

Mathematics (MATH)

Faculty

Professors: Gregory T. Adams, M. Lynn Breyfogle (Associate Dean of Arts and Sciences), Peter Brooksbank, Thomas Cassidy (Chair), Ulrich Daepf, George R. Exner, Michael R. Frey, Pamela B. Gorkin, Paul J. McGuire

Associate Professors: KB Boomer, Emily Dryden, Sharon A. Garthwaite, James E. Hutton, Peter McNamara, Adam Piggott, Nathan C. Ryan, Linda B. Smolka, Karl Voss (Associate Dean of Natural Sciences and Mathematics)

Assistant Professors: Kelly A. Bickel, Van T. Cyr, Lara Dick, Gabrielle Flynt, Jeffrey Langford, Mark J. Meyer

Visiting Assistant Professor: Bonnie B. Smith

Visiting Instructor: Amy Donner

Lecturer: Joseph Klobusicky

Mathematics has long been the basic language of the natural sciences, and has been studied for its own sake since ancient times. An understanding of the basics of calculus, statistics, and linear algebra has become a requirement for proficiency in many of the social sciences. The study of mathematics has its own rewards because accomplishment in the subject, even at a relatively elementary level, requires and promotes clarity of both thought and expression. For many, the study of mathematics offers entrance into an exciting world of challenges where beauty and utility coexist in balanced harmony.

A major in mathematics may be seen as the first step toward obtaining a graduate degree in one of the mathematical sciences, or it may constitute preparation for a professional degree program in a field such as education, medicine, law, or business. It also opens the door to a whole range of employment opportunities, as the analytical skills that a student develops in pursuing a major in mathematics are greatly valued by potential employers. There are, for example, excellent career prospects in actuarial work and in the rapidly growing areas of biomathematics and biostatistics (interpreting results of clinical trials), modeling (in industry, government, and finance) and cryptology (in banking, television, the Internet, and elsewhere).

Secondary Teacher Certification

Prospective secondary school teachers (grades 7 – 12) must complete one of the three majors within the department. This certification requires specific mathematics and education courses. Students seeking teacher certification should confer as early as possible with the mathematics and education departments to devise a program of study, which normally will include all requirements for certification in the Commonwealth of Pennsylvania.

Mathematics Majors

The Mathematics Department offers three majors. Students may earn a Bachelor of Arts in Mathematics, a Bachelor of Science in Mathematics, or a Bachelor of Science in Applied Mathematical Sciences. Students in each major complete an introductory year of calculus either by taking MATH 201 Calculus I or MATH 202 Calculus II during their first year, or by achieving a high score on the Advanced Placement Test of the College Entrance Examination Board.

The College Core Curriculum disciplinary depth requirements for Bachelor of Science and Bachelor of Arts majors are satisfied as follows:

- *writing within the major* in MATH 280 Logic, Sets, and Proofs, MATH 308 Real Analysis I, and MATH 320 Abstract Algebra I (all W2 courses);
- *formal presentation* in MATH 280 Logic, Sets, and Proofs and
- *information literacy* in MATH 308 Real Analysis I and MATH 320 Abstract Algebra I.

The requirement for a *Culminating Experience* within the major may be satisfied in any of the following ways: (1) taking a full credit 400-level mathematics course; or (2) completing an honors thesis, senior thesis, or other research project in the senior year that involves mathematics or statistics; or (3) completing student teaching for secondary certification. The Culminating Experience cannot double-count as one of the mathematics electives required in the major, with the one exception that students earning a Bachelor of Arts in Mathematics may count a 400-level mathematics course both as their mathematics-related course and as the Culminating Experience.

The choice of degree program depends largely upon the student's mathematical objectives and interests in fields other than mathematics. Students with strong interests outside mathematics have options including a Bachelor of Science in Applied Mathematical Sciences, a Bachelor of Arts in Mathematics, or a Bachelor of Science in the Interdisciplinary Studies in Economics and Mathematics (<http://coursecatalog.bucknell.edu/collegeofartsandsciencescurricula/areasofstudy/interdisciplinarystudiesineconomicsandmathematicsecma>) program. Students with a strong interest in a career in mathematics or science – and in particular, students planning to continue on to Ph.D. programs in the mathematical sciences – are strongly advised to take courses beyond the minimum requirements for the major. Since the number of courses to be taken in any one department is restricted to 12 for a Bachelor of Arts degree, such students are advised to choose one of the Bachelor of Science majors.

