during the Academic Year 2020-2021
Information about the Department of Mathematics and Statistics Pass/Fail policies during the Academic Year 2020-2021 can be found here.

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.

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. Note that during the Academic Year 2020-2021 the winter study requirement for thesis and “minithesis” is waved. 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 100 (W) Mathematics Immersion: The Beauty of Numbers (QFR)
This course will be an introduction to logic and number theory, with emphasis throughout on mathematics as a way of thinking. Have you ever wondered what keeps your credit card information safe every time 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. This course is meant to give you an appreciation for numbers and mathematics and to enhance your logical reasoning skills. Although most people will not use calculus or geometry in their jobs or everyday lives, mathematics enhances our abilities to think logically and reason effectively. This skill is useful in all aspects of life. Number theory, in particular, is a great area of mathematics that allows one to jump in right away without a lot of pre-requisite knowledge. We will look at examples, look for patterns, make conjectures, and we will spend a lot of time learning how to rigorously prove those conjectures.

Class Format: Students will attend lecture Monday - Thursday mornings from 10am - noon. In the afternoons, students will attend interactive math labs from approximately 1 - 3 pm Monday - Thursday.

Requirements/Evaluation: Evaluation will be based on daily homework and activities, exams, projects, and participation in class and math labs.

Prerequisites: Permission of a dean.

Enrollment Limit: 20

Enrollment Preferences: Students who need to make up a deficiency.

Expected Class Size: 15

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

Unit Notes: This course is designed to count for both full semester, Winter Study, and QFR credit. Once a dean approves enrollment, the Registrar's Office will register students in both MATH 100 and MATH 40.

Distributions: (D3) (QFR)

Quantative/Formal Reasoning Notes: We will be proving theorems and learning mathematical logic.

Not offered current academic year

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 2022
TUT Section: T1  TBA  Mihai Stoiciu

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)

*Not offered current academic year*

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**MATH 119 (F) The Mathematics of Pandemics: From the Spread of Infections to Cost-Benefit Analyses of Responses** (QFR)

The goal of the class is to help students learn to ask the right questions, and to gather and analyze the data needed to answer them, to understand the covid pandemic and the worldwide responses. Through local experts and numerous guest speakers playing key roles in these problems, we will discuss numerous aspects, from mathematical models for virus propagation to analyzing the economic, educational, social and emotional consequences of lockdowns and social distancing; from moral and legal dilemmas created by the pandemic and responses to the international political scene and relations between countries. Offered as Math 119 or Math 312 (those taking as Math 312 will have some of the readings replaced with more technical modeling papers and subsequent homework). Pre-requisites: None for Math 119; for Math 312 linear algebra is recommended.

**Requirements/Evaluation:** Homework, writing, class participation.

**Prerequisites:** none

**Enrollment Limit:** 30

**Enrollment Preferences:** all students will have an equal chance; if possible none will be turned away.

**Expected Class Size:** 30

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

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

**Quantative/Formal Reasoning Notes:** We will discuss mathematical models and use statistics to analyze data.

*Not offered current academic year*

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**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:** Weekly homework and quizzes, 2 exams during the semester, and one final

**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:** first-year students

**Expected Class Size:** 20

**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)

**Quantative/Formal Reasoning Notes:** This a calculus course.

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Fall 2022

LEC Section: 01 MWF 11:00 am - 11:50 am Lori A. Pedersen

LEC Section: 02 MWF 12:00 pm - 12:50 pm Lori A. Pedersen

Spring 2023
MATH 140 (F)(S) Calculus II (QFR)

Calculus answers two basic questions: how fast is something changing (the derivative) and how much is there (the integral). This course is about integration, and the miracle that unites the derivative and the integral (the Fundamental Theorem of Calculus.) Understanding calculus requires in part the understanding of methods of integration. This course will also solve equations involving derivatives ("differential equations") for population growth or pollution levels. Exponential and logarithmic functions and trigonometric and inverse functions will also 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
Enrollment Preferences: based on who needs calculus the soonest
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)
Quantative/Formal Reasoning Notes: This is a math class

Fall 2022
LEC Section: 01 MWF 9:00 am - 9:50 am Bhagya Athukorallage
LEC Section: 02 MWF 10:00 am - 10:50 am Bhagya Athukorallage

Spring 2023
LEC Section: 01 MWF 10:00 am - 10:50 am Colin C. Adams
LEC Section: 02 MWF 11:00 am - 11:50 am Colin C. Adams
LEC Section: 03 MWF 12:00 pm - 12:50 pm Colin C. Adams

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: Problem sets and exams
Prerequisites: MATH 140 or equivalent, such as satisfactory performance on an Advanced Placement Examination
Enrollment Limit: 50
Enrollment Preferences: Preference will be given to prospective math and stats majors, or students who need this as a course to serve as a prerequisite for other courses.
Expected Class Size: 40
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)
Quantative/Formal Reasoning Notes: mathematics

Fall 2022
LEC Section: 01 MWF 10:00 am - 10:50 am Colin C. Adams
LEC Section: 02 MWF 11:00 am - 11:50 am Colin C. Adams
LEC Section: 03 MWF 12:00 pm - 12:50 pm Colin C. Adams

LEC Section: 01 MWF 9:00 am - 9:50 am Bhagya Athukorallage
LEC Section: 02 MWF 10:00 am - 10:50 am Bhagya Athukorallage
MATH 151 (F) 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 and multiple integrals. 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: problem sets and exams
Prerequisites: AP BC 3 or higher or integral calculus with infinite series
Enrollment Limit: 50
Enrollment Preferences: First-years, sophomores, and juniors
Expected Class Size: 40
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)
Quantitative/Formal Reasoning Notes: This course builds quantitative skills

Fall 2022
LEC Section: 01 MWF 8:00 am - 8:50 am Susan R. Loepp
LEC Section: 02 MWF 9:00 am - 9:50 am Susan R. Loepp
LEC Section: 03 MWF 10:00 am - 10:50 am Susan R. Loepp

MATH 197 (F) Independent Study: Mathematics
Directed 100-level independent study in Mathematics.
Requirements/Evaluation: decided by the department
Prerequisites: permission of department
Enrollment Limit: 20
Enrollment Preferences: decided by the department
Expected Class Size: 1
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3)

Fall 2022
IND Section: 01 TBA Mihai Stoiciu

MATH 198 (S) Independent Study: Mathematics
Directed 100-level independent study in Mathematics.
Requirements/Evaluation: decided by the department
Prerequisites: permission of the department
Enrollment Limit: 20
Enrollment Preferences: decided by the department
Expected Class Size: 1
Grading: yes pass/fail option, yes fifth course option
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, and graphs. Emphasis will be given on the methods and styles of mathematical proofs, in order to prepare the students for more advanced math courses.

