

# MATHEMATICAL SCIENCES, BACHELOR OF SCIENCE (B.S.) WITH A CONCENTRATION IN GENERAL MATHEMATICAL SCIENCES

The curriculum in mathematical sciences promotes understanding of the mathematical sciences and their structures, uses and relationships to other disciplines. To this end, the scholarly growth of the faculty and students in the mathematical sciences is nurtured through study, research and a high standard of teaching. The curriculum provides a sound foundation for the student seeking to enter a career with a technological orientation or for the student who wishes to pursue graduate study in applied mathematics, biomathematics, mathematics, operations research, statistics, teaching mathematics in secondary schools or related fields.

A Bachelor of Science is offered jointly by the Department of Mathematics and Applied Mathematics and the Department of Statistical Sciences and Operations Research.

## Student learning outcomes

### Upon completing this program:

- Students will write mathematics (not including mathematical proofs) clearly, concisely and correctly.
- Students will write mathematical proofs clearly, concisely and correctly.
- Students will solve mathematical problems.
- Students will solve and interpret mathematical problems which originate from applications outside of mathematics.
- Students will use technology to solve and/or explore mathematics problems.
- Students will read and comprehend mathematical works.
- Students will collaborate on projects.
- Students will make effective presentations to demonstrate their understanding of mathematical ideas.
- Students will write prose about mathematics.

## Special requirements

The B.S. in Mathematical Sciences requires a minimum of 120 credits. Along with the general education requirements of the College of Humanities and Sciences and the undergraduate degree requirements, students are required to take core courses and fulfill specific requirements for the degree.

Based on the results of the Mathematics Placement Test, students may be required to take MATH 151. No more than one course in mathematics (MATH) at the 100 level can count for the general requirements toward the degree. Credit for 100-level mathematical sciences courses cannot be applied toward the mathematical sciences courses required for the major in mathematical sciences.

## Double major

Students who meet the requirements for two of the concentrations within the mathematical sciences curriculum can receive a double major. To initiate a double major, students must obtain the appropriate form from the Office of Records and Registration.

## Second baccalaureate degree

For students possessing a bachelor's degree and wishing to gain undergraduate preparation in an area of mathematical sciences, second baccalaureate degrees are offered through the department. For detailed information about these programs, refer to the "Academic regulations and general degree requirement" section of this bulletin.

## Degree requirements for Mathematical Sciences, Bachelor of Science (B.S.) with a concentration in general mathematical sciences

Course	Title	Hours
General education ( <a href="http://bulletin.vcu.edu/undergraduate/undergraduate-study/general-education-curriculum/">http://bulletin.vcu.edu/undergraduate/undergraduate-study/general-education-curriculum/</a> )		
Select 12-13 credits from general education foundations and 17-18 credits from areas of inquiry.		30
<b>Major requirements</b>		
• Major core requirements		
MATH 201	Calculus with Analytic Geometry II <sup>1</sup>	4
MATH 307	Multivariate Calculus <sup>1</sup>	4
MATH 310	Linear Algebra <sup>1</sup>	3
• Additional major requirements		
MATH 300	Introduction to Mathematical Reasoning <sup>1</sup>	3
• Concentration requirements		
Select one of the two course groups.		12-13
Group 1		
MATH 407	Advanced Calculus	
MATH 490	Mathematical Expositions	
MATH 255	Introduction to Computational Mathematics	
or CMSC 245	Introduction to Programming Using C++	
or EGRE 245	Engineering Programming	
MATH 301	Differential Equations	
or OPER 327	Mathematical Modeling	
Group 2		
SSOR 490	Developing Professional Skills in Operations Research and Statistics	
SSOR 495	Expositions in Statistical Sciences and Operations Research	
STAT 309	Introduction to Probability Theory	
STAT 321	Introduction to Statistical Computing	
or MATH 255	Introduction to Computational Mathematics	
or CMSC 245	Introduction to Programming Using C++	
or EGRE 245	Engineering Programming	
STAT 403	Introduction to Stochastic Processes	
Concentration electives		
Select one of the following options:		12-18

Additional upper-division credits in MATH, STAT or OPER, with at least nine credits from course offerings at 400 to 500 level  
 Additional upper-division credits in MATH, STAT or OPER, with at least six credits from course offerings at 400 to 500 level and complete a minor or double major