Bachelor of Arts in Mathematics

The **Bachelor of Arts in Mathematics** major consists of eight mathematics courses beyond the introductory year of calculus, plus one additional course in a related field and a Culminating Experience.

Of the eight mathematics courses beyond the introductory year of calculus, five are specified:

Program Requirements

MATH 211	Calculus III	1
MATH 245	Linear Algebra	1
MATH 280	Logic, Sets, and Proofs	1
MATH 308	Real Analysis I	1
MATH 320	Abstract Algebra I	1

Electives

Three electives at the 300- or 400-level ¹		3
---	--	---

Related Field Course

Select one of the following:		1
Fourth Mathematics course at the 300- or 400-level (including MATH 417)		
MATH 207	The Teaching of Mathematics in Secondary Schools	
MATH 212	Differential Equations	
MATH 216	Statistics I	
MATH 219	Topics in Applied Mathematics	
An additional full-credit course in which college-level mathematics or statistics plays a major role. ²		

¹ not including MATH 417 Topics in Mathematics and Statistics

² Examples include any computer science or science course (beyond those required for all liberal arts students), including nearly all courses in computer science or physics at or above the 200-level, or an appropriate course from the humanities, social sciences, or engineering in which mathematics plays a significant role at a reasonable level of sophistication.

The mathematics department chair shall make the determination of whether or not a particular course outside the mathematics department may count as the course in a related field.

A single 400-level course may be used to satisfy both the Culminating Experience requirement and the related course requirement.

Students with a special interest in pure mathematics or statistics can earn formal concentration in these areas by completing an appropriate suite of 300- and 400-level courses, as described below.

Pure Mathematics Concentration

MATH 345	Advanced Linear Algebra	1
MATH 409	Real Analysis II	1
MATH 446	Abstract Algebra II	1
Select two of the following:		2
MATH 311	Theory of Numbers	
MATH 333	Topology	
MATH 362	Complex Analysis	

Statistics Concentration

MATH 303	Probability	1
MATH 305	Statistical Modeling	1
MATH 307	Statistical Design of Scientific Studies	1
MATH 404	Mathematical Statistics	1
MATH 345	Advanced Linear Algebra	1
or MATH 409	Real Analysis II	

Students majoring in mathematics with a special interest in computer science are encouraged to consider a minor in computer science or a double major with computer science.

Bachelor of Science in Mathematics

The **Bachelor of Science in Mathematics** major requires 10 mathematics courses beyond the introductory year of calculus and a Culminating Experience.

Six of the 10 mathematics courses are specified:

Program Requirements

MATH 211	Calculus III	1
MATH 212	Differential Equations	1
MATH 245	Linear Algebra	1
MATH 280	Logic, Sets, and Proofs	1
MATH 308	Real Analysis I	1
MATH 320	Abstract Algebra I	1

Electives

Four mathematics electives at the 300 or 400-level ³		4
Select one of the following:		2
PHYS 211 & PHYS 212 or PHYS 212E	Classical and Modern Physics I and Classical and Modern Physics II Classical and Modern Physics II	
CSCI 203	Introduction to Computer Science I	1
One additional laboratory science course ⁴		1

³ not including MATH 417 Topics in Mathematics and Statistics

⁴ The additional laboratory science courses may be chosen from any discipline in the natural sciences or from computer science. Any course in physics beyond PHYS 212 Classical and Modern Physics II, and any laboratory course in computer science at the level of CSCI 203 Introduction to Computer Science I or beyond, may be chosen.

Students with a special interest in pure mathematics or statistics can earn formal concentration in these areas by completing an appropriate suite of 300- and 400-level courses, as described below. In particular, those intending to pursue graduate study in mathematics or statistics should plan to complete the relevant concentration.