**Requirements/Evaluation:** Fall: Homework, proof portfolio, group work, presentations, quizzes/exams, reflections. Spring: The grade will be based on homework and 4 exams.

**Prerequisites:** Calculus at the level of an AP course or Williams College Math 130 or 140. Students who have taken a 300-level or 400-level math course should obtain permission of the instructor before enrolling.

**Enrollment Limit:** 40

**Enrollment Preferences:** Preference given to first and second year students intending to major in mathematics or computer science.

**Expected Class Size:** 40

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

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

**Quantitative/Formal Reasoning Notes:** This course involves developing the formal mathematical language of logic and set theory. It also involves using quantitative tools to solve problems relating to combinatorics, probability, and other fields of discrete mathematics.

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

Quantitative/Formal Reasoning Notes: This course will have weekly problem sets using advanced calculus methods.

Spring 2023
LEC Section: 01    TR 9:55 am - 11:10 am    Daniel P. Aalberts

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:  60
Enrollment Preferences:  Students who have officially declared a major that requires Math 250.
Expected Class Size:  40
Grading:  yes pass/fail option, yes fifth course option
Distributions:  (D3)  (QFR)
Quantitative/Formal Reasoning Notes: In this course, students will engage in both quantitative and formal reasoning.
Attributes:  COGS Related Courses

Fall 2022
LEC Section: 01    TR 8:30 am - 9:45 am    Thomas A. Garrity
LEC Section: 02    TR 9:55 am - 11:10 am    Thomas A. Garrity

Spring 2023
LEC Section: 01    MWF 10:00 am - 10:50 am    Jenna Zomback
LEC Section: 02    MWF 11:00 am - 11:50 am    Jenna Zomback

MATH 297  (F)  Independent Study: Mathematics
Directed 200-level independent study in Mathematics.
Requirements/Evaluation:  decided by the department
Prerequisites:  permission of department
Enrollment Limit:  20
Enrollment Preferences:  decided by the department
Expected Class Size:  1
Grading:  yes pass/fail option, yes fifth course option
Distributions:  (D3)

Fall 2022
IND Section: 01    TBA    Mihai Stoiciu

MATH 298  (S)  Independent Study: Mathematics
Directed 200-level independent study in Mathematics.
MATH 303  (F) Introduction to Dynamics, p-Adics, and Measure  (QFR)
At its most basic level a dynamical system consists of a set of points and a transformation or map acting on the set (i.e., sending points in the set to other points in the set). In this setting we can already ask about the existence, and prevalence, of periodic points (points that come back to themselves). One can also ask about the orbit of a point: the set of points that is obtained as one iteratively applies the transformation the point. An important dynamical notion that comes up here is that of chaos. The course will start by studying basic dynamical systems using notions from calculus. Then we will introduce the p-adic numbers and use them to study dynamical systems. The course will end with an exploration of the notion of measure and its connection with dynamical systems.

Requirements/Evaluation: Homework, class participation, exams.
Prerequisites: Math 250.
Enrollment Limit: 30
Enrollment Preferences: Juniors
Expected Class Size: 20
Grading: no pass/fail option, yes fifth course option
Distributions: (D3)  (QFR)
Quantative/Formal Reasoning Notes: Mathematics
Not offered current academic year

MATH 307  (F)(S) Computational Linear Algebra  (QFR)
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; data scraping; singular value decomposition; and more. This course could also be considered a course in numerical analysis or computational science.

Class Format: This course is taught in a flipped classroom format. Students read and watch lecture videos prior to each class session. The instructor uses class time for discussion and collaborative learning activities. This course will be a good fit for students with a strong interest in applied mathematics and a willingness to devote significant effort to learning/doing computer programming.

Requirements/Evaluation: Students will complete checkpoint quizzes, regularly assigned homework problems and projects, and reflective writing assignments. To move towards a non-hierarchical, transparent, and egalitarian grading system, the instructor follows the policy of "ungrading." Over the course of the semester, students will develop a rubric to assess their own learning and will evaluate themselves according to this rubric.
Prerequisites: MATH 250; COMP 134 or equivalent prior experience with computer programming (in any language)
Enrollment Limit: 24
Enrollment Preferences: Preference given to majors and prospective majors.
Expected Class Size: 24
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)

Quantitative/Formal Reasoning Notes: This course involves developing the formal mathematical language of linear algebra. It also involves using quantitative tools to solve problems relating to a wide range of applications in the physical and social sciences.

Fall 2022
LEC Section: 01   TR 8:30 am - 9:45 am   Chad M. Topaz

Spring 2023
LEC Section: 01   TR 8:30 am - 9:45 am   Chad M. Topaz

MATH 308  (F)(S)  Mathematical and Computational Approaches to Social Justice  (DPE) (QFR)
Cross-listings: STS 363  WGSS 363  AMST 363  MATH 308

Primary Cross-listing

Civil rights activist, educator, and investigative journalist Ida B. Wells said that "the way to right wrongs is to shine the light of truth upon them." In this research-based tutorial, students will bring the vanguard of quantitative approaches to bear on issues of social justice. Each tutorial group will carry out a substantial project in an area such as criminal justice, education equity, environmental justice, health care equity, economic justice, or inclusion in arts/media. All students should expect to invest substantial effort in reading social justice literature and in acquiring new skills in data science.

Class Format: This is a research-based tutorial.

Requirements/Evaluation: To move towards a non-hierarchical, transparent, and egalitarian grading system, the instructor follows an "ungrading" methodology.

Prerequisites: Across each 3 - 5 person tutorial group: multivariable calculus (e.g., Math 150/151), linear algebra (e.g., Math 250), statistics (e.g., Stat 161/201), computer programming (e.g., Comp 134), some working knowledge of or interest in social justice issues.

Enrollment Limit: 20

Enrollment Preferences: Students will be admitted in groups of 3 - 5 based on a proposal submitted prior to registration. The instructor is happy to facilitate formation of groups and to give feedback on draft proposals. Contact the instructor early, prior to preregistration.

Expected Class Size: 20

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

Distributions: (D3) (DPE) (QFR)

This course is cross-listed and the prefixes carry the following divisional credit:
STS 363 (D2)  WGSS 363 (D2)  AMST 363 (D2)  MATH 308 (D3)

Difference, Power, and Equity Notes: Students study issues of equity, diversity, and inclusion in areas such as criminal justice, arts/media, environmental justice, education, and health care, and along identity axes such as gender, race/ethnicity, disability status, and sexual orientation.

Quantitative/Formal Reasoning Notes: Students use multiple mathematical, statistical, and computational frameworks to acquire, model, and analyze real-world data.