**Ancillary requirements**

HUMS 202	Choices in a Consumer Society	1
MATH 200	Calculus with Analytic Geometry I (satisfies general education quantitative foundations) <sup>1</sup>	4
STAT 212	Concepts of Statistics	3
Experiential fine arts <sup>2</sup>		1-3
Foreign language through the 102 level (by course or placement)		0-6
Natural science sequence: Select one sequence from list below (satisfies general education BOK for natural sciences and AOI for scientific and logical reasoning)		8-10
Natural science elective (different from chosen science sequence)		3-5
<b>Open electives</b>		
Select any course.		21-40
<b>Total Hours</b>		<b>120</b>

<sup>1</sup>

These courses/credits require a minimum grade of C.

<sup>2</sup>

Course offered by the School of the Arts

The minimum number of credit hours required for this degree is 120.

**Natural science sequence**

Course	Title	Hours
Select one of the following sequences: 8-10		
<b>Sequence 1</b>		
BIOL 151	Introduction to Biological Sciences I (satisfies general education BOK for natural sciences and AOI for scientific and logical reasoning)	3
BIOZ 151	Introduction to Biological Science Laboratory I	1
BIOL 152	Introduction to Biological Sciences II	3
BIOZ 152	Introduction to Biological Science Laboratory II	1
<b>Sequence 2</b>		
CHEM 101	General Chemistry I (satisfies general education BOK for natural sciences and AOI for scientific and logical reasoning)	3
CHEZ 101	General Chemistry Laboratory I (satisfies general education AOI for scientific and logical reasoning)	1
CHEM 102	General Chemistry II	3
CHEZ 102	General Chemistry Laboratory II	1
<b>Sequence 3</b>		

PHYS 201	General Physics I (satisfies general education BOK for natural sciences and AOI for scientific and logical reasoning)	4
PHYS 202	General Physics II	4
<b>Sequence 4</b>		
PHYS 207	University Physics I (satisfies general education BOK for natural sciences and AOI for scientific and logical reasoning)	5
PHYS 208	University Physics II	5

What follows is a sample plan that meets the prescribed requirements within a four-year course of study at VCU. Please contact your adviser before beginning course work toward a degree.

**Freshman year**

Fall semester		Hours
MATH 200	Calculus with Analytic Geometry I (satisfies general education quantitative foundations)	4
UNIV 101	Introduction to the University	1
UNIV 111	Focused Inquiry I (satisfies general education UNIV foundations)	3
Play course	video for Focused Inquiry I	
	General education course (select AOI for creativity, innovation and aesthetic inquiry)	3
	General education course (select AOI for diversities in the human experience)	3

**Term Hours: 14**

**Spring semester**

HUMS 202	Choices in a Consumer Society	1
MATH 201	Calculus with Analytic Geometry II	4
STAT 212	Concepts of Statistics	3
UNIV 112	Focused Inquiry II (satisfies general education UNIV foundations)	3
Play course	video for Focused Inquiry II	
Experiential fine arts		1-3
	General education course (select AOI for global perspectives)	3

**Term Hours: 15-17**

**Sophomore year**

Fall semester		Hours
MATH 300	Introduction to Mathematical Reasoning	3
MATH 307	Multivariate Calculus	4
UNIV 200	Inquiry and the Craft of Argument (satisfies general education UNIV foundations)	3
Foreign language 101		3
Group course		3
MATH 255	Introduction to Computational Mathematics (Group 1)	3
STAT 321	Introduction to Statistical Computing (Group 2)	3

**Term Hours: 16**

**Spring semester**

MATH 310	Linear Algebra	3
Select one:		3
MATH 301	Differential Equations	3
OPER 327	Mathematical Modeling (Group 1)	3
STAT 309	Introduction to Probability Theory (Group 2)	3
Foreign language 102		3
General education course (select BOK to complete breadth of knowledge requirement)		3
General education course (select BOK to complete breadth of knowledge requirement)		3

**Term Hours: 15**

**Junior year**

**Fall semester**

Select one:		3
MATH 407	Advanced Calculus (Group 1)	3
STAT 403	Introduction to Stochastic Processes	3
Natural sciences sequence (select one of the following) (satisfies general education BOK for natural sciences and AOI for scientific and logical reasoning)		4-5
BIOL 151 & BIOZ 151	Introduction to Biological Sciences I and Introduction to Biological Science Laboratory I	-
CHEM 101 & CHEZ 101	General Chemistry I and General Chemistry Laboratory I	-
PHYS 201	General Physics I	-
PHYS 207	University Physics I	-
Open electives		7