Pure Mathematics Concentration

MATH 345	Advanced Linear Algebra	1
MATH 409	Real Analysis II	1
MATH 446	Abstract Algebra II	1
Select two of the following:		2
MATH 311	Theory of Numbers	
MATH 333	Topology	
MATH 362	Complex Analysis	

Statistics Concentration

MATH 303	Probability	1
MATH 305	Statistical Modeling	1
MATH 307	Statistical Design of Scientific Studies	1
MATH 404	Mathematical Statistics	1
MATH 345 or MATH 409	Advanced Linear Algebra Real Analysis II	1

The recommended sequence for the Bachelor of Science in Mathematics major is as follows:

First Year

First Semester	Credits	Second Semester	Credits
MATH 201		1 MATH 202	1
PHYS 211		1 PHYS 212	1
		2	2

Sophomore

First Semester	Credits	Second Semester	Credits
MATH 211		1 MATH 212	1
MATH 245		1 MATH 280	1
CSCI 203		1 Laboratory science	1
		3	3

Junior

First Semester	Credits	Second Semester	Credits
MATH 308 or 320		1 MATH 308 or 320	1
Elective in mathematics		1 Elective in mathematics	1
		2	2

Senior

First Semester	Credits	Second Semester	Credits
Elective in mathematics		1 Elective in mathematics	1
		Culminating Experience	1
		1	2

Total Credits: 17

Students majoring in mathematics with a special interest in computer science are encouraged to consider a minor in computer science or a double major with computer science.

Bachelor of Science in Applied Mathematical Sciences

The **Bachelor of Science in Applied Mathematical Sciences** major (with a concentration in statistics or applied mathematics) requires 10 mathematics courses beyond the introductory year of calculus, a computing course, at least five approved courses in an approved program, and a Culminating Experience. More specifically, there are six required core mathematics courses consisting of:

Program Requirements

MATH 211	Calculus III	1
MATH 216	Statistics I	1
MATH 245	Linear Algebra	1
MATH 280	Logic, Sets, and Proofs	1
MATH 303	Probability	1
MATH 308	Real Analysis I	1

Courses in Area of Concentration

Four concentration related courses in statistics or applied mathematics	4
---	---

Further, the major requires a computing course and significant coursework in an approved outside department or program as described below. While the Culminating Experience may be met in any of the ways specified above, students earning a Bachelor of Science in Applied Mathematical Sciences are strongly encouraged to consider the option of a thesis or research experience integrating the outside coursework.

Statistics Concentration

MATH 217	Statistics II	1
Select three of the following: ⁵		3
MATH 305	Statistical Modeling	
MATH 307	Statistical Design of Scientific Studies	
MATH 345	Advanced Linear Algebra	
MATH 404	Mathematical Statistics	
MATH 409	Real Analysis II	

⁵ At least two courses must be selected from MATH 305, MATH 307 and MATH 404.

Appropriate courses could be additional electives counting toward the concentration if so determined by the academic adviser in consultation with the mathematics department chair.

Applied Mathematics Concentration

MATH 212	Differential Equations	1
Select three of the following:		3
MATH 343	Numerical Analysis	
MATH 345	Advanced Linear Algebra	
MATH 350	Methods in Applied Mathematics	
MATH 358	Topics in Operations Research	
MATH 362	Complex Analysis	
MATH 409	Real Analysis II	

Appropriate courses could be additional electives counting toward the concentration if so determined by the academic adviser in consultation with the mathematics department chair.

The **computing course** can be a computer science course at or above the 200-level or a computing course appropriate to the program of study as determined through consultation with the academic adviser and the mathematics department chair.

Outside Coursework

For the purpose of completing a coherent sequence of courses that provide a solid introduction to the discipline, all students must partner with an approved department or program in a discipline that applies statistics or mathematics. In this regard, a minimum of five approved courses chosen in consultation with the Mathematics Department adviser and the outside department or program is required. A partner department/program will usually be chosen from the College of Engineering, the School of Management, the Division of Social Sciences, or the Division of Natural Sciences. Entering students can declare the intended major in the summer after acceptance to Bucknell, but must consult with the Mathematics Department and formally declare the outside coursework by the end of their third semester. All other students must consult with the Mathematics Department at the point of declaring the major and specify the outside coursework. In either case the Mathematics Department will consult with the partner department or program to ensure that the coursework is appropriate and can be completed.