Fall 2022
TUT Section: T1   TBA   Chad M. Topaz

Spring 2023
TUT Section: T1   TBA   Chad M. Topaz

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

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

Requirements/Evaluation: quizzes/exams, problem sets, participation

Prerequisites: MATH 150/151 and MATH 250
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)
Quantative/Formal Reasoning Notes: 300-level mathematics course

Fall 2022
LEC Section: 01    TR 11:20 am - 12:35 pm     Julie C. Blackwood
Spring 2023
LEC Section: 01    TR 9:55 am - 11:10 am     Julie C. Blackwood

MATH 311  (F) Advanced topics in applied mathematics  (QFR)
Applied mathematics is an expansive field that uses mathematical methods to explore problems that arise in biology, physics, engineering, and many other disciplines. In this course, we will explore a diversity of methods that may include stochastic processes, optimization, signal processing, and numerical analysis. We will also explore how these methods can be utilized to understand questions in other disciplines.

Requirements/Evaluation: This course will have some combination of problem sets, presentations, exams, and a final project
Prerequisites: Differential equations (Math 309) or permission of the instructor
Enrollment Limit: 10
Enrollment Preferences: If over-enrolled, the instructor will request a statement of interest
Expected Class Size: 10
Grading: yes pass/fail option, no fifth course option
Distributions: (D3) (QFR)
Quantative/Formal Reasoning Notes: Mathematics course

Fall 2022
TUT Section: T1    TBA     Julie C. Blackwood

MATH 312  (F) The Mathematics of Pandemics: From the Spread of Infections to Cost-Benefit Analyses of Responses  (QFR)
The goal of the class is to help students learn to ask the right questions, and to gather and analyze the data needed to answer them, to understand the covid pandemic and the worldwide responses. Through local experts and numerous guest speakers playing key roles in these problems, we will discuss numerous aspects, from mathematical models for virus propagation to analyzing the economic, educational, social and emotional consequences of lockdowns and social distancing; from moral and legal dilemmas created by the pandemic and responses to the international political scene and relations between countries. Offered as Math 119 or Math 312 (those taking as Math 312 will have some of the readings replaced with more technical modeling papers and subsequent homework). Pre-requisites: None for Math 119; for Math 312 linear algebra is recommended.

Requirements/Evaluation: Class participation, writing, homework problems.
Prerequisites: Linear algebra recommended.
Enrollment Limit: none
Enrollment Preferences: all students will have an equal chance; if possible none will be turned away.
Expected Class Size: 30
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)
Quantative/Formal Reasoning Notes: We will discuss mathematical models and use statistics to analyze data.
Not offered current academic year
MATH 313 (S) 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 numbers and primes in more general settings, and consider fascinating questions that are simple to understand, but can be quite difficult to answer.

Requirements/Evaluation: Problem sets and exams
Prerequisites: MATH 250 or permission of instructor
Enrollment Limit: 30
Enrollment Preferences: Students who have not taken Math 355 and seniors who need the course to complete the major and have no other options.
Expected Class Size: 30
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)
Quantative/ Formal Reasoning Notes: This course requires working with various number systems, performing explicit computations, and proving mathematical results using logical reasoning practices.

Spring 2023
LEC Section: 01 MWF 10:00 am - 10:50 am Susan R. Loepp

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)
Quantative/ Formal Reasoning Notes: The course will contain mathematical proofs.
Not offered current academic year

MATH 315 (S) Methods for Solving Diophantine Equations (QFR)
A Diophantine equation is an equation with integer (or rational) coefficients that is to be solved in integers (or rational numbers). A focus of study for hundreds of years, Diophantine analysis remains a vibrant area of research. It has yielded a multitude of beautiful results and has wide ranging applications in other areas of mathematics, in cryptography, and in the natural sciences. In this project-based tutorial, we will focus on studying and implementing various methods for solving previously unsolved infinite families of Diophantine equations. Depending on their interests, students may choose one or several methods to apply to open problems in the field. Please note that this tutorial will be held virtually.

Requirements/Evaluation: The grade for this course will be a combination of weekly problem sets, weekly oral presentations (approx. 15 min. each), quarterly self-reflections, and a final written project manuscript that will be continually edited throughout the semester (minimum of 5 pages).
Prerequisites: MATH 250 or permission of the instructor
Enrollment Limit: 10
Enrollment Preferences: Sophomores, Juniors, and Seniors based on a short questionnaire of interests. In the event of over-enrollment, preference will be given to those that need the course to graduate.
Expected Class Size: 10
Grading: no pass/fail option, no fifth course option
**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, or permission of the instructor.

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

**Prerequisites:** MATH 150, MATH 250 and one other 200-level or higher CSCI, MATH or STATS course, or permission from the instructor.

**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)

**Quantitative/Formal Reasoning Notes:** 300 level mathematics course.

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

What can computational biology teach us about cancer? In this lab-intensive 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, and phylogenetics 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 inflammatory and MAPK signal transduction pathways 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 may also be used to study networks of interacting proteins in colon tumor cells.

**Class Format:** The lab for this course will meet for two afternoons per week. Some lab sessions will be shorter than 3 hours.

**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 a CSCI course, or CSCI/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, no 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:
MATH 319 (D3) CHEM 319 (D3) BIOL 319 (D3) PHYS 319 (D3) CSCI 319 (D3)

Quantative/Formal Reasoning Notes: Through lab work, homework sets and a major project, students will learn or further develop their skills in programming in Python, and about the basis of Bayesian approaches to phylogenetic tree estimation.

Attributes: BIGP Courses BIMO Interdepartmental Electives

Spring 2023

SEM Section: 01 TR 9:55 am - 11:10 am Lois M. Banta
LAB Section: 02 TR 1:00 pm - 4:00 pm Lois M. Banta

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

Enrollment Preferences: seniors, junior, sophomores, first year

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)

Not offered current academic year

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)

Not offered current academic year

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**MATH 329 (F) Discrete Geometry (QFR)**

Discrete geometry is one of the oldest and most consistently vibrant areas of mathematics, stretching from the Platonic Solids of antiquity to the modern day applications of convex optimization and linear programming. In this course 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:** Problem sets, exams, and a final project

**Prerequisites:** MATH 200 or Math 250, or permission of instructor

**Enrollment Limit:** 30

**Enrollment Preferences:** Sophomores, juniors, and seniors

**Expected Class Size:** 20

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

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

**Quantitative/Formal Reasoning Notes:** All of the content in this course is quantitative or formal reasoning.

Not offered current academic year

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**MATH 334 (F) 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, exams, and a short final project

**Prerequisites:** MATH 200 or MATH 250

**Enrollment Limit:** 30

**Enrollment Preferences:** Math majors

**Expected Class Size:** 25

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

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

**Quantitative/Formal Reasoning Notes:** This course involves the writing of mathematical proofs.

Fall 2022

LEC Section: 01    MWF 11:00 am - 11:50 am    Ralph E. Morrison
Given goals, options, and uncertainty, how does one make a rational choice? What happens when we interact with others who are also choosing? How might this play out over time? We will first cover the principles of decision theory including preference, uncertainty, utility, imperfect information, and rational choice. The majority of the course will be spent on the main topics of game theory: sequential games, bimatrix games, parlor games, Nash equilibria, bargaining, repeated games, Bayesian belief, and signaling. Applying these principles to populations that evolve over time through variation, selection, and copying, we will develop basic models of the dynamics of evolution.

