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

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 statistics, which teaches students how mathematical models used in the investigation of uncertain phenomena are developed and applied to experimental and nonexperimental data.

Learning outcomes

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

- Understand basic statistical concepts and terms
- Perform data collection
- Analyze data
- Use statistical software packages
- Understand probability and inference
- Understand calculus and linear algebra
- Communicate results in writings and orally
- Use general linear model

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 statistics

General education requirements

University Core Education Curriculum (minimum 21 credits)

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>UNIV 111 Play</td>
<td>Focused Inquiry I</td>
<td>3</td>
</tr>
<tr>
<td>UNIV 112 Play</td>
<td>Focused Inquiry II</td>
<td>3</td>
</tr>
<tr>
<td>UNIV 200</td>
<td>Inquiry and the Craft of Argument</td>
<td>3</td>
</tr>
<tr>
<td>Approved humanities/fine arts</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>Approved natural/physical sciences</td>
<td></td>
<td>3-4</td>
</tr>
<tr>
<td>Approved quantitative literacy</td>
<td></td>
<td>3-4</td>
</tr>
<tr>
<td>Approved social/behavioral sciences</td>
<td></td>
<td>3-4</td>
</tr>
<tr>
<td>Total Hours</td>
<td></td>
<td>21-24</td>
</tr>
</tbody>
</table>

Additional College of Humanities and Sciences requirements (11-23 credits)

<table>
<thead>
<tr>
<th>Course</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<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></td>
<td>3</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>
<tr>
<td>Approved H&amp;S literature and civilization (fulfills University Core humanities/fine arts)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approved H&amp;S science and technology (fulfills University Core natural/physical sciences)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Approved H&amp;S general education electives</td>
<td></td>
<td>6-8</td>
</tr>
<tr>
<td>Experiential fine arts</td>
<td></td>
<td>1-3</td>
</tr>
<tr>
<td>Total language through the 102 level (by course or placement)</td>
<td></td>
<td>0-8</td>
</tr>
<tr>
<td>Total Hours</td>
<td></td>
<td>11-23</td>
</tr>
</tbody>
</table>

Collateral requirements

Select one of the following natural science sequences: 8-10

<table>
<thead>
<tr>
<th>Sequence</th>
<th>Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sequence 1</td>
<td>Introduction to Biological Sciences I and Introduction to Biological Science Laboratory I</td>
<td></td>
</tr>
<tr>
<td>BIOL 151 &amp; BIOZ 151</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BIOL 152 &amp; BIOZ 152</td>
<td>Introduction to Biological Sciences II and Introduction to Biological Science Laboratory II</td>
<td></td>
</tr>
</tbody>
</table>
Mathematical Sciences, Bachelor of Science (B.S.) with a concentration in statistics

Sequence 2
CHEM 101 & CHEZ 101 General Chemistry I and General Chemistry Laboratory I
CHEM 102 & CHEZ 102 General Chemistry II and General Chemistry Laboratory II

Sequence 3
PHYS 201 & PHYS 202 General Physics I and General Physics II

Sequence 4
PHYS 207 & PHYS 208 University Physics I and University Physics II

Select another course in the natural sciences that is not from the general education science and technology list. This course must be in a science different from the sequence chosen above.

Total Hours 11-15

Major requirements

MATH 200 & MATH 201 Calculus with Analytic Geometry and Calculus with Analytic Geometry 8
MATH 211 or MATH 300 Mathematical Structures or Introduction to Mathematical Reasoning 3
MATH 307 Multivariate Calculus 4
MATH 310 Linear Algebra 3
SSOR 490 Developing Professional Skills in Operations Research and Statistics (capstone) 3
SSOR 495 Expositions in Statistical Sciences and Operations Research (capstone) 1
STAT 212 Concepts of Statistics (fulfills University Core quantitative literacy) 3
STAT 305 Intermediate Statistics 3
STAT 309 Introduction to Probability Theory 3
STAT 310 Introduction to Statistical Inference 3
STAT 321 Introduction to Statistical Computing 3

Select statistics concentration electives to complete major requirement (listed below) 18

Total Hours 55

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

Open electives
Select three to 22 credits 3-22

Total minimum requirement 120 credits

Electives

For the statistics concentration, six electives (18 credits) must be chosen from the following list:

