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

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 Statistical Sciences and Operations Research, students pursuing the Bachelor of Science in Mathematical Sciences can choose a concentration of operations research, which focuses on modern mathematical techniques for solving problems arising from other fields, such as engineering, business or economics.

Student learning outcomes

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

Bachelor of Science in Mathematical Sciences core outcomes

- Solve mathematical problems
- Solve and interpret mathematical problems which originate from applications outside of mathematics
- Use technology to solve and/or explore mathematical problems

Operations research concentration-specific outcomes

- Explain the theory of mathematical programming and apply basic mathematical programming methods
- Explain the theory of stochastic models and decision analysis and apply these methods effectively
- Obtain, analyze and interpret the data necessary to perform operations research projects
- Solve a wide variety of operations research problems using the software commonly used in industry, such as Microsoft Excel's Solver, @RISK and AMPL, and common programming software such as Matlab, Python and R
- Model situations in which operations research can be applied
- Apply the mathematics required to perform operations research methods
- Clearly and concisely present technical information in writing
- Clearly and concisely present technical information through oral presentations

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 operations research

Course	Title	Hours
General education (https://bulletin.vcu.edu/undergraduate/undergraduate-study/general-education-curriculum/)		
Select 30 credits of general education courses in consultation with an adviser.		30
Major requirements		
• Major core requirements		
MATH 201	Calculus with Analytic Geometry II [1]	4
MATH 307	Multivariate Calculus [1]	4
MATH 310	Linear Algebra [1]	3
• Additional major requirements		
MATH 300	Introduction to Mathematical Reasoning [1]	3
SSOR 480	Consulting Using Advanced Analytics [1]	3
SSOR 485	Career Planning and Professional Development for Statistics and Operations Research [1]	1
STAT 309	Introduction to Probability Theory [1]	3
• Concentration requirements		
MATH 401	Introduction to Abstract Algebra [1]	3
or MATH 407	Real Analysis	
or MATH 409	General Topology	
OPER 327	Mathematical Modeling [1]	3
OPER 427	Deterministic Operations Research [1]	3
OPER 428	Stochastic Operations Research [1]	3
STAT 403	Introduction to Stochastic Processes [1]	3

Select one of the following computing sequences:		6-7
CMSC 245 & CMSC 246	Introduction to Programming Using C++ and Advanced Programming Using C++	
CMSC 255 & CMSC 256	Object-oriented Programming and Introduction to Data Structures	
EGRE 245 & EGRE 246	Engineering Programming and Advanced Engineering Programming	
Concentration electives		
Select from concentration electives below.		9-12
Ancillary requirements		
HUMS 202	Choices in a Consumer Society	1
MATH 200	Calculus with Analytic Geometry I [1]	4
STAT 212	Concepts of Statistics (satisfies general education quantitative foundations)	3
Experiential fine arts [2]		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
Open electives		
Select any course.		11-26
Total Hours		**120**

[1]

These courses/credits require a minimum grade of C.

[2]

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
Sequence 1		
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
Sequence 2		
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	1
CHEM 102	General Chemistry II	3
CHEZ 102	General Chemistry Laboratory II	1
Sequence 3		
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
Sequence 4		
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

Electives

For the operations research concentration, three electives must be chosen from the following list:

Course	Title	Hours
CMSC 302	Introduction to Discrete Structures	3
CMSC 303	Introduction to the Theory of Computation	3
CMSC 391	Topics in Computer Science [1]	3
CMSC 401	Algorithm Analysis with Advanced Data Structures	3
INFO 364	Database Systems	3
MATH 301	Differential Equations	3
MATH 305	Elementary Number Theory	3
MATH/BNFO 380	Introduction to Mathematical Biology	4
MATH 391	Topics in Mathematics [1]	1-3
MATH 401	Introduction to Abstract Algebra	3
MATH 407	Real Analysis	3
MATH 409	General Topology	3
MATH 432	Ordinary Differential Equations	3
MATH 433	Partial Differential Equations	3
MATH 434	Discrete Dynamical Systems	3
MATH 507	Bridge to Modern Analysis	3
MATH 511	Applied Linear Algebra	3
MATH 515	Numerical Analysis	3
OPER 591	Topics in Operations Research [1]	1-3
SSOR 492	Independent Study [1]	2-4
SSOR 493	Internship	1-3
STAT 305	Intermediate Statistics [2]	3
STAT 310	Introduction to Statistical Inference	3
STAT 314	Applications of Statistics [2]	4
STAT 321	Introduction to Statistical Computing for Data Science	3
STAT 391	Topics in Statistics [1]	3
STAT 421	Statistical Computing for Machine Learning and Artificial Intelligence	3
STAT 422	Structured Problem Solving Using Statistics	3
STAT 423	Nonparametric Statistics	3
STAT 425	Multivariate Statistics	3
STAT 435	Industrial Statistics	3
STAT 441	Applied Statistics for Engineers and Scientists [3]	3