Class Format: lecture

Requirements/Evaluation: Weekly homework, midterm exams, and a final.

Prerequisites: Math 150/151 and Math 250. Some background in probability and differential equations is highly recommended.

Enrollment Limit: 35

Enrollment Preferences: Math majors.

Expected Class Size: 35

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

Distributions: (D3) (QFR)

Quantitative/Formal Reasoning Notes: Lots of math.

Not offered current academic year

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:

PHIL 338 (D2) MATH 338 (D3)

Quantitative/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.

Attributes: PHIL Contemp Metaphysics + Epistemology Courses

Spring 2023

SEM Section: 01 Cancelled
MATH 340  Applications of Mathematics to the Real World  (QFR)

Often for real world applications one does not need to find the optimal solution, which can be extremely difficult, but instead just find something close, or at least better than what is currently being done. We will develop material and techniques from mathematics, statistics and allied fields with an eye to applications. In addition to standard homework assignments and exams there will be a group project where students will work with a local business, write a report and present the results. Pre-requisites are multivariable calculus and linear algebra, or permission of the instructor. Knowledge of some statistics or programming is beneficial but not required.

Class Format: In addition to standard lectures and assignments, we will be partnering with local businesses to apply mathematics to solve real world problems.

Requirements/Evaluation: Lectures and class participation, homework, exams and encouragement to do a project. We already have several local businesses with projects for students. Working on a project will entail meeting with officials from the company, clearly defining what the problem is, and writing a solution. This will include a presentation, a write-up, and potentially implementable code. Based on previous similar courses, these papers typically run from 10 to 40 pages.

Prerequisites: Mathematics 150 or 151, and Linear Algebra, or permission of the instructor.

Enrollment Limit: 40

Enrollment Preferences: Students who have taken at least one statistics or computer science class

Expected Class Size: 25

Grading:

Distributions:  (D3)  (QFR)

Quantitative/Formal Reasoning Notes: This is a 300 level mathematics class

Not offered current academic year

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

Cross-listings: STAT 341  MATH 341

Primary Cross-listing

The historical roots of probability lie in the study of games of chance. Modern probability, however, is a mathematical discipline that has wide applications in a myriad of other mathematical and physical sciences. Drawing on classical gaming examples for motivation, this course will present axiomatic and mathematical aspects of probability. Included will be discussions of random variables (both discrete and continuous), distribution and expectation, independence, laws of large numbers, and the well-known Central Limit Theorem. Many interesting and important applications will also be presented, including some from classical Poisson processes, random walks and Markov Chains.

Requirements/Evaluation: homework, classwork, and exams

Prerequisites: MATH 150 and MATH 250 or permission of the instructor

Enrollment Limit: 30

Enrollment Preferences: Priority will be given to Mathematics majors and to Statistics Majors.

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:

STAT 341 (D3) MATH 341 (D3)

Quantitative/Formal Reasoning Notes: This is a 300-level Math/Stat course.

Fall 2022
LEC Section: 01    TF 2:35 pm - 3:50 pm     Mihai Stoiciu

Spring 2023
LEC Section: 01    TF 2:35 pm - 3:50 pm     Mihai Stoiciu

MATH 342  (F) Logic  (QFR)
This course will introduce the main ideas and basic results of mathematical logic, and explain their applications to other areas of mathematics and computer science. We will begin with a study of first-order logic, covering structures and definability, theories, models and categoricity, as well as formal proofs. We will prove Gödel's completeness and compactness theorems and the Lowenheim-Skolem theorems. The course will briefly dive into computability theory, enough to prove Gödel's Incompleteness theorems and basic undecidability results.

**Requirements/Evaluation:** Evaluation based on homework, exams, and class participation.

**Prerequisites:** Math 250 - Linear Algebra

**Enrollment Limit:** 20

**Enrollment Preferences:** Junior and Senior Math Majors

**Expected Class Size:** 20

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

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

**Quantitative/Formal Reasoning Notes:** Mathematics course in logic and applications.

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**Fall 2022**

LEC Section: 01  MWF 9:00 am - 9:50 am  Jenna Zomback

**MATH 344 (S) The Mathematics of Sports** (QFR)

The purpose of this class is to use sports as a springboard to study applications of mathematics, especially in gathering data to build and test models and develop predictive statistics. Examples will be drawn from baseball, basketball, cross country, football, hockey, soccer, track, as well as class choices. Pre-requisites are linear algebra (Math 250) and either a 200 level statistics class or a 100 level programming class, or permission of the instructor.

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

**Prerequisites:** Math 250: Linear Algebra

**Enrollment Limit:** 40

**Enrollment Preferences:** None. If the course is over-enrolled preference will be given to math and stats majors, and then if needed by performance on a small assignment.

**Expected Class Size:** 30

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

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

**Quantitative/Formal Reasoning Notes:** This is a 300 level mathematics course.

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**Spring 2023**

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

**MATH 345 (S) Introduction to Numerical Analysis** (QFR)

Numerical analysis is the study of algorithms that use numerical approximation to solve problems which arise in scientific applications. This course provides an introduction to the theory, development, and analysis of algorithms for obtaining numerical solutions. Topics discussed in the course include: Error Analysis and Convergence Rates of Algorithms; Root Finding for Nonlinear Equations; Approximating Functions using Lagrange Interpolation and Cubic Spline Approximation; Numerical Differentiation and Integration; Numerical Solution of Ordinary Differential Equations; Iterative Methods for Solving Linear Systems

**Requirements/Evaluation:** Evaluation will be based on homework, projects, and exams.

**Prerequisites:** Math 250

**Enrollment Limit:** 30

**Enrollment Preferences:** Mathematics and Statistics majors.

**Expected Class Size:** 15

**Grading:** yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)

Quantitative/Formal Reasoning Notes: This is an advanced mathematics class that will cover the fundamental ideas of Numerical Analysis. The students will study in depths various algorithms that provide numerical solutions to various questions in science.