SSOR 493 Internship 3
STAT 403 Introduction to Stochastic Processes 3
STAT 415 Statistical Consulting 3
STAT 421 Applied Statistical Computing Using R 3
STAT 423 Nonparametric Statistics 3
STAT 425 Multivariate Statistics 3

STAT 435 Industrial Statistics 3
STAT 443 Regression 3
STAT 475 Time Series 3

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

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
MATH 200 Calculus with Analytic Geometry 4
STAT 212 Concepts of Statistics 3
UNIV 101 Introduction to the University 1
UNIV 111 Focused Inquiry I 3

Term Hours: 14-15

Spring semester
HUMS 202 Choices in a Consumer Society 1
MATH 201 Calculus with Analytic Geometry 4
MATH 211 Mathematical Structures 3
UNIV 112 Focused Inquiry II 3

Term Hours: 14-15

Sophomore year

Fall semester
MATH 307 Multivariate Calculus 4
STAT 305 Intermediate Statistics 3
UNIV 200 Inquiry and the Craft of Argument 3
Approved H&S diverse and global communities 3
Foreign language 101 4

Term Hours: 17

Spring semester
MATH 310 Linear Algebra 3
STAT 321 Introduction to Statistical Computing 3
Approved H&S literature and civilization 3
Approved H&S science and technology 3-4
Foreign language 102 4

Term Hours: 16-17

Junior year

Fall semester
STAT 309 Introduction to Probability Theory 3
Approved H&S general education elective 3-4

Experiential fine arts 1-3

Natural sciences sequence: Select one of the following: 4-5
<table>
<thead>
<tr>
<th>Course Code</th>
<th>Course Title</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>BIOL 151 &amp; BIOZ 151</td>
<td>Introduction to Biological Sciences I and Introduction to Biological Science Laboratory I</td>
<td>4</td>
</tr>
<tr>
<td>CHEM 101 &amp; CHEZ 101</td>
<td>General Chemistry I and General Chemistry Laboratory I</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 201 &amp; CHEM 102</td>
<td>General Physics I and General Chemistry Laboratory II</td>
<td>4</td>
</tr>
<tr>
<td>PHYS 207 &amp; CHEM 101</td>
<td>University Physics I and General Chemistry Laboratory II</td>
<td>4</td>
</tr>
<tr>
<td>Statistics concentration elective (see list)</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>SSOR 490</td>
<td>Developing Professional Skills in Operations Research and Statistics</td>
<td>3</td>
</tr>
<tr>
<td>SSOR 495</td>
<td>Expositions in Statistical Sciences and Operations Research</td>
<td>1</td>
</tr>
<tr>
<td>SSOR 492</td>
<td>Independent Study</td>
<td>2-4</td>
</tr>
<tr>
<td>SSOR 493</td>
<td>Internship</td>
<td>3</td>
</tr>
<tr>
<td>SSOR 495</td>
<td>Expositions in Statistical Sciences and Operations Research</td>
<td>3</td>
</tr>
<tr>
<td>STAT 206</td>
<td>Data Analysis and Statistics for Elementary Education</td>
<td>3</td>
</tr>
</tbody>
</table>

### Statistics

**STAT 206. Data Analysis and Statistics for Elementary Education. 3 Hours.**

Semester course; 3 lecture hours. 3 credits. Enrollment is restricted to students majoring in liberal studies for early and elementary education who have received a passing score on the PRAXIS I exam. Understanding probability, describing data both graphically and numerically, regression/correlation, common distributions and interpretation, item analysis for tests, interpreting test scores and educational studies, experimental design and limitations, comparing results using t-tests. This course relies heavily on using a graphing calculator as a data-analysis tool. Students may receive credit toward graduation for only one of STAT 206, STAT 208, STAT 210, STAT 212, STAT 312 or SCMA 301.
STAT 208. Statistical Thinking. 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, or a minimum grade of C in MATH 131, MATH 141, MATH 151, MATH 200 or MATH 201. An exploration of the use of statistics in the world around us through in-depth case studies. Emphasis is on understanding statistical studies, charts, tables and graphs frequently seen in various media sources. Some lectures involve activities centered on case studies. Students may receive credit toward graduation for only one of STAT 206, STAT 208, STAT 210, STAT 212, STAT 312 or SCMA 301.

