

Bachelor of Science in Applied Mathematics and Statistics

Program Description

The Bachelor of Science in Applied Mathematics and Statistics (AMS) at the Colorado School of Mines prepares students to design and implement solutions to practical, real-world problems. Students are prepared at the intersection of computational mathematics, applied mathematics, statistics, and modern data science tools. Modeling, computing, and data analysis are emphasized to provide students with the technical and soft skills necessary to be successful in both industry and graduate school. To help our students find the path that aligns with their interests, our program offers three areas of emphasis: Computational and Applied Mathematics (CAM), statistics (STAT), and data science (DS).

CAM students gain experience in mathematical modeling, applied analysis, development and analysis of numerical algorithms and using mathematical software; STAT students gain a thorough foundation in applied statistics, data science and probability; DS students gain experience and tools to handle and make inferences from large data sets, with an emphasis on interpretation and analysis.

Unique to AMS at the Colorado School of Mines, all three tracks allow students to explore the real-world applications emphasizing interactions between mathematical and statistical modeling, with a common emphasis on the use of data to inform models. AMS features course sequences that introduce concepts and techniques in mathematical modeling, leading to senior capstone experiences designed to engage students in problems of practical applicability for potential employers. Mathematics, statistics, and data science play essential roles in practically every industry and professional field. They are the building blocks for engineering and the sciences. Our faculty lead students in research in scientific computing, multivariate analysis, numerical analysis, spatial statistics, wave theory, biostatistics, multi-scale simulation, partial differential equations, inverse problems, uncertainty quantification, optimization, climate modeling, and biomathematics. Following graduation, our students find positions in several different sectors, including technology, engineering aerospace, data science, artificial intelligence, and finance to name a few.

Student Learning Outcomes

Upon successful completion of the program, AMS graduates will be able to:

1. Compute and interpret solutions to mathematics problems.
 - a. Select appropriate techniques.
 - b. Solve problems in calculus, differential equations, linear algebra, and probability.
 - c. Interpret solutions geometrically, mathematically, and/or physically.
2. Visualize and analyze data.

- a. Select appropriate visualization techniques.
 - b. Obtain and wrangle data.
 - c. Create appropriate hypotheses for data.
 - d. Compute and interpret correct confidence intervals and p-values.
3. Compute and visualize approximate solutions to problems using appropriate algorithms and software.
 - a. Select appropriate algorithms.
 - b. Create well-structured and documented code to perform computations.
 - c. Interpret algorithm outputs.
 - d. Quantify errors in approximations.
 4. Develop and apply mathematical theory.
 - a. Read and interpret mathematical proofs and results.
 - b. Write correct and well-structured proofs.
 - i. Appeal to existing theory to reach correct conclusions.
 - ii. Prove mathematical truth using various techniques.
 5. Develop, evaluate, and interpret mathematical and statistical models for data and phenomena from other fields.
 - a. Construct mathematical and statistical models.
 - b. Evaluate the strengths and weaknesses of a model.
 - c. Interpret model results in context.
 6. Clearly communicate mathematical and statistical findings in writing and orally.
 - a. Write mathematics with correct notation.
 - b. Communicate in writing and orally the background, creation, analysis, and results of a model.
 - c. Deliver clear content to three types of audience: a lay audience (an elevator pitch), a student audience (a teaching presentation), and an expert audience (a research presentation).

Primary Contact

Dr. Steve Pankavich
<https://ams.mines.edu/undergraduate-program/>

Program Educational Objectives

Bachelor of Science in Applied Mathematics and Statistics

In addition to contributing toward achieving the educational objectives described in the Mines Graduate Profile and the Accreditation Board for Engineering and Technology's (ABET) accreditation criteria, the Applied Mathematics and Statistics Program at Mines has established the following program educational objectives:

Students will demonstrate technical expertise within mathematics and statistics by:

- Designing and implementing solutions to practical problems in science and engineering.
- Using appropriate technology as a tool to solve problems in mathematics.

Students will demonstrate a breadth and depth of knowledge within mathematics by:

- Extending course material to solve original problems.
- Applying knowledge of mathematics to the solution of problems.
- Identifying, formulating and solving mathematics problems.
- Analyzing and interpreting statistical data.