A sample sequence for the Bachelor of Science in Applied Mathematical Sciences major is provided below. It should be noted that each student's sequence will be unique, depending on when the program is started, how many AP or transfer credits are applied, and when the desired courses are offered.

First Year

First Semester	Credits	Second Semester	Credits
MATH 201	1	MATH 202	1
	1		1

Sophomore

First Semester	Credits	Second Semester	Credits
MATH 211	1	MATH 245	1
MATH 216	1	MATH 303	1
Computing course	1	Outside course	1
	3		3

Junior

First Semester	Credits	Second Semester	Credits
MATH 280	1	MATH 308	1
MATH 217 or 212	1	Concentration elective	1
Outside course	1	Outside course	1
	3		3

Senior

First Semester	Credits	Second Semester	Credits
Concentration elective	1	Concentration elective	1
Outside course	1	Outside course	1
		Culminating Experience	1
	2		3

Total Credits: 19

Departmental Honors

Students who complete departmental honors normally have a grade point average of 3.5 both in their mathematics courses and overall. Students in the Bachelor of Arts in Mathematics major or Bachelor of Science in Mathematics major have usually completed MATH 308 Real Analysis I and MATH 320 Abstract Algebra I by the end of their junior year. Students in the Bachelor of Science in Applied Mathematical Sciences major have usually completed MATH 308 Real Analysis I by the end of their junior year. To be accepted into the Honors Program, a student must submit an honors proposal for approval by the adviser, the department chairperson, and the Honors Council. The student must then complete an honors thesis under the adviser's direction, must have completed a total of at least three mathematics courses at the 300- or 400-level by the end of their junior year, and satisfy all other requirements as put forth by the University Honors Council. Such students usually complete at least two half-credit semesters of independent study in mathematics (MATH 491 Reading and Research).

Mathematics Minor

A **minor** in mathematics consists of either:

MATH courses MATH 211 or above (at least one of them at the 300- or 400-level)	4
Total Credits	4

or

MATH courses MATH 211 or above (at least two of them at the 300- or 400-level)	3
Total Credits	3

All credits must come from courses taken at Bucknell University.

Mathematics (Statistics) Specific Minor

The minor can be specified as mathematics (statistics), if at least two of the required credits are from among:

MATH 217	Statistics II	1
MATH 303	Probability	1
MATH 305	Statistical Modeling	1
MATH 307	Statistical Design of Scientific Studies	1
MATH 404	Mathematical Statistics	1

Mathematics (Applied/Modeling Mathematics) Specific Minor

The minor can be specified as mathematics (applied/modeling mathematics) if at least two of the required credits are from among the courses:

MATH 212	Differential Equations	1
MATH 222	Differential Equations for Engineers	.5
MATH 226	Probability and Statistics for Engineers	.5
MATH 343	Numerical Analysis	1
MATH 350	Methods in Applied Mathematics	1
MATH 358	Topics in Operations Research	1

The Department of Mathematics aims to provide both majors and non-majors with the mathematical and statistical knowledge and skills needed to succeed in their chosen field of endeavor. It is also intended that the student experience the elegance and broader impacts of the discipline.

Courses

MATH 112. Introduction to Mathematical Modeling. 1 Credit.

Offered Spring Semester Only; Lecture hours:3

Introduction for the non-specialist to mathematical modeling of real-world phenomena such as voting and networks, using graph theory, probability, and other accessible tools.

MATH 117. Introduction to Mathematical Thought. 1 Credit.

Offered Spring Semester Only; Lecture hours:3, Lab:1.5

An investigation of number, numeration, and operations from the perspective of elementary school teachers and pupils. Open only to B.S. in Education Early Childhood Pre-K to 4 students. Required fieldwork.

MATH 118. Elementary Geometry and Statistics. 1 Credit.**Offered Fall Semester Only; Lecture hours:3**

Investigation of geometric, probabilistic, and statistical concepts related to Pre-K to 4 mathematics and how children learn and make sense of these concepts. Prerequisite: permission of the instructor. Prerequisite: MATH 117 or permission of the instructor.