Spring 2023
LEC Section: 01    TR 8:30 am - 9:45 am     Bhagya Athukorallage

MATH 350 (F)(S) Real Analysis (QFR)
Why is the product of two negative numbers positive? Why do we depict the real numbers as a line? Why is this line continuous, and what do we mean when we say that? Perhaps most fundamentally, what is a real number? Real analysis addresses such questions, delving into the structure of real numbers and functions of them. Along the way we'll discuss sequences and limits, series, completeness, compactness, derivatives and integrals, and metric spaces. Results covered will include the Cantor-Schroeder-Bernstein theorem, the monotone convergence theorem, the Bolzano-Weierstrass theorem, the Cauchy criterion, Dirichlet's and Riemann's rearrangement theorem, the Heine-Borel theorem, the intermediate value theorem, and many others. This course is excellent preparation for graduate studies in mathematics, statistics, and economics.

Requirements/Evaluation: Problem sets, exams, and an expository essay.

Prerequisites: MATH 250 or permission of instructor.

Enrollment Limit: 40

Enrollment Preferences: Juniors and Seniors.

Expected Class Size: 25

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

Distributions: (D3) (QFR)

Quantative/Formal Reasoning Notes: It's math.

Fall 2022
LEC Section: 01    MR 2:35 pm - 3:50 pm     Leo Goldmakher

Spring 2023
LEC Section: 01    MR 2:35 pm - 3:50 pm     Leo Goldmakher

MATH 351 (S) 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: homework, classwork, and exams

Prerequisites: MATH 150 and MATH 250 or permission of the instructor.

Enrollment Limit: 30

Enrollment Preferences: Seniors

Expected Class Size: 20

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

Distributions: (D3) (QFR)

Quantative/Formal Reasoning Notes: Math

Spring 2023
LEC Section: 01    MR 2:35 pm - 3:50 pm     Mihai Stoiciu

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
Enrollment Limit: 30
Enrollment Preferences: Students who have officially declared a major that requires Math 355.
Expected Class Size: 20
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)
Quantative/Formal Reasoning Notes: 300-level math course

Fall 2022
LEC Section: 01  MWF 9:00 am - 9:50 am  Ralph E. Morrison

Spring 2023
LEC Section: 01  MWF 11:00 am - 11:50 am  Thomas A. Garrity
LEC Section: 02  MWF 12:00 pm - 12:50 pm  Thomas A. Garrity

MATH 361 (F) Theory of Computation  (QFR)
Cross-listings: MATH 361  CSCI 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.

Class Format: Lecture content will be delivered through asynchronously viewed video modules. Conference sections meeting twice per week will be
used for synchronous discussions. Students should sign up for lecture and one conference section.

Requirements/Evaluation: online multiple choice and short answer questions, weekly problem sets in groups, a research project, and a final
examination
Prerequisites: CSCI 256 or both a 300-level MATH course and permission of instructor
Enrollment Limit: 48 (12/con)
Enrollment Preferences: current or expected Computer Science majors
Expected Class Size: 48
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 361 (D3) CSCI 361 (D3)

Quantative/Formal Reasoning Notes: This course include regular and substantial problem sets in which quantitative/formal reasoning skills are
practiced and evaluated.
Attributes: COGS Interdepartmental Electives

Fall 2022
LEC Section: 01  ASYN  Aaron M. Williams
CON Section: 02  MWF 11:00 am - 12:15 pm  Aaron M. Williams
In Real Analysis you learned about metric spaces---any set of objects endowed with a way of measuring distance---and the topology of sets in such spaces (open, closed, bounded, etc). In this course we flip this on its head: we explore how to develop analysis (limits, continuity, etc) in spaces where the topology is known but the metric is not. This will lead us to a bizarre and fascinating version of geometry in which we cannot distinguish between shapes that can be continuously deformed into one another. Not only does this theory turn out to be beautiful in the abstract, it plays an important role in math, physics, and data analysis. This course is excellent preparation for graduate programs in mathematics.

Requirements/Evaluation: Problem sets, exams, an expository essay.

Prerequisites: MATH 350 or 351; not open to students who have taken MATH 323. If you didn't cover metric spaces in real analysis, that's OK!

Enrollment Limit: 30

Enrollment Preferences: Juniors and seniors

Expected Class Size: 20

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

Distributions: (D3) (QFR)

Quantative/Formal Reasoning Notes: It's math.

Fall 2022

LEC Section: 01 TR 9:55 am - 11:10 am Leo Goldmakher

MATH 383 (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.

Requirements/Evaluation: homework, classwork, and exams

Prerequisites: MATH 350 or MATH 351 or permission of instructor

Enrollment Limit: 40

Enrollment Preferences: 40

Expected Class Size: 30

Grading: yes 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)

Quantative/Formal Reasoning Notes: Advanced mathematics course with weekly or daily problem sets.

Not offered current academic year

MATH 390 Undergraduate Research Topics in Algebra (QFR)

The well-known trace map on matrices can be generalized to a map on other algebraic objects. Undergraduates, graduates students and experts in Representation Theory, Commutative Algebra and Algebraic Geometry have been driving recent developments in the theory of trace modules and finding exciting new applications in all of these fields. This course will serve as an introduction to mathematical research with the aim of producing original research in modern trace theory. Students in this tutorial will read and synthesize research papers, discuss the formation of research questions in pure mathematics, and engage in original mathematical research.

Requirements/Evaluation: oral presentations; writing assignments (summarizing papers, reflections on mathematical research, original research);
participation in the course project

Prerequisites: Math 355

Enrollment Limit: 10

Enrollment Preferences: Juniors and Seniors

Expected Class Size: 7

Grading:

Distributions: (D3) (QFR)

Quantitative/Formal Reasoning Notes: This is a post-core math class; students will be required to produce mathematical proofs.

Not offered current academic year

MATH 391 (F) Introduction to computer algebra (QFR)

Students will learn new mathematics in the context of computer-based exposition, experimentation, and interaction. They will gain proficiency with Sage, GAP, Macaulay2, or Mathematica, and possibly one of the more-specialized systems SnapPea, kenzo, magma, MATLAB, Perseus, coq, etc. Individuals and teams will build interactive demonstrations of mathematical theorems, which will then be appreciated by the instructor and the rest of the class. No prior programming experience is expected.

Class Format: Class will be held online, but there will be recorded components, asynchronous interactive components, and outside-of-class small-group online meetings.

