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

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. In the Department of Mathematics and Applied Mathematics, students pursuing the Bachelor of Science in Mathematical Sciences can choose a concentration of mathematics, which fosters the understanding of the power and the beauty of pure mathematics and its applications to various branches of knowledge.

Learning outcomes

Upon completing this program, students will know and know how to do the following:

- Pursue goals and careers in education and industry
- Think creatively
- Analyze and write mathematical arguments
- Read and interpret literature
- Use technology in problem-solving and experimentation

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 mathematics

General education requirements

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Hours</th>
</tr>
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<tbody>
<tr>
<td>University Core Education Curriculum (minimum 21 credits)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>UNIV 111 Play course video for Focused Inquiry I</td>
<td>3</td>
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</tr>
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<td>Approved humanities/fine arts</td>
<td>3</td>
<td></td>
</tr>
<tr>
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<td></td>
</tr>
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<td>Total Hours</td>
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Course offered by the School of the Arts

Collateral requirements

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<tr>
<th>Course</th>
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<tbody>
<tr>
<td>HUMS 202</td>
<td>Choices in a Consumer Society</td>
<td>1</td>
</tr>
<tr>
<td>Approved H&amp;S diverse and global communities</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Approved H&amp;S human, social and political behavior (fulfills University Core social/behavioral sciences)</td>
<td></td>
<td></td>
</tr>
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</tr>
<tr>
<td>Approved H&amp;S general education electives</td>
<td>6-8</td>
<td></td>
</tr>
<tr>
<td>Experiential fine arts</td>
<td>1-3</td>
<td></td>
</tr>
<tr>
<td>Foreign language through the 102 level (by course or placement)</td>
<td>0-8</td>
<td></td>
</tr>
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Degree requirements for Mathematical Sciences, Bachelor of Science (B.S.) with a concentration in mathematics

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<td>MATH 200 &amp; MATH 201</td>
<td>Calculus with Analytic Geometry I and Calculus with Analytic Geometry II</td>
<td>8</td>
</tr>
<tr>
<td>MATH 255 or CMSC 245 or EGRE 245</td>
<td>Introduction to Computational Mathematics or Programming Using C++ or Engineering Programming</td>
<td>3</td>
</tr>
<tr>
<td>MATH 300</td>
<td>Introduction to Mathematical Reasoning</td>
<td>3</td>
</tr>
<tr>
<td>MATH 301</td>
<td>Differential Equations</td>
<td>3</td>
</tr>
<tr>
<td>MATH 307</td>
<td>Multivariate Calculus</td>
<td>4</td>
</tr>
<tr>
<td>MATH 310</td>
<td>Linear Algebra</td>
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<td>MATH 428</td>
<td>Excursions in Analysis: Complex</td>
<td>3</td>
</tr>
<tr>
<td>MATH 429</td>
<td>Excursions in Analysis: Applied</td>
<td>3</td>
</tr>
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<td>MATH 490</td>
<td>Mathematical Expositions (capstone)</td>
<td>3</td>
</tr>
<tr>
<td>STAT 212</td>
<td>Concepts of Statistics (fulfills University Core quantitative literacy)</td>
<td>3</td>
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Mathematics concentration electives 2 0-6

Total Hours 42-48

1

A minimum grade of C is required in these courses/credits.

2

Six additional upper-level credits in the mathematical sciences (MATH, STAT, OPER, CMSC) or the completion of a minor or a double major
The minimum total of credit hours required for this degree is 120.

Students registering for:

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<td>CMSC 255</td>
<td>Introduction to Programming</td>
<td>4</td>
</tr>
<tr>
<td>MATH 131</td>
<td>Introduction to Contemporary Math</td>
<td>3</td>
</tr>
</tbody>
</table>

1

Not from general education science and technology list and different science than chosen for sequence.

The minimum total of credit hours required for this degree is 120.
MATH 141. Algebra with Applications. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: 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. An exception to this policy is made in the case where the stated alternative prerequisite course has been completed at VCU. Topics include sets, functions, exponents, logarithms, matrix algebra, systems of linear equations, inequalities, binomial theorems, sequences, series, complex numbers and linear programming.

MATH 151. Precalculus Mathematics. 4 Hours.
Semester course; 3 lecture and 1 mathematics laboratory/recitation hours. 4 credits. Prerequisite: 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 SCMA 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.

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 
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 handshake 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: BINFO 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; the equivalent of at least 15 work hours per week for a 15-week semester. 3 credits. Mathematical sciences majors only with permission of instructor and department chair. Students must submit a proposal 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 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 chairman. 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.