MATH 192. Topics in Calculus. 1 Credit.**Offered Spring Semester Only; Lecture hours:3**

Elementary calculus and applications taken primarily from economics. Topics include algebraic, exponential, and logarithmic functions, graphs, limits, derivatives and integration. Not open to students who have taken MATH 201.

MATH 201. Calculus I. 1 Credit.**Offered Both Fall and Spring; Lecture hours:4**

An introduction to the calculus of algebraic, trigonometric and transcendental functions. Interpretation, significance and calculations of a derivative. Applications to geometry, biology, physics, economics, and other subjects. Introduction to the definite integral, including the Fundamental Theorem of Calculus. Not open to students who have taken MATH 192.

MATH 202. Calculus II. 1 Credit.**Offered Both Fall and Spring; Lecture hours:4**

Methods of integration including substitution, integration by parts, numerical approximations, and improper integrals. Series, including Taylor series. Complex numbers, polar coordinates, differential equations, and applications. Prerequisite: MATH 201.

MATH 207. The Teaching of Mathematics in Secondary Schools. 1 Credit.**Offered Fall Semester Only; Lecture hours:3,Other:.5**

Investigation into the components of effective secondary school mathematics instruction, including lesson design/ implementation (curriculum, tasks, discourse, and assessment). Required fieldwork. Prerequisite: EDUC 201 or permission of the instructor.

MATH 208. Mathematical Explorations. .5 Credits.**Offered Fall Semester Only; Lecture hours:1.5**

An exploration of topics from pure mathematics, applied mathematics and statistics, illustrating the power and beauty of mathematical reasoning. For students considering a major in mathematics. Corequisites: MATH 201 or MATH 202 or MATH 211 or MATH 212 or MATH 216. Open to first-year students only.

MATH 209. Mathematical Problem Solving. .5 Credits.**Offered Fall Semester Only; Lecture hours:Varies; Repeatable**

Mathematical problem solving, with an emphasis on problems and topics that appear in contests such as the Putnam Competition. Prerequisite: permission of the instructor.

MATH 211. Calculus III. 1 Credit.**Offered Both Fall and Spring; Lecture hours:4**

Calculus of vector-valued functions and functions of several variables. Multiple, line, and surface integrals; applications, and extrema. Green's, Stokes' and Divergence Theorems. Prerequisite: MATH 202.

MATH 212. Differential Equations. 1 Credit.**Offered Both Fall and Spring; Lecture hours:3**

Basic methods of solving ordinary differential equations. Systems of linear differential equations, Laplace transform, applications and selected topics. Prerequisite: MATH 211. Not open to students who have taken MATH 222.

MATH 216. Statistics I. 1 Credit.**Offered Both Fall and Spring; Lecture hours:3,Other:1**

Exploratory data analysis, sampling distributions, regression, sampling designs, confidence intervals, hypothesis testing, ANOVA. Statistical software is used and applications, including projects, are undertaken. Not open to students who have taken MATH 226 or PSYC 215.

MATH 217. Statistics II. 1 Credit.**Offered Fall Semester Only; Lecture hours:3,Other:1**

Exploratory data analysis, design of experiments and inference emphasizing applications to a range of disciplines. Includes multiple linear regression, analysis of variance, categorical data analysis, nonparametric statistics. Prerequisite: MATH 216 or equivalent. Crosslisted as MATH 617.

MATH 219. Topics in Applied Mathematics. 1 Credit.**Offered Occasionally; Lecture hours:3; Repeatable**

Topics such as financial mathematics, mathematical biology, cryptography, social networks, etc. Topic varies by semester. Prerequisite: varies by topic.

MATH 222. Differential Equations for Engineers. .5 Credits.**Offered Spring Semester Only; Lecture hours:3**

First order differential equations, second order linear equations, higher order linear equations, numerical approximations. Prerequisite: MATH 211. Open only to civil engineering and computer science engineering students. Not open to students who have taken MATH 212.

MATH 226. Probability and Statistics for Engineers. .5 Credits.**Offered Fall Semester Only; Lecture hours:3**

Descriptive modeling and statistics, sampling and experimental design, discrete and continuous random variables, central limit theorem, and elementary inference. Prerequisite: MATH 202. Open only to engineering students and students in computer science. Not open to students who have taken MATH 216.