Requirements/Evaluation: exams, homework, projects

Prerequisites: Math 355 or permission of instructor

Enrollment Limit: 20

Enrollment Preferences: math majors

Expected Class Size: 15

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

Distributions: (D3) (QFR)

Quantitative/Formal Reasoning Notes: Mathematical programming requires complete synthesis of abstract concepts to produce computer code, which is necessarily formal.

Not offered current academic year

MATH 392 (S) Undergraduate Research Topics in Graph Theory (WS) (QFR)

Graph theory is a vibrant area of research with many applications to the social sciences, psychology, and economics. In this project-based tutorial, students will select among the presented topics and will develop research questions and undertake original research in the field. Student assessment is based on drafts of research project manuscript and presentations.

Requirements/Evaluation: 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) (WS) (QFR)

Writing Skills Notes: This course will require multiple revisions of a manuscript related to the research project at hand. The final result will be a 10-20 page research article and the course will be designed as a writing intensive course.

Quantitative/Formal Reasoning Notes: The course deals with mathematical research in graph theory and is a quantitative and formal reasoning course.

Not offered current academic year

MATH 393 (S) Research Topics in Combinatorics (WS) (QFR)
Combinatorics provides techniques and tools to enumerate, examine, and investigate the existence of discrete mathematical structures with certain properties. There are numerous areas of applications including algebra, discrete geometry, and number theory. In this project-based research course students will work in small groups to learn combinatorial techniques and tools in order to develop research questions and begin tackling unsolved problems in combinatorics.

Requirements/Evaluation: Students will be evaluated through written drafts of a manuscript and its revisions and multiple in-class presentation.
Prerequisites: Math 355
Enrollment Limit: 19
Enrollment Preferences: Post-core mathematics majors
Expected Class Size: 19
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (WS) (QFR)

Writing Skills Notes: The main goal of this course is to undertake original research in combinatorics, as such student assessment is based on developing positive collaboration skills, and improving technical written and oral skills in mathematics through manuscript draft submissions and in-class presentations. Students will provide multiple drafts of their manuscript and in right of this the course will be writing intensive.

Quantative/Formal Reasoning Notes: The main goal of this course is to undertake original research in the math field of mathematics. See above for more details.

Spring 2023
SEM Section: 01 Cancelled

MATH 394 (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 and exams
Prerequisites: MATH 355
Enrollment Limit: 50
Enrollment Preferences: discretion of the instructor
Expected Class Size: 10
Grading: yes 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)

Quantative/Formal Reasoning Notes: This is a math class
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 2022
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 2023
IND Section: 01 TBA Mihai Stoiciu

MATH 401 (S) Functional Analysis (QFR)
Functional analysis can be viewed as linear algebra on infinite-dimensional spaces. It is a central topic in Mathematics, which brings together and extends ideas from analysis, algebra, and geometry. Functional analysis also provides the rigorous mathematical background for several areas of theoretical physics (especially quantum mechanics). We will introduce infinite-dimensional spaces (Banach and Hilbert spaces) and study their properties. These spaces are often spaces of functions (for example, the space of square-integrable functions). We will consider linear operators on Hilbert spaces and investigate their spectral properties. A special attention will be dedicated to various operators arising from mathematical physics, especially the Schrodinger operator.
Class Format: lecture
Requirements/Evaluation: weekly problem sets, two midterm exams, final exam
Prerequisites: MATH 350 or 351 or permission of instructor
Enrollment Limit: 40
Enrollment Preferences: Mathematics and Physics majors; seniors
Expected Class Size: 30
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)
Quantitative/Formal Reasoning Notes: This is an advance course in Mathematical Analysis.
Not offered current academic year

MATH 402 (F) Measure Theory and Hilbert Spaces (QFR)
How large is the unit square? One might measure the number of individual points in the square (uncountably infinite), the area of the square (1), or the dimension of the square (2). But what about for more complicated sets, e.g., the set of all rational points in the unit square? What's the area of this set? What's the dimension? In this course we'll come up with precise ways to measure size -- length, area, volume, dimension -- that apply to a broad array of sets. Along the way we'll encounter Lebesgue measure and Lebesgue integration, Hausdorff measure and fractals, space-filling curves and the Banach-Tarski paradox. We will also investigate Hilbert spaces, mathematical objects that combine the tidiness of linear algebra with the power of analysis and are fundamental to the study of differential equations, functional analysis, harmonic analysis, and ergodic theory, and also apply to fields like quantum mechanics and machine learning. This material provides good preparation for graduate studies in mathematics, statistics and economics.
Class Format: Discussion-based course held remotely.
Requirements/Evaluation: performance on homework assignments and exams
Prerequisites: MATH 350 or MATH 351 or permission of instructor
Enrollment Limit: 30
Enrollment Preferences: Seniors
Expected Class Size: 20
Grading: no pass/fail option, yes fifth course option
Distributions: (D3) (QFR)
Quantitative/Formal Reasoning Notes: Math
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)

Quantative/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.

Not offered current academic year

MATH 405 (S) Representation Theory and Special Functions (QFR)

Representation theory is at the heart of much of modern mathematics. It provides a link between ideas of symmetries, groups and matrices. It has applications from number theory to Fourier Analysis to elementary particle theory. In part, representation theory is a method for producing interesting functions. While not having a single definition, special functions are "functions that have names." Over the last few hundred years, scientists have needed to define and develop certain families of functions, in order to describe different physical phenomena. These families started to be named, and include Bessel functions, Hermite functions, Laguerre functions and more generally hypergeometric functions. In recent years it has been seen that these different types of functions are best understood through the lens of symmetry and in particular via representation theory. This course will be an introduction to representation theory, starting with finite groups, while at the same time being an introduction to special functions. Thus the course will be a mix of abstract algebra, matrices, calculus and analysis.

Requirements/Evaluation: By exams and homework

Prerequisites: Math 350 or Math 351, and Math 355

Enrollment Limit: 50

Enrollment Preferences: By instructor preference

Expected Class Size: 10

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

Distributions: (D3) (QFR)

Quantative/Formal Reasoning Notes: This is a math course

Not offered current academic year

MATH 408 (F) L-Functions and Sphere Packing (QFR)

Optimal packing problems arise in many important problems, and have been a source of excellent mathematics for centuries. The Kepler Problem (what is the most efficient way to pack balls in three-space) is a good example. The original formulation has been used in such diverse areas as stacking cannonballs on battleships to grocers preparing fruit displays, and its generalizations allow the creation of powerful error detection and
correction codes. While the solution of the Kepler Problem is now known, the higher dimensional version is very much open. There has been remarkable progress in the last few years, with number theory playing a key role in these results. We will develop sufficient background material to understand many of these problems and the current state of the field. Pre-requisites are real analysis.