STAT 443	Regression	3
STAT 447	Introduction to Statistical Data Science	3
STAT 475	Time Series	3
STAT/BIOS 513	Mathematical Statistics I	3
STAT/BIOS 514	Mathematical Statistics II	3
STAT 544	Statistical Methods II	3
STAT 546	Linear Models	3
STAT 591	Topics in Statistics [1]	3

1

Special topics and independent study courses require prior approval from the department chair or the student's adviser.

2

Students may choose only one of STAT 305, STAT 314 or STAT 441.

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.

Recommended course sequence/plan of study

Freshman year

Fall semester

		Hours
MATH 200	Calculus with Analytic Geometry I	4
UNIV 101	Introduction to the University	1
UNIV 111 Play course video for Introduction to Focused Inquiry: Investigation and Communication	Introduction to Focused Inquiry: Investigation and Communication (satisfies general education UNIV foundations) [1]	3
General education course [2]		3
General education course [2]		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 (satisfies general education quantitative foundations) [1]	3
UNIV 112 Play course video for Focused Inquiry II	Focused Inquiry II (satisfies general education UNIV foundations) [1]	3
General education course [2]		3
	Term Hours:	14

Sophomore year

Fall semester

MATH 300	Introduction to Mathematical Reasoning	3
OPER 327	Mathematical Modeling	3

UNIV 200	Advanced Focused Inquiry: Literacies, Research and Communication (satisfies general education UNIV foundations) [1]	3
Computing sequence:		
CMSC 245 or CMSC 255 or EGRE 245	Introduction to Programming Using C++ or Object-oriented Programming or Engineering Programming	3-4
Foreign language 101		3
	Term Hours:	15-16

Spring semester

MATH 307	Multivariate Calculus	4
MATH 310	Linear Algebra	3
Computing sequence: Select appropriate matching course from previous semester.		
CMSC 246 or CMSC 256 or EGRE 246	Advanced Programming Using C++ or Introduction to Data Structures or Advanced Engineering Programming	3
Foreign language 102		3
General education course [2]		3
	Term Hours:	16

Junior year

Fall semester

STAT 309	Introduction to Probability Theory	3
Concentration elective		3-4
Experiential fine arts		1-3
General education course [2]		3
Natural sciences sequence (select one of the following) [1]		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	-
	Term Hours:	14-18

Spring semester

STAT 403	Introduction to Stochastic Processes	3
Concentration elective		3-4
Natural sciences elective [3]		3-5
Natural sciences sequence (Select one of the following with appropriate matching course from previous semester.)		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 elective		3
	Term Hours:	16-20

Senior year

Fall semester

MATH 401	Introduction to Abstract Algebra	3
OPER 427	Deterministic Operations Research	3
OPER 428	Stochastic Operations Research	3
SSOR 480	Consulting Using Advanced Analytics	3
SSOR 485	Career Planning and Professional Development for Statistics and Operations Research	1
Open elective		3
	Term Hours:	**16**
Spring semester		
Concentration elective		3-4
Open electives		12
	Term Hours:	**15-16**
	Total Hours:	**120-130**

1

Satisfies a general education requirement (excludes BIOZ 151 and CHEZ 101).

2

Select general education courses in consultation with an adviser.

3

Different science than chosen for sequence.

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

Accelerated B.S. and M.S.

The accelerated B.S. and M.S. program allows qualified students to earn both the B.S. and M.S. in Mathematical Sciences with concentration in operations research in a minimum of five years by completing approved graduate courses during the senior year of their undergraduate program. Students in the program may count up to nine hours of graduate courses toward both the B.S. and M.S. degrees. Thus, the two degrees may be earned with a minimum of 141 credits rather than the 150 credits necessary if the two degrees are pursued separately.

Students holding these degrees will demonstrate a comprehensive understanding of the theory and application of mathematical programming and of stochastic models. They will know how to obtain, analyze and interpret data, and learn how to use software common in the industry, allowing them to model operations research problems. Students will know how to clearly and concisely present technical information in writing and through oral presentations. The program will also provide students with opportunities to participate in research projects, internships and other training programs where they develop the skills to evaluate, refine and apply what they learn in the classroom.