**Term Hours: 14-15**

**Spring semester**

Concentration electives (upper level)		6
Natural sciences sequence (Select one of the following with appropriate matching course.)		4-5
BIOL 152 & BIOZ 152	Introduction to Biological Sciences II and Introduction to Biological Science Laboratory II	-
CHEM 102 & CHEZ 102	General Chemistry II and General Chemistry Laboratory II	-
PHYS 202	General Physics II	-
PHYS 208	University Physics II	-
Open electives		6

**Term Hours: 16-17**

**Senior year**

**Fall semester**

SSOR 490	Developing Professional Skills in Operations Research and Statistics (taken by Group 2 only)	3
Concentration electives (400-500 level; Group 1 takes six credits; Group 2 takes three credits)		3-6
Natural sciences elective <sup>1</sup>		3-5
Open electives		6

**Term Hours: 15-17**

**Spring semester**

MATH 490 or SSOR 495	Mathematical Expositions (Group 1 capstone) or Expositions in Statistical Sciences and Operations Research	1-2
Concentration elective (upper-level) or elective to complete minor or double major		3
Concentration elective (400-500 level) or elective to complete minor or double major		3-4
Open electives		6
<b>Term Hours:</b>		<b>15</b>
<b>Total Hours:</b>		<b>120-126</b>

<sup>1</sup>

Different science than chosen for sequence.

**The minimum number of credit hours required for this degree is 120.**

Students registering for:

Course	Title	Hours
CMSC 255	Introduction to Programming	4
MATH 131	Introduction to Contemporary Mathematics	3
MATH 141	Algebra with Applications	4
MATH 151	Precalculus Mathematics	4
MATH 200	Calculus with Analytic Geometry I	4
MATH 211	Mathematical Structures	3
MATH 300	Introduction to Mathematical Reasoning	3
STAT 208	Statistical Thinking	3
STAT 210	Basic Practice of Statistics	3

must place into these courses either from receiving VCU credit for stated prerequisite courses (for instance, MATH 151 is a stated prerequisite course for MATH 200) or from a satisfactory score (within a 39-month period immediately preceding the beginning of the course) on the VCU Mathematics Placement Test.

**MATH 001. Elementary Algebra. 0 Hours.**

Semester course; 3 lecture or 3 laboratory/tutorial hours. No credit. Prerequisite: permission of the department chair. The purpose of this course is to provide laboratory and tutorial instruction for those seeking remediation or review of high school algebra. Topics include basic properties of real numbers, operations with algebraic expressions, solution of equations and inequalities, exponents and radicals, introduction to functions and graphing.

**MATH 120. Seeing, Playing, Deciding – This is Math?. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Students will learn about the beautiful and often surprising interactions between mathematics and three broad areas: the visual arts, games and public policy. Representative topics include perspective in the visual arts; tessellations; origami; games and strategies in recreational settings and in the social and natural sciences; the often hidden mathematics behind public policy; and assessing quantitative claims in the public arena.

**MATH 121. Perspective Geometry. 1 Hour.**

Short course (5 weeks); 3 lecture hours. 1 credit. Students will examine ways in which Renaissance artists who developed linear perspective in geometry in order to paint scenes realistically influenced the development of mathematics and geometry. Topics covered will include the foundations of projective geometry. Pascal's mystic hexagram, Brianchon's Theorem and duality. A need for higher mathematics will also be introduced and explained. MATH 121-122-123 fulfills the math requirement for art students. The sequence can be taken in any order.

**MATH 122. Tessellations. 1 Hour.**

Short course (5 weeks); 3 lecture hours. 1 credit. Students will examine ways in which mathematics is rooted in both natural philosophy and art by examining tiling theory. Course topics include Penrose tilings, symmetries and various other tessellations. MATH 121-122-123 fulfills the math requirement for art students. The sequence can be taken in any order.

**MATH 123. Visualization. 1 Hour.**

Short course (5 weeks); 3 lecture hours. 1 credit. Students will examine ways in which mathematics has been visualized artistically and will develop their own way to express a mathematical idea. Topics covered will include fractals, knots, minimal surfaces, non-Euclidean geometry and the fourth dimension. MATH 121-122-123 fulfills the math requirement for art students. The sequence can be taken in any order.