Requirements/Evaluation: Class participation, homework, exams and participation in writing a textbook on the material. Each student will be responsible for working on a chapter of a book based on this material. In addition to obtaining critical writing feedback from myself and my co-author (who is a world expert in the subject), depending on timing we will also be able to share comments from an editor of a major publishing house or a referee. Chapters can range from short snapshots of a subject, on the order of 5 pages, to longer technical derivations of perhaps 10-30 pages.

Prerequisites: Math 350 or 351

Enrollment Limit: 40

Enrollment Preferences: Senior math majors, students planning on graduate study in a STEM field

Expected Class Size: 20

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

Distributions: (D3) (QFR)

Quantative/Formal Reasoning Notes: This is a 400 level math class

Not offered current academic year

MATH 409  (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, exams, presentations.

Prerequisites: Real Analysis (either Math 350 or 351) and Abstract Algebra (Math 355), or permission of the instructor.

Enrollment Limit: 30

Enrollment Preferences: Math/stat senior majors

Expected Class Size: 20

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

Distributions: (D3) (QFR)

Quantative/Formal Reasoning Notes: This is a 400 level math class.

Fall 2022

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

MATH 411  (F)  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. Commutative algebra has applications ranging from algebraic geometry to coding theory. For example, one can use commutative algebra to create error correcting codes. It is perhaps most often used, however, to study curves and surfaces in different spaces. To understand these structures, one must study polynomial rings over fields. This course will be an introduction to commutative algebra. Possible topics include polynomial rings, localizations, primary decomposition, completions, and modules.

Requirements/Evaluation: homework and exams

Prerequisites: MATH 355 or permission of instructor

Enrollment Limit: 25

Enrollment Preferences: Math majors

Expected Class Size: 15
MATH 412 (S) Mathematical Biology (QFR)
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, quizzes/exams, participation, final project and paper
Prerequisites: MATH 250 and MATH 309, or permission of instructor
Enrollment Limit: 20
Enrollment Preferences: if over-enrolled, will have students submit reasons for taking class; preference to those with interest in both subjects
Expected Class Size: 20
Grading: no pass/fail option, no fifth course option
Distributions: (D3) (QFR)
Quantitative/Formal Reasoning Notes: The course will introduce methods for developing and analyzing mathematical models.
Attributes: PHLH Methods in Public Health

Spring 2023
LEC Section: 01 TBA Julie C. Blackwood

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)
Not offered current academic year

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? Precise formulas for these quantities probably don't exist, but over the past 150 years tremendous progress has been made towards understanding these and similar questions using 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 will include some subset of the following: 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, and sieve methods and gaps between primes.

**Requirements/Evaluation:** Regularly preparing lectures and writing expository essays in LaTeX. No exams.

**Prerequisites:** MATH 350 or MATH 351 and familiarity with basic modular arithmetic are hard prerequisites. Familiarity with complex analysis and abstract algebra recommended, but not required.

**Enrollment Limit:** 10

**Enrollment Preferences:** Students with complex analysis background will be given priority.

**Expected Class Size:** 10

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

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

**Quantitative/Formal Reasoning Notes:** It’s math.

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**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)

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

Since people 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, types of tilings, random tilings, the classification of
tilings and aperiodic tilings. We will also look at tilings of the sphere, tilings of the hyperbolic plane, and tilings in 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: 25

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

Distributions: (D3) (QFR)

Quantitative/Formal Reasoning Notes: Mathematics course

Spring 2023

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

Distributions: (D3) (QFR)

Quantitative/Formal Reasoning Notes: The course will involve mathematical proofs.

Not offered current academic year

MATH 433  (S) Mathematical Modeling (QFR)

Mathematical modeling means (1) translating a real-life problem into a mathematical object, (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 strong enthusiasm for applied mathematics, data science, and collaborative teamwork.

Class Format: To afford students flexibility during the COVID pandemic, this course is taught online, largely asynchronously. There is no lecture component. Students will read research literature, work on structured and open-ended projects, and participate in synchronous small-group meetings with the instructor via videoconference. The vast majority of work in this course requires students to collaborate with each other.

Requirements/Evaluation: Students will complete reading assignments, writing assignments, modeling activities, research projects, and will record several presentations to be shared with the rest of the class. To move towards a non-hierarchical, transparent, and egalitarian grading system, the instructor follows the policy of "ungrading." Over the course of the semester, students will develop a rubric to assess their own learning and will evaluate themselves according to this rubric.

Prerequisites: MATH 250; MATH 309 or similar; and some experience with computer programming (equivalent to CSCI 134 or MATH 307).

Enrollment Limit: 20
Enrollment Preferences: Professor's discretion

Expected Class Size: 20

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

Distributions: (D3) (QFR)

Quantitative/Formal Reasoning Notes: This course focuses substantially on using mathematical and statistical tools and frameworks to describe, predict, and understand real-world systems.

Not offered current academic year

MATH 434  (F)  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: 20

Enrollment Preferences: Preference will be given to senior math majors.

Expected Class Size: 20

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

Distributions: (D3) (QFR)

Quantitative/Formal Reasoning Notes: This is a 400 level math course.

Not offered current academic year

MATH 435  (F)  Chip-firing Games on Graphs  (QFR)

Starting with a graph (a collection of nodes connected by edges), place an integer number of poker chips on each vertex. Move these chips around according to "chip-firing moves", where a vertex donates a chip along each edge. These simple and intuitive games quickly lead to challenging mathematics with applications ranging from dynamical systems to algebraic geometry. In this course we'll build up a mathematical framework for studying chip-firing games, drawing on linear algebra and group theory. We'll discover algorithms for winning these games, and study their complexity; and we'll prove graph-theoretic versions of famous results like the Riemann-Roch theorem. A key component of this course will be research projects that draw on open questions about chip-firing.

Requirements/Evaluation: Weekly homework for the first eight weeks, four quizzes spaced evenly throughout the semester, and a cumulative project worked on throughout the semester (10-20 pages)

Prerequisites: Math 250 and Math 355

Enrollment Limit: 25

Enrollment Preferences: Math majors who need the course to graduate

Expected Class Size: 15

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

Distributions: (D3) (QFR)

Quantitative/Formal Reasoning Notes: All topics are quantitative

Not offered current academic year

MATH 441  (F)  Information Theory and Applications

Cross-listings: MATH 441  CSCI 441  STAT 441

Secondary Cross-listing

What is information? And how do we communicate information effectively? This course will introduce students to the fundamental ideas of Information
Theory including entropy, communication channels, mutual information, and Kolmogorov complexity. These ideas have surprising connections to a fields as diverse as physics (statistical mechanics, thermodynamics), mathematics (ergodic theory and number theory), statistics and machine learning (Fisher information, Occam's razor), and electrical engineering (communication theory).