MATH 240. Combinatorics and Graph Theory. .5 Credits.**Offered Spring Semester Only; Lecture hours:3**

Counting techniques and traversal problems. Does not count toward the major. Students join MATH 241 mid-semester. Corequisite: MATH 280. Only for computer science students or students seeking secondary certification.

MATH 241. Discrete Structures. 1 Credit.**Offered Spring Semester Only; Lecture hours:3**

Logic, sets; mathematical induction; relations, functions; combinatorics and graph theory. Does not count toward the mathematics major. Prerequisite: MATH 202.

MATH 245. Linear Algebra. 1 Credit.**Offered Both Fall and Spring; Lecture hours:3**

Linear equations, matrices, vector spaces, linear transformations, determinants, eigenvalues. Prerequisite: MATH 202.

MATH 280. Logic, Sets, and Proofs. 1 Credit.**Offered Both Fall and Spring; Lecture hours:3**

Logic, sets; proof techniques; relations, functions, sequences and convergence; cardinality. Skills and tools for independent reading, problem solving and exploration. Prerequisite: MATH 211 or MATH 245.

MATH 291. Undergraduate Readings. .5-2 Credits.**Offered Either Fall or Spring; Lecture hours:Varies; Repeatable**

Readings and research in special topics at an intermediate level. Prerequisites: permission of the instructor, adviser, and department chair.

MATH 303. Probability. 1 Credit.**Offered Both Fall and Spring; Lecture hours:3**

Elementary probability, random variables, moments, central limit theorem, conditional expectation, statistical distributions derived from the normal distribution. Probability simulations and applications from various fields. Prerequisite: MATH 211. Crosslisted as MATH 603.

MATH 305. Statistical Modeling. 1 Credit.**Offered Spring Semester Only; Lecture hours:3**

Regression and analysis of (co)variance. Model diagnosis and remediation. Model selection, multicollinearity, logistic regression. R or SAS will be used. Prerequisites: MATH 216 or equivalent, MATH 245, and MATH 303 or permission of the instructor. Crosslisted as MATH 605.

MATH 307. Statistical Design of Scientific Studies. 1 Credit.**Offered Spring Semester Only; Lecture hours:3**

Experiments, observational studies. Completely randomized, block, mixed models, crossed, nested design. Simple random, stratified, cluster sampling. Estimation procedures, sample size calculations. Uses R or SAS. Prerequisite: MATH 217 or MATH 303. Crosslisted as MATH 607.

MATH 308. Real Analysis I. 1 Credit.**Offered Both Fall and Spring; Lecture hours:3**

Real numbers and elementary topology of Cartesian spaces, convergence, continuity, differentiation, and history of the development of analysis. Prerequisites: MATH 211, MATH 245, and MATH 280.

MATH 311. Theory of Numbers. 1 Credit.**Offered Alternate Fall or Spring; Lecture hours:3**

Classical number theory in an algebraic setting. Topics include unique factorization, diophantine equations, and linear and quadratic congruences. Advanced topics from algebraic or analytic number theory. Prerequisites: MATH 245 and MATH 280 and permission of the instructor. Crosslisted as MATH 611.

MATH 319. Topics in Advanced Mathematics. 1 Credit.**Offered Alternate Fall or Spring; Lecture hours:3; Repeatable**

Special topics, to be selected from algebra, analysis, geometry, statistics, applied mathematics, etc. Crosslisted as MATH 619.

MATH 320. Abstract Algebra I. 1 Credit.**Offered Both Fall and Spring; Lecture hours:3**

Groups and rings; homomorphisms and isomorphism theorems; history of the development of algebra. Additional selected topics. Prerequisites: MATH 245 and MATH 280.

MATH 333. Topology. 1 Credit.**Offered Alternate Fall or Spring; Lecture hours:3**

Topological spaces, connectedness, compactness, continuity, separation, and countability axioms. Metric, product, function, and uniform spaces. Prerequisites: MATH 211 and MATH 280, or permission of the instructor. Crosslisted as MATH 633.