**MATH 129. Introduction to College Algebra. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. A study in algebraic functions through graphical, numerical, symbolic and verbal representations. Topics include the exploration of linear, quadratic, polynomial, exponential and logarithmic functions. Real-world applications and the development of algebra skills are an integral part of the course. This course will not satisfy any general education requirements. Students may receive credit toward graduation for only one of MATH 129 and MATH 141.

**MATH 131. Introduction to Contemporary Mathematics. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisite: satisfactory score on the VCU Mathematics Placement Test within the one-year period immediately preceding the beginning of the course. An exception to this policy is made in the case where the stated alternative prerequisite course has been completed at VCU. Topics include optimization problems, data handling, growth and symmetry, and mathematics with applications in areas of social choice. Major emphasis is on the process of taking a real-world situation, converting the situation to an abstract modeling problem, solving the problem and applying what is learned to the original situation. Does not serve as a prerequisite for MATH 151 or other advanced mathematical sciences courses.

**MATH 139. College Algebra with Applications. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 129 with a minimum grade of C or placement through the VCU Math Placement Test within the one-year period immediately preceding the beginning of the course. An in-depth exploration of the characteristics, graphs and applications of linear, exponential, logarithmic and power functions. Topics include fundamental concepts of functions, including but not limited to transformations, inverses, arithmetic operations and composition. Opportunities to investigate, analyze and communicate findings from real-world scenarios will be supported by the use of technology. Students may receive credit toward graduation for only one of MATH 139 and MATH 141.

**MATH 141. Algebra with Applications. 4 Hours.**

Semester course; 4 lecture hours. 4 credits. Prerequisite: one year of high school algebra and satisfactory score on the VCU Mathematics Placement Test within the one-year period immediately preceding the beginning of the course. Topics include concepts and applications of linear, exponential, logarithmic, power and quadratic functions; graphing; transformations and inverses of functions; algebra and composition of functions. Students may not receive credit toward graduation for both MATH 141 and either MATH 129 or MATH 139.

**MATH 151. Precalculus Mathematics. 4 Hours.**

Semester course; 3 lecture and 1 mathematics laboratory/recitation hours. 4 credits. Prerequisite: MATH 139 or MATH 141 with a minimum grade of C, or satisfactory score on the VCU Mathematics Placement Test within the one-year period immediately preceding the beginning of the course. An exception to this policy is made in the case where the stated alternative prerequisite course has been completed at VCU. Concepts and applications of algebra and trigonometry. Topics include graphics, transformations and inverses of functions; linear, exponential, logarithmic, power, polynomial, rational and trigonometric functions.

**MATH 191. Topics in Mathematics. 1-3 Hours.**

Semester course; 1-3 credits. May be repeated for credit. A study of selected topics in mathematics. For a course to meet the general education requirements it must be stated in the Schedule of Classes. See the Schedule of Classes for specific topics to be offered each semester and prerequisites.

**MATH 200. Calculus with Analytic Geometry I. 4 Hours.**

Semester course; 4 lecture hours. 4 credits. Prerequisite: MATH 151 with a minimum grade of C or satisfactory score on the VCU Mathematics Placement Test within the one-year period immediately preceding the beginning of the course. Limits, continuity, derivatives, differentials, antiderivatives and definite integrals.

**MATH 201. Calculus with Analytic Geometry II. 4 Hours.**

Semester course; 4 lecture hours. 4 credits. Prerequisite: MATH 200 with a minimum grade of C. Applications of differentiation and integration. Selected topics in analytic geometry. Infinite series.

**MATH 211. Mathematical Structures. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 151, MATH 200, MATH 201 or BUSN 212\* with a minimum grade of C, or calculus-level placement on the VCU Mathematics Placement Test within the one-year period immediately preceding enrollment in the course. An alternative prerequisite course may be approved at the discretion of the academic adviser. An introduction to mathematical logic and set theory, including applications in Boolean algebras and graph theory. \*Previously MGMT 212, SCMA 212.

**MATH 230. Mathematics in Civilization. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. For Honors College students only. The growth, development and far-reaching applications of trigonometry, navigation, cartography, logarithms and algebra through ancient, medieval, post-Renaissance and modern times are explored. Will include methods to solve mathematical problems using various historical procedures and will involve collaboration through group projects.