Entrance to the accelerated program

Interested undergraduate students should consult with their adviser as early as possible to receive specific information about the accelerated program, determine academic eligibility and submit (no later than two semesters prior to graduating with a baccalaureate degree, that is, before the end of the spring semester of their junior year) an Accelerated Program Declaration Form to be approved by the graduate program director. Limited spaces may be available in the accelerated program. Academically qualified students may not receive approval if capacity has been reached.

Minimum qualifications for entrance to this accelerated program include completion of 90 undergraduate credit hours including MATH 200, MATH 201 and MATH 307 (calculus sequence), STAT 212, STAT 309, OPER 327 and STAT 403; an overall minimum GPA of 3.0; and a minimum GPA of 3.3 in mathematics, operations research and statistics course work. Students who do not meet the minimum GPA requirements may submit GRE scores to receive further consideration. The adviser of graduate studies for the mathematical sciences master's program with a concentration in operations research will provide guidance of students in this program. Students who are interested in the accelerated program should consult with the faculty adviser to the operations research concentration of the M.S. program before they have completed 90 credits. Successful applicants would enter the program in the fall semester of their senior year.

Once enrolled in the accelerated program, students must meet the standards of performance applicable to graduate students as described in the "Satisfactory academic progress (https://bulletin.vcu.edu/academic-regs/grad/satisfactory-academic-progress/)" section of the Graduate Bulletin, including maintaining a 3.0 GPA. Guidance to students admitted to the accelerated program is provided by both the undergraduate mathematical sciences adviser and the faculty adviser to the graduate program.

Admission to the graduate program

Entrance to the accelerated program enables the student to take the approved shared courses that will apply to the undergraduate and graduate degrees. However, entry into an accelerated program via an approved Accelerated Program Declaration Form does not constitute application or admission into the graduate program. Admission to the graduate program requires a separate step that occurs through a formal application to the master's program, which is submitted through Graduate Admissions no later than a semester prior to graduation with the baccalaureate degree, that is, before the end of the fall semester of the senior year. In order to continue pursuing the master's degree after the baccalaureate degree is conferred, accelerated students must follow the admission to graduate study requirements outlined in the VCU Bulletin. Three reference letters (at least one from a Department of Statistical Sciences and Operations Research faculty member) must accompany the application.

Degree requirements

The Bachelor of Science in Mathematical Sciences degree with concentration in operations research will be awarded upon completion of a minimum of 120 credits and the satisfactory completion of all undergraduate degree requirements as stated in the Undergraduate Bulletin.

A maximum of 12 graduate credits may be taken prior to completion of the baccalaureate degree. Nine of these credits are shared with the graduate program, meaning that they will be applied to both undergraduate and graduate degree requirements.

The graduate operations research and statistics courses that may be taken as an undergraduate, once a student is admitted to the program, are in the table below.

Course	Title	Hours
OPER 527	Optimization I	3
OPER 528	Stochastic Simulation	3
Approved 500-level OPER or STAT course, or approved 600-level OPER or STAT with OPER 527 or OPER 528 as prerequisites		3
Approved 500-level or 600-level OPER or STAT course		3

Course	Title	Hours
OPER 643	Decision and Risk Analysis	3
STAT 613	Stochastic Processes	3
Graduate operations research elective		3
Term Hours:		9

Recommended course sequence/plan of study

What follows is the recommended plan of study for students interested in the accelerated program beginning in the fall of the junior year prior to admission to the accelerated program in the senior year.

Course	Title	Hours
Junior year		
Fall semester		
STAT 309	Introduction to Probability Theory	3
Experiential fine arts		1-3
General education course		3-4
Natural science sequence		4-5
Operations research concentration elective		3-4
Term Hours:		14-19
Spring semester		
STAT 403	Introduction to Stochastic Processes	3
General education course		3-4
Natural sciences elective (not from general education science and technology list and different science than chosen for sequence)		3-5
Natural science sequence		4-5
Operations research concentration elective		3-4
Term Hours:		16-21
Senior year		
Fall semester		
OPER 528	Stochastic Simulation	3
SSOR 480	Consulting Using Advanced Analytics	3
SSOR 485	Career Planning and Professional Development for Statistics and Operations Research	1
Advanced mathematical science elective		3
Open electives		6
Term Hours:		16
Spring semester		
OPER 527	Optimization I	3
Open electives		6-8
Operations research concentration elective		3-4
Term Hours:		12-15
Fifth year		
Fall semester		
OPER 639	Practical Optimization	3
SSOR 690	Research and Communications Seminar	3
Graduate operations research electives		6
Term Hours:		12
Spring semester		