MATH 335. Geometry. 1 Credit.**Offered Fall Semester Only; Lecture hours:3**

Historical and axiomatic foundations of geometry. Euclidean and non-Euclidean geometries. Prerequisite: MATH 280 or permission of the instructor. Crosslisted as MATH 635.

MATH 343. Numerical Analysis. 1 Credit.**Offered Fall Semester Only; Lecture hours:3,Lab:2**

Floating point arithmetic, development of computational algorithms and error estimates for root approximation, interpolation and approximation by polynomials, numerical differentiation and integration, cubic splines, least-squares, linear systems, lab component. Prerequisites: MATH 211 and CSCI 203, or permission of the instructor. Crosslisted as MATH 643.

MATH 345. Advanced Linear Algebra. 1 Credit.**Offered Alternate Fall or Spring; Lecture hours:3**

Systems of linear equations, determinants, vector spaces, canonical forms for linear transformations and matrices, bilinear forms, inner product spaces, applications to such other areas as geometry, differential equations, linear programming. Prerequisites: MATH 245 and either MATH 280 or permission of the instructor. Crosslisted as MATH 645.

MATH 350. Methods in Applied Mathematics. 1 Credit.**Offered Alternate Fall or Spring; Lecture hours:3**

Techniques drawn from partial differential equations, transform methods, Fourier and complex analysis, and variational calculus. Prerequisite: MATH 212 or MATH 222 or permission of the instructor. Crosslisted as MATH 650.

MATH 358. Topics in Operations Research. 1 Credit.**Offered Spring Semester Only; Lecture hours:3**

Mathematical and statistical techniques in operations research. Queueing theory. Additional topics may include simulation, forecasting, non-linear programming, inventory models. Methods and applications drawn from various fields. Prerequisite: MATH 303 or permission of the instructor. Crosslisted as MATH 658.

MATH 362. Complex Analysis. 1 Credit.**Offered Alternate Fall or Spring; Lecture hours:3**

Limits, analytic functions, integrals including contour integrals. Cauchy's Integral Theorem, entire functions and singularities. Prerequisites: MATH 211 and MATH 280, or permission of the instructor. Crosslisted as MATH 662.

MATH 378. Seminar. .5 Credits.**Offered Either Fall or Spring; Lecture hours:2; Repeatable**

Seminar based on topics from algebra, analysis, topology, differential equations, statistics, or applied mathematics; topics selected according to demand or interest. Prerequisite: permission of the instructor. Crosslisted as MATH 678.

MATH 391. Reading and Research. .5-2 Credits.**Offered Either Fall or Spring; Lecture hours:Varies; Repeatable**

Reading and research in various topics for qualified undergraduate students. Prerequisite: permission of the instructor.

MATH 404. Mathematical Statistics. 1 Credit.**Offered Alternate Fall or Spring; Lecture hours:3**

Point and interval estimation, hypothesis testing, Fisher's likelihood theory, frequentist versus Bayesian approach, computational statistics. Prerequisites: MATH 216 or equivalent and MATH 303 or permission of the instructor.

MATH 409. Real Analysis II. 1 Credit.**Offered Alternate Fall or Spring; Lecture hours:3**

Continuation of MATH 308. Integration theory and advanced topics in analysis. Prerequisite: MATH 308. Crosslisted as MATH 609.

MATH 417. Topics in Mathematics and Statistics. 1 Credit.**Offered Either Fall or Spring; Lecture hours:3**

Topics in statistics and mathematics. This course is designed for seniors to satisfy the Culminating Experience requirement. Prerequisites: MATH 280 and a 300-level mathematics course or permission of the instructor.

MATH 446. Abstract Algebra II. 1 Credit.**Offered Alternate Fall or Spring; Lecture hours:3**

Advanced topics in group theory including solvable groups, field theory and Galois theory. Prerequisite: MATH 320. Crosslisted as MATH 646.

MATH 491. Reading and Research. .5-2 Credits.**Offered Either Fall or Spring; Lecture hours:Varies; Repeatable**

Reading and research in various topics for qualified undergraduates or graduate students at a level appropriate for a Culminating Experience. Prerequisite: permission of the instructor, adviser, and department chair.