Students will demonstrate an understanding and appreciation for the relationship of mathematics to other fields by:

- Applying mathematics and statistics to solve problems in other fields.
- Working in cooperative multidisciplinary teams.
- Choosing appropriate technology to solve problems in other disciplines.

Students will demonstrate an ability to communicate mathematics effectively by:

- Giving oral presentations.
- Completing written explanations.
- Interacting effectively in cooperative teams.
- Understanding and interpreting written material in mathematics.

Curriculum

The calculus sequence emphasizes mathematics applied to problems students are likely to see in other fields. This supports the curriculum in other programs where prepared in mathematics. Priorities in the mathematics curriculum include applied problems in the mathematics courses and ready utilization of mathematics in the science and engineering courses.

This emphasis on the utilization of mathematics continues through the upper-division courses. Another aspect of the curriculum is the use of a spiraling mode of learning in which concepts are revisited to deepen the students' understanding.

The applications, teamwork, assessment, and communications emphasis directly address ABET criteria and the Mines graduate profile. The curriculum offers the following two areas of emphasis:

Degree Requirements (Applied Mathematics and Statistics)

Computational and Applied Mathematics (CAM) EMPHASIS

First Year

		lec	lab	sem.hrs
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0

HASS100	NATURE AND HUMAN VALUES			3.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
MATH201	INTRODUCTION TO STATISTICS			3.0
PHGN100	PHYSICS I - MECHANICS			4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
S&W	SUCCESS AND WELLNESS			1.0
				30.0

Sophomore

Fall		lec	lab	sem.hrs
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
PHGN200	PHYSICS II- ELECTROMAGNETISM AND OPTICS			4.0
CSCI200	FOUNDATIONAL PROGRAMMING CONCEPTS & DESIGN			3.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
HASS215	FUTURES			3.0
				15.0

Spring

		lec	lab	sem.hrs
MATH225	DIFFERENTIAL EQUATIONS			3.0
MATH300	FOUNDATIONS OF ADVANCED MATHEMATICS			3.0
MATH324	STATISTICAL MODELING			3.0
MATH332	LINEAR ALGEBRA or 342		3.0	3.0
FREE	FREE ELECTIVE			3.0
				15.0

Junior

Fall		lec	lab	sem.hrs
MATH307	INTRODUCTION TO SCIENTIFIC COMPUTING	3.0		3.0
MATH310	INTRODUCTION TO MATHEMATICAL MODELING			3.0
MATH334	INTRODUCTION TO PROBABILITY	3.0		3.0
CSCIxxx	COMPUTING ELECTIVE ¹			3.0
EBGN321	ENGINEERING ECONOMICS			3.0
				15.0

Spring

		lec	lab	sem.hrs
MATH301	INTRODUCTION TO ANALYSIS	3.0		3.0
MATH455	PARTIAL DIFFERENTIAL EQUATIONS			3.0
MATH	MATHEMATICS-AMS ELECTIVE ²	3.0		3.0
MATH	MATHEMATICS-AMS ELECTIVE ²			3.0
CAS Elective	Culture and Society mid-level			3.0
				15.0

Senior

		lec	lab	sem.hrs
Fall				
MATH408	COMPUTATIONAL METHODS FOR DIFFERENTIAL EQUATIONS	3.0		3.0
MATH431	MATHEMATICAL BIOLOGY			3.0
MATH	MATHEMATICS-AMS ELECTIVE ²	3.0		3.0
MATH	MATHEMATICS-AMS ELECTIVE ²	3.0		3.0
CAS ELECTIVE	Culture and Society mid-level			3.0
				15.0

		lec	lab	sem.hrs
Spring				
MATH484	MATHEMATICAL AND COMPUTATIONAL MODELING (CAPSTONE)	3.0		3.0
MATH	MATHEMATICS-CAM ELECTIVE ³	3.0		3.0
MATH	MATHEMATICS-CAM ELECTIVE ³	3.0		3.0
FREE	FREE ELECTIVE	3.0		3.0
CAS Elective	Culture and Society 400-level			3.0
				15.0

Total Semester Hrs: 120.0

¹ May be satisfied CSCI220, CSCI303, CSCI403, CSCI441, CSCI470, CSCI474, or CSCI478

² The AMS Electives list can be found at the end of this page (after the DS Electives List).