**MATH 255. Introduction to Computational Mathematics. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 201 with a minimum grade of C. (A core course for mathematics/applied mathematics majors.) An introduction to computer algebra systems (CAS) and their use in mathematical, scientific and engineering investigations/computations. Introductory mathematical computer programming using a CAS, including implementation of problem-specific algorithms.

**MATH 291. Topics in Mathematics. 1-3 Hours.**

Semester course; 1-3 credits. May be repeated for credit. A study of selected topics in mathematics. See the Schedule of Classes for specific topics to be offered each semester and prerequisites.

**MATH 300. Introduction to Mathematical Reasoning. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 201 with a minimum grade of C. (A core course for mathematics/applied mathematics majors.) An introduction to basic concepts of mathematical reasoning and the writing of proofs in an elementary setting. Direct, indirect and induction proofs. Illustrations of the concepts include basic proofs from mathematical logic, elementary set theory, elementary number theory, number systems, foundations of calculus, relations, equivalence relations, functions and counting with emphasis on combinatorial proofs.

**MATH 301. Differential Equations. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 201 with a minimum grade of C. Solutions of ordinary differential equations of first order. Solutions of higher order linear differential equations with constant coefficients and variable coefficients by the methods of undetermined coefficients and variation of parameters, solutions by Laplace transforms and applications.

**MATH 302. Numerical Calculus. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 255 (or knowledge of a programming language/mathematical software package) and MATH 201, each with a minimum grade of C, or permission of the instructor. An introduction to numerical algorithms for solving systems of linear equations, finding zeroes, numerical differentiation and definite integration, optimization.

**MATH 303. Investigations in Geometry. 3 Hours.**

Semester course; 2 lecture and 3 laboratory hours. 3 credits. Prerequisite: MATH 361 with a minimum grade of C. Enrollment is restricted to students majoring in the liberal studies for early and elementary education in the Bachelor of Interdisciplinary Studies program. A study of topics in Euclidean geometry to include congruence, similarity, measurement, coordinate geometry, symmetry and transformation in both two and three dimensions. These topics will be investigated using manipulatives and computer software.

**MATH 305. Elementary Number Theory. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 300 with a minimum grade of C. Divisibility, congruences, Euler phi-function, Fermat's Theorem, primitive roots, Diophantine equations.

**MATH 307. Multivariate Calculus. 4 Hours.**

Semester course; 4 lecture hours. 4 credits. Prerequisite: MATH 201 with a minimum grade of C. The calculus of vector-valued functions and of functions of more than one variable. Partial derivatives, multiple integrals, line integrals, surface integrals and curvilinear coordinates. Lagrange multipliers; theorems of Green, Gauss and Stokes. Applications.

**MATH 310. Linear Algebra. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 201 with a minimum grade of C. Systems of linear equations, vector spaces, linear dependence, bases, dimensions, linear mappings, matrices, determinants, quadratic forms, orthogonal reduction to diagonal form, eigenvalues and geometric applications.

**MATH 350. Introductory Combinatorics. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 201 with a minimum grade of C. An introduction to basic combinatorial concepts such as combinations, permutations, binomial coefficients, Fibonacci numbers and Pascal's triangle; basic theorems such as the pigeonhole principle and Newton's binomial theorem; algorithms such as bubble sort and quicksort; and discussion of basic applications such as chessboard problems, combinatorial games, magic squares and Latin squares.

**MATH 351. Applied Abstract Algebra. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 300 with a minimum grade of C. A survey of several areas in applied abstract algebra which have applications in computer science such as groups, codes, matrix algebra, finite fields and advanced graph theory.

**MATH 353. Experimental Mathematics. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 201 with a minimum grade of C. An introduction to a mathematical computing package, computer manipulation of lists and sets, and symbolic computing. Numerical computation will be used to investigate mathematical objects, such as integers, prime numbers, graphs, matrices and to identify properties and patterns among these objects. Random methods will be used to explore properties and patterns in long sequences and large collections.

**MATH 356. Graphs and Algorithms. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 201 with a minimum grade of C. An introduction to basic graph theoretic concepts such as trees, colorings and matchings; basic theorems such as the handshaking lemma and the Gallai identities; algorithms such as Dijkstra's and Kruskal's; and discussion of famous open problems such as finding shortest tours for a traveling salesman.