STAT 210. Basic Practice of Statistics. 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, or a minimum grade of C in MATH 131, MATH 141, MATH 151, MATH 200 or MATH 201. An exception to this policy is made in the case where the stated alternative prerequisite course has been completed at VCU. Designed for students who will likely take another quantitative reasoning course for which statistics may be a prerequisite. Not open to mathematical sciences or computer science majors. Topics include examining distributions, examining relationships, producing data, sampling distributions and probability, introduction to inference. Students may receive credit toward graduation for only one of STAT 206, STAT 208, STAT 210, STAT 212, STAT 312 or SCMA 301.

STAT 212. Concepts of Statistics. 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, or a minimum grade of C in MATH 131, MATH 141, MATH 151, MATH 200 or MATH 201. Introductory statistics course with an emphasis on descriptive statistics, correlation and regression, probability, normal distributions, t distributions, and statistical inference. Graphing calculators will be used extensively. A core course for mathematical sciences. Students may receive credit toward graduation for only one of STAT 206, STAT 208, STAT 210, STAT 212, STAT 312 or SCMA 301.

STAT 291. Topics in Statistics. 1-3 Hours.
Semester course; 1-3 lecture hours. 1-3 credits. A study of selected topics in statistics. Specific topics may fulfill general education requirements. See the Schedule of Classes for specific topics and prerequisites.

STAT 305. Intermediate Statistics. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 200 and STAT 212, or their equivalents. A study of intermediate-level statistical inference procedures, including categorical data analysis, analysis of variance, multiple regression and nonparametric procedures. Students may receive credit toward graduation for only one of STAT 305 or STAT 314.

STAT 309. Introduction to Probability Theory. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 307 and either MATH 211 or MATH 300. A study of the mathematical theory of probability, including finite and infinite sample spaces, random variables, discrete and continuous distributions, mathematical expectation, functions of random variables and sampling distributions.

STAT 310. Introduction to Statistical Inference. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: STAT 212 and STAT 309, or permission of instructor. Framework for statistical inference. Point and interval estimation of population parameters. Hypothesis testing concepts, power functions, Neyman-Pearson lemma and likelihood ratio tests. Elementary decision theory concepts.

STAT 314. Applications of Statistics. 4 Hours.
Semester course; 4 lecture hours. 4 credits. Prerequisite: STAT 210 or 212. A study of the concepts and application of statistical methods including: estimation and hypothesis testing for two sample problems; one factor analysis of variance and multiple comparisons; randomized block designs and analysis; inferences on categorical data, including chi-square test for independence for contingency tables; simple linear regression and correlation; multiple linear regression. Special topics include distribution-free (nonparametric) methods in various statistical problems, two factor analysis of variance and the use of a statistical software package for data analysis. Students may receive credit toward graduation for only one of STAT 305 or STAT 314.

STAT 315. Statistical Consulting. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: STAT 212 and MATH 200 or their equivalents. The application of computers and computing software to statistical concepts using R, SAS and other quantitative software. Topics include data storage and retrieval, data modification and file handling, standard statistical analyses, graphical representations, practical presentation of results.

STAT 403. Introduction to Stochastic Processes. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 307 and STAT 309. Introduction to the theory of stochastic processes and their applications. In-depth studies of random variables, conditional probability and conditional expectation. Topics include Markov chains, random walks, Poisson processes, birth and death processes and applications to classical problems (e.g., gambler’s ruin, physics, etc.).

STAT 415. Statistical Consulting. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: STAT 305 and STAT 321, or their equivalents. An introduction to the techniques of statistical consulting. Topics include applying statistical concepts to real-world scenarios, dealing with messy data and communicating results.

Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 310 and either STAT 305 or STAT 314, or their equivalents. Completion of STAT 321 is strongly recommended. Introduction to object-oriented programming in the R environment for use with statistical analyses. Topics include basic algorithms in R and applications involving random number generation, parametric and non-parametric data analysis and inference, linear models, simulation, and advanced data manipulation.