³ The Mathematics-CAM elective list can be found immediately below.

Mathematics-CAM elective list. CAM students must choose at least 2 electives from this list.

MATH440	PARALLEL SCIENTIFIC COMPUTING	3.0
MATH454	COMPLEX ANALYSIS	3.0
MATH457	INTEGRAL EQUATIONS	3.0
MATH458	ABSTRACT ALGEBRA	3.0
MATH459	ASYMPTOTICS	3.0
MATH472	MATHEMATICAL AND COMPUTATIONAL NEUROSCIENCE	3.0
MATH500	LINEAR VECTOR SPACES	3.0
MATH501	APPLIED ANALYSIS	3.0
MATH514	APPLIED MATHEMATICS I	3.0
MATH515	APPLIED MATHEMATICS II	3.0
MATH550	NUMERICAL SOLUTION OF PARTIAL DIFFERENTIAL EQUATIONS	3.0
MATH551	COMPUTATIONAL LINEAR ALGEBRA	3.0
MATH552	KERNEL-BASED APPROXIMATION METHODS	3.0
MATH	Department approval required for courses not on this list.	

Statistics (STATS) EMPHASIS

First Year

		lec	lab	sem.hrs
MATH111	CALCULUS FOR SCIENTISTS AND ENGINEERS I			4.0
CSCI128	COMPUTER SCIENCE FOR STEM			3.0
CHGN121	PRINCIPLES OF CHEMISTRY I			4.0
HASS100	NATURE AND HUMAN VALUES			3.0
CSM101	FRESHMAN SUCCESS SEMINAR			1.0
MATH112	CALCULUS FOR SCIENTISTS AND ENGINEERS II			4.0
MATH201	INTRODUCTION TO STATISTICS			3.0
PHGN100	PHYSICS I - MECHANICS			4.0
EDNS151	CORNERSTONE - DESIGN I			3.0
S&W	SUCCESS AND WELLNESS			1.0
				30.0

Sophomore

		lec	lab	sem.hrs
Fall				
MATH213	CALCULUS FOR SCIENTISTS AND ENGINEERS III	4.0		4.0
PHGN200	PHYSICS II- ELECTROMAGNETISM AND OPTICS	3.0	3.0	4.0
CSCI200	FOUNDATIONAL PROGRAMMING CONCEPTS & DESIGN			3.0
CSM202	INTRODUCTION TO STUDENT WELL-BEING AT MINES			1.0
HASS215	FUTURES			3.0
				15.0

		lec	lab	sem.hrs
Spring				
MATH225	DIFFERENTIAL EQUATIONS			3.0
MATH300	FOUNDATIONS OF ADVANCED MATHEMATICS			3.0
MATH324	STATISTICAL MODELING			3.0
MATH332	LINEAR ALGEBRA or 342	3.0		3.0
FREE	FREE ELECTIVE			3.0
				15.0

Junior

		lec	lab	sem.hrs
Fall				
MATH307	INTRODUCTION TO SCIENTIFIC COMPUTING	3.0		3.0
MATH310	INTRODUCTION TO MATHEMATICAL MODELING			3.0
MATH334	INTRODUCTION TO PROBABILITY	3.0		3.0
CSCIxxx	COMPUTING ELECTIVE ¹			3.0
EBGN321	ENGINEERING ECONOMICS			3.0

15.0

Spring		lec	lab	sem.hrs
MATH301	INTRODUCTION TO ANALYSIS			3.0
MATH335	INTRODUCTION TO MATHEMATICAL STATISTICS	3.0		3.0
MATH	MATHEMATICS-AMS ELECTIVE ²	3.0		3.0
MATH	MATHEMATICS-AMS ELECTIVE ²	3.0		3.0
CAS ELECTIVE	Culture and Society mid-level	3.0		3.0
				15.0