**MATH 361. Numbers and Operations. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisite: TEDU 101 with a minimum grade of C; and either MATH 131 with a minimum grade of C or satisfactory score on the VCU Mathematics Placement Test within the one-year period immediately preceding the beginning of the course. Ways of representing numbers, relationships between numbers, number systems, the meanings of operations and how they relate to one another, and computation within the number systems as a foundation for algebra. Structured observations and tutoring of elementary-level students. Restricted to students majoring in the liberal studies concentration for early and elementary education in the Bachelor of Interdisciplinary Studies program.

**MATH 362. Algebra and Functions. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 361 with a minimum grade of C. Topics include algebraic concepts, linear, quadratic, exponential, logarithmic, trigonometric functions including graphical modeling of physical phenomena. Attention will be given to the use of graphing technology, the transition from arithmetic to algebra, working with quantitative change, and the description and prediction of change. Structured observations and tutoring of elementary-level students. Restricted to B.I.S. students in the liberal studies for early and elementary education concentration.

**MATH 380. Introduction to Mathematical Biology. 4 Hours.**

Semester course; 3 lecture and 2 laboratory hours. 4 credits. Prerequisites: MATH 200 and BIOL 151, both with a minimum grade of C, or permission of instructor. An introduction to mathematical biology. Various mathematical modeling tools will be covered and implemented in a range of biological areas. Additionally, the collaborative research process will be presented and discussed. Crosslisted as: BNFO 380.



**MATH 391. Topics in Mathematics. 1-3 Hours.**

Semester course; 1-3 credits. May be repeated for credit. A study of selected topics in mathematics. See the Schedule of Classes for specific topics to be offered each semester and prerequisites.

**MATH 401. Introduction to Abstract Algebra. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 300 and MATH 310, each with a minimum grade of C. An introduction to groups, rings and fields from an axiomatic point of view. Coset decomposition and basic morphisms.

**MATH 404. Algebraic Structures and Functions. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 300 and MATH 310, each with a minimum grade of C; one additional mathematical sciences course; and permission of instructor. Semigroups, groups, rings, integral domains and fields. Exponential, logarithmic and trigonometric functions. Graphing in parametric and polar coordinates. Arithmetic and geometric sequences and series.

**MATH 407. Advanced Calculus. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 300 with a minimum grade of C. Theoretical aspects of calculus. Topics include properties of real numbers, countable and uncountable sets, sequences and series, limits, continuity, derivatives, and Riemann integration.

**MATH 409. General Topology. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 407 with a minimum grade of C. Foundations and fundamental concepts of point-set topology. Topological spaces, continuity, convergence, connected sets, compactness, product spaces, quotient spaces, function spaces, separation properties.

**MATH 415. Numerical Methods. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 255, MATH 301 and MATH 310, each with a minimum grade of C. Numerical methods for interpolation, solving systems of linear equations and initial value problems (ordinary differential equations) and the exploration of computational error.

**MATH 427. Excursions in Analysis: Real. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 307, MATH 310 and MATH 407, each with a minimum grade of C. May be repeated once for credit with a different emphasis and permission of the instructor. Intensive study of ideas and applications from real analysis.

**MATH 428. Excursions in Analysis: Complex. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 307, MATH 310 and MATH 407, each with a minimum grade of C. May be repeated once for credit with a different emphasis and permission of the instructor. Intensive study of ideas and applications from complex analysis.

**MATH 429. Excursions in Analysis: Applied. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 301, MATH 307, MATH 310 and MATH 407, each with a minimum grade of C. May be repeated once for credit with a different emphasis and permission of the instructor. Intensive study of ideas and applications from applied analysis.

**MATH 430. The History of Mathematics. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 300, MATH 307, MATH 310, and either MATH 301 or OPER 327, all with a minimum grade of C. Surveys major trends in the development of mathematics from ancient times through the 19th century and considers the cultural and social contexts of mathematical activity.

**MATH 431. Expositions in Modern Mathematics. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 300, MATH 307, MATH 310, and either MATH 301 or OPER 327, all with a minimum grade of C. Descriptively studies several major ideas relevant to present-day mathematics, such as the advent of pure abstraction, difficulties in the logical foundations of mathematics, the impact of mathematics and statistics in the 20th century and the computer revolution.