STAT 422. Structured Problem Solving Using Statistics. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: STAT 314, PSYC 214 or SCMA 302, or permission of instructor. Focuses on using analytic frameworks and applying statistics to solve problems in a real-world environment. Topics include discussion of analytical frameworks, problem restatement, divergent/convergent thinking. Causal flow diagramming, the matrix method, decision tree analysis, review of sampling, confidence intervals, regression, ANOVA, chi squared tests, as well as applications of these concepts to solve case studies.
STAT 423. Nonparametric Statistics. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: STAT 305 and STAT 321. Introduction to statistical estimation and inference methods that require relatively mild assumptions about the underlying population distribution. Topics include classical nonparametric hypothesis testing methods, permutation tests, bootstrap methods and density estimation.

STAT 425. Multivariate Statistics. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: MATH 307, MATH 310, STAT 309, and either STAT 305 or STAT 314. Completion of STAT 421 is strongly recommended. Introduction to multivariate statistical analysis methods. Topics include multivariate probability distributions and their properties, conditional and marginal distributions, multivariate normal distribution, Hotelling's T² distribution, multivariate analysis of variance, repeated measures, multivariate regression, principle component analysis, exploratory factor analysis, linear discriminant analysis, cluster analysis, and regression trees. Students will use modern statistical software to perform these analyses.

STAT 435. Industrial Statistics. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: STAT 309; and STAT 305 or STAT 314. Introduction to statistical methods for quality control and process improvement. Topics include special versus common causes of variation, statistical thinking in industrial settings, Shewhart control charts, capability analysis, components of variation, design of experiments and response surface methods. Incorporates use of statistical software.

STAT 441. Applied Statistics for Engineers and Scientists. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 201 or equivalent. An introduction to applied statistics intended primarily for students in engineering. The fundamental ideas about the collection and display of information, descriptive statistics and exploratory data analysis, elementary probability theory, frequency distributions, and sampling are covered. Other topics include tests of hypotheses and confidence intervals for one and two sample problems; ANOVA; principles of one-factor experimental designs including randomized complete block designs, fixed and random effects and multiple comparisons; correlation and linear regression analysis; control charts; contingency tables and goodness-of-fit. Statistical software is used extensively in this course, so a working knowledge of computers is necessary. Students may receive degree credit for only one of BIOS 543, STAT 441, STAT 541, STAT 543 or STAT 641.

STAT 443. Regression. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: STAT 305 and STAT 321, or permission of instructor. Completion of MATH 310 is strongly recommended. Introduction to the concepts and methods of linear regression, logistic regression, and other nonlinear regression models. Topics include model development and assumptions, estimation of model parameters, statistical inferences about the regression model, selection of an appropriate model, and diagnostics regarding multicollinearity and influence points. Applications involve the use of a statistical software package.

STAT 475. Time Series. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: STAT 321 and either STAT 305 or STAT 314. Completion of STAT 421 is strongly recommended. Introduction to the modeling of univariate time series data. Topics include simple and exponential moving averages, Brown's double exponential smoothing, Holt-Winters model, autocorrelation, partial autocorrelation, autoregressive integrated moving average models, seasonal autoregressive moving average models, harmonic analysis and time series regression. Students will use modern statistical software to perform these analyses.

Operations Research
OPER 327. Mathematical Modeling. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisite: MATH 200. Fundamental concepts of mathematical modeling. Topics may include differential equation models, optimization models and probabilistic models. Practical problems will be discussed throughout.

OPER 391. Topics in Operations Research. 1-3 Hours.
Semester course; 1-3 lecture hours. 1-3 credits. May be repeated with different topics for a maximum of 6 credits. A study of selected topics in operations research. See the Schedule of Classes for specific topics to be offered each semester and prerequisites. Because of the changing subject matter to be treated in this course, enrollment requires permission of the instructor.

OPER 427. Deterministic Operations Research. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: CMSC 245 or CMSC 255, MATH 310 and OPER 327. Introduction to topics in optimization including linear programming, network models and integer programming. Focuses on constructing sound models and on solving them using appropriate software. Algorithms and model properties are also discussed. Students may not receive degree credit for both OPER 427 and OPER 527.

OPER 428. Stochastic Operations Research. 3 Hours.
Semester course; 3 lecture hours. 3 credits. Prerequisites: CMSC 245 or CMSC 255, MATH 310 and STAT 309. Introduction to topics in discrete-event and Monte Carlo simulation including the application of probabilistic models in real-world situations, random number generation, random variate generation and Monte Carlo integration. Students may not receive degree credit for both OPER 428 and OPER 528.