Requirements/Evaluation: Weekly homeworks, midterm(s), final exam.
Prerequisites: Math/Stat 341; Math 150 or 151; or permission of instructor.
Enrollment Limit: 30
Enrollment Preferences: Seniors; mathematics and statistics majors.
Expected Class Size: 25
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3)
This course is cross-listed and the prefixes carry the following divisional credit:
MATH 441 (D3) CSCI 441 (D3) STAT 441 (D3)
Not offered current academic year

MATH 442 (F) Introduction to Descriptive Set Theory (QFR)
Descriptive set theory (DST) combines techniques from analysis, topology, set theory, combinatorics, and other areas of mathematics to study definable (typically Borel) subsets of Polish spaces. The first part of this course will cover the topics necessary to understand the main objects of study in DST: we will develop comfort with point-set topology (enough to juggle with Polish spaces and Borel sets), and set theory (just well-orderings and cardinality). The second part of the course will feature selected topics in descriptive set theory: for example, trees, the perfect set property, Baire category, and infinite games.
Requirements/Evaluation: Evaluation based on homework, exams, and classroom participation.
Prerequisites: Math 250 - Linear Algebra, Math 350/351 Real Analysis/Applied Real Analysis
Enrollment Limit: 14
Enrollment Preferences: Senior Math Majors, then non-Senior Math Majors
Expected Class Size: 14
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)
Quantative/Formal Reasoning Notes: Mathematics course in descriptive set theory.

Fall 2022
LEC Section: 01    MWF 11:00 am - 11:50 am     Jenna Zomback

MATH 453 (S) Partial Differential Equations (QFR)
In this course, we further explore the world of differential equations. Mainly, we cover topics in partial differential equations. Partial Differential Equations (PDEs) are fundamental to the modeling of many natural phenomena, arising in many fields, including fluid mechanics, heat and mass transfer, electromagnetic theory, finance, elasticity, and more. The goals of this course are to discuss the following topics: classification of PDEs in terms of order, linearity and homogeneity; physical interpretation of canonical PDEs; solution techniques, including separation of variables, series solutions, integral transforms, and the method of characteristics.
Requirements/Evaluation: Evaluation will be based on homework, projects, and exams.
Prerequisites: MATH 150-151; MATH/PHYS 210 or MATH 309
Enrollment Limit: 20
Enrollment Preferences: Mathematics and Physics majors.
Expected Class Size: 15
Grading: yes pass/fail option, yes fifth course option
Distributions: (D3) (QFR)
Quantative/Formal Reasoning Notes: This is an advanced mathematics class dedicated to the study of partial differential equations (PDEs). These
equations are the most important mathematical tools for the study of complex physical phenomena such as waves and fluids (including both air and water), heat transfer, electromagnetism, and finance.

Spring 2023
LEC Section: 01    TR 11:20 am - 12:35 pm     Bhagya Athukorallage

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.

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)
Quantative/Formal Reasoning Notes: This is a 400-level Math course.

Not offered current academic year

MATH 458  (S)  Algebraic Combinatorics  (WS) (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. In this collaborative project-based course, students will select among the presented topics, develop research questions, and undertake original research in the field. Student assessment is based building positive and supportive collaborative working relationships with their peers, drafts of research project manuscript, and oral presentations.

Requirements/Evaluation: Drafts of manuscript, oral presentations, reflections, peer collaboration skills
Prerequisites: MATH 200 and MATH 355
Enrollment Limit: 25
Enrollment Preferences: Senior mathematics majors, students with programming experience, students with interests in algebra and combinatorics.
Expected Class Size: 20
Grading: no pass/fail option, no fifth course option
Distributions: (D3)  (WS) (QFR)
Writing Skills Notes: This course will require multiple revisions of a manuscript on the mathematical tent and collaborative work. The final result will be a 10-20 page research article and the course will be designed as a writing intensive course.
Quantative/Formal Reasoning Notes: This is a mathematics course in the area of algebraic combinatorics and is a quantitative and formal reasoning course.

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.

Class Format: Hybrid; if possible we will have classes in person, with remote students attending via Zoom.
MATH 481  (S)  Measure theory and Hilbert spaces  (QFR)
How large is the unit square? One might measure the number of individual points in the square (uncountably infinite), the area of the square (1), or the dimension of the square (2). But what about for more complicated sets, e.g., the set of all rational points in the unit square? What's the area of this set? What's the dimension? In this course we'll come up with precise ways to measure size—length, area, volume, dimension, etc.—that apply to a broad array of sets. Along the way we'll encounter Lebesgue measure and Lebesgue integration, Hausdorff measure and fractals, space-filling curves and the Banach-Tarski paradox. We will also investigate Hilbert spaces, mathematical objects that combine the tidiness of linear algebra with the power of analysis and are fundamental to the study of differential equations, functional analysis, harmonic analysis, and ergodic theory, and also apply to fields like quantum mechanics and machine learning. This material provides excellent preparation for graduate studies in mathematics, statistics and economics.

Requirements/Evaluation:  Problem sets, exams, an expository essay
Prerequisites:  At least one previous course that has Math 350 or 351 as a prerequisite (e.g. Math 374, 383, 401, 404, 408, 420, 426, 485), or permission of instructor.
Enrollment Limit:  20
Enrollment Preferences:  Juniors and seniors.
Expected Class Size:  10
Grading:  no pass/fail option, yes fifth course option
Distributions:  (D3)  (QFR)
Quantitative/Formal Reasoning Notes:  It's math.

Spring 2023
LEC Section:  01    TF 2:35 pm - 3:50 pm     Leo Goldmakher

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)
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.

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

**Distributions:** (D3)

**Fall 2022**

HON Section: 01    TBA    Mihai Stoiciu

**Spring 2023**

HON Section: 01    TBA    Mihai Stoiciu

Directed 400-level independent study in Mathematics.

**Prerequisites:** permission of department

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

**Distributions:** (D3)

**Fall 2022**

IND Section: 01    TBA    Mihai Stoiciu

Directed 400-level independent study in Mathematics.

**Prerequisites:** permission of department

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

**Distributions:** (D3)

**Spring 2023**

IND Section: 01    TBA    Mihai Stoiciu

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 2022
LEC Section: 01  MR 1:10 pm - 2:25 pm  Mihai Stoiciu
LEC Section: 02  W 1:10 pm - 3:50 pm  Mihai Stoiciu

Spring 2023
LEC Section: 01  MR 1:10 pm - 2:25 pm  Mihai Stoiciu
LEC Section: 02  W 1:10 pm - 3:50 pm  Mihai Stoiciu