**MATH 432. Ordinary Differential Equations. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 300, MATH 301, MATH 307 and MATH 310, each with a minimum grade of C. Existence and uniqueness of solutions, linearization and stability analysis, Lyapunov stability theory, periodic solutions, and bifurcations. Applications and simulations are emphasized.

**MATH 433. Partial Differential Equations. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 300, MATH 301, MATH 307 and MATH 310, each with a minimum grade of C. Parabolic (heat), hyperbolic (wave) and elliptic (steady-state) partial differential equations are studied. Solution techniques such as separation of variables, reflection methods, integral transform methods and numerical methods are demonstrated. Practical problems and applications are emphasized.

**MATH 434. Discrete Dynamical Systems. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 300, MATH 301, MATH 307 and MATH 310, each with a minimum grade of C. Theory and applications of difference equations including existence and uniqueness of solutions, linearization and stability, periodic solutions, and bifurcations.

**MATH 435. Mathematical and Computational Modeling. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 301 and MATH 310, each with minimum grade of C. Focuses on general mathematical modeling principles. A variety of application areas are explored through a complete model development cycle. This process involves the theoretical development of a mathematical model, implementation of a computational solution and exploration of the solution within the context of the application area.

**MATH 454. Using Technology in the Teaching of Mathematics. 3 Hours.**

Semester course; 2 lecture and 2 laboratory hours. 3 credits. Prerequisites: MATH 200 and STAT 212, each with a minimum grade of C; six additional credits in the mathematical sciences; and permission of the instructor. Using graphing calculators, calculator-based labs and computer software packages in teaching topics in algebra, geometry, trigonometry, statistics, finance and calculus.

**MATH 480. Methods of Applied Mathematics for the Life Sciences: Discrete. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 301, MATH 307, MATH 310 and MATH 380, each with a minimum grade of C. Focuses on the use of discrete dynamical system models to describe phenomena in biology and medicine. Students will explore the theoretical mathematics necessary to analyze these models. Computational solutions to these models will be developed and implemented to validate the models and to further explore the biological phenomena.

**MATH 481. Methods of Applied Mathematics for the Life Sciences: ODE.****3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 301, MATH 307, MATH 310 and MATH 380, each with a minimum grade of C. Focuses on the use of ordinary differential equation models to describe phenomena in biology and medicine. Students will explore the theoretical mathematics necessary to analyze these models. Computational solutions to these models will be developed and implemented to validate the models and to further explore the biological phenomena.

**MATH 482. Methods of Applied Mathematics for the Life Sciences: PDE.****3 Hours.**

Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 301, MATH 307, MATH 310 and MATH 380, each with a minimum grade of C. Focuses on the use of partial differential equation models to describe phenomena in biology and medicine. Students will explore the theoretical mathematics necessary to analyze these models. Computational solutions to these models will be developed and implemented to validate the model and to further explore the biological phenomena.

**MATH 490. Mathematical Expositions. 3 Hours.**

Semester course; 2 lecture hours. 2 credits. Prerequisites: UNIV 200 or HONR 200 with a minimum grade of C. Restricted to seniors in mathematical sciences with at least 85 credit hours taken toward the degree. Required for all majors in the Department of Mathematics and Applied Mathematics. A senior capstone course in the major designed to help students attain proficiency in expository mathematical writing and oral presentation, which require the efficient and effective use of mathematics and the English language. Students will learn a variety of topics in mathematics, write reviews of selected award-winning mathematics papers and write a senior paper.

**MATH 492. Independent Study. 1-4 Hours.**

Semester course; variable hours. 1-4 credits. Maximum 4 credits per semester; maximum total of 6 credits. Generally open only to students of junior or senior standing who have acquired at least 12 credits in the departmental discipline. Determination of the amount of credit and permission of instructor and department chair must be procured prior to registration for the course. The student must submit a proposal for investigating some area or problem not contained in the regular curriculum. The results of the student's study will be presented in a report.

**MATH 493. Mathematical Sciences Internship. 3 Hours.**

Semester course; the equivalent of at least 15 work hours per week for a 15-week semester. 3 credits. Mathematical sciences majors only with junior or senior standing. Admission by permission from the department chair. Through placement in a position in business, industry, government or the university, the student will serve as an intern in order to obtain a broader knowledge of the mathematical sciences and their applications.