Senior		lec	lab	sem.hrs
Fall				
MATH436	ADVANCED STATISTICAL MODELING			3.0
MATH	MATHEMATICS-AMS ELECTIVE ²	3.0		3.0
MATH	MATHEMATICS-AMS ELECTIVE ²			3.0
MATH	MATHEMATICS-STAT ELECTIVE ³			3.0
CAS ELECTIVE	Culture and Society mid-level			3.0
				15.0

Spring		lec	lab	sem.hrs
MATH437	MULTIVARIATE ANALYSIS			3.0
MATH482	STATISTICS PRACTICUM (CAPSTONE) (STAT Capstone)	3.0		3.0
MATH	MATHEMATICS-STAT ELECTIVE ³			3.0
CAS ELECTIVE	Culture and Society 400-level			3.0
FREE	FREE ELECTIVE	3.0		3.0
				15.0

Total Semester Hrs: 120.0

¹ May be satisfied CSCI220, CSCI303, CSCI403, CSCI441, CSCI470, CSCI474, or CSCI478

² The AMS Electives list can be found at the end of this page (after the DS Electives List).

³ The Mathematics-STAT Electives list can be found immediately below.

Mathematics-STAT Elective List. STAT students must choose at least 2 electives from this list.

MATH432	SPATIAL STATISTICS	3.0
MATH433	TIME SERIES AND ITS APPLICATIONS	3.0
MATH438	STOCHASTIC MODELS	3.0
MATH443	INTRODUCTION TO BAYESIAN STATISTICS	3.0
MATH531	THEORY OF LINEAR MODELS	3.0
MATH534	MATHEMATICAL STATISTICS I	3.0
MATH535	MATHEMATICAL STATISTICS II	3.0
MATH560	INTRODUCTION TO KEY STATISTICAL LEARNING METHODS I	3.0

MATH561	INTRODUCTION TO KEY STATISTICAL LEARNING METHODS II	3.0
CSCI403	DATA BASE MANAGEMENT	3.0
DSCI560	INTRODUCTION TO KEY STATISTICAL LEARNING METHODS I	3.0
DSCI561	INTRODUCTION TO KEY STATISTICAL LEARNING METHODS II	3.0
MATH	Department approval required for courses not on this list.	

Data Science (DS) Emphasis

First Year

	lec	lab	sem.hrs
MATH111			4.0
CSCI128			3.0
CHGN121			4.0
HASS100			3.0
CSM101			1.0
MATH112			4.0
MATH201			3.0
PHGN100			4.0
EDNS151			3.0
S&W			1.0
30.0			

Sophomore

Fall	lec	lab	sem.hrs
MATH213	4.0		4.0
PHGN200	3.0	3.0	4.0
CSCI200			3.0
CSM202			1.0
HASS215			3.0
15.0			

Spring	lec	lab	sem.hrs
MATH225			3.0
MATH300			3.0
MATH324			3.0
MATH332	3.0		3.0
FREE			3.0
15.0			

Junior

Fall		lec	lab	sem.hrs
MATH307	INTRODUCTION TO SCIENTIFIC COMPUTING	3.0		3.0
MATH310	INTRODUCTION TO MATHEMATICAL MODELING			3.0
MATH334	INTRODUCTION TO PROBABILITY	3.0		3.0
CSCIxxx	COMPUTING ELECTIVE ¹			3.0
EBGN321	ENGINEERING ECONOMICS			3.0

15.0

Spring		lec	lab	sem.hrs
MATH301	INTRODUCTION TO ANALYSIS			3.0
MATH	MATHEMATICS-AMS ELECTIVE ²	3.0		3.0
MATH	MATHEMATICS-AMS ELECTIVE ²	3.0		3.0
DSCI403	INTRODUCTION TO DATA SCIENCE			3.0
CAS ELECTIVE	Culture and Society mid-level	3.0		3.0

15.0**Senior**

Fall		lec	lab	sem.hrs
MATH436	ADVANCED STATISTICAL MODELING			3.0
MATH	MATHEMATICS-AMS ELECTIVE ²			3.0
CAS ELECTIVE	Culture and Society mid-level			3.0
CSCI470	INTRODUCTION TO MACHINE LEARNING			3.0
MATH335	INTRODUCTION TO MATHEMATICAL STATISTICS			3.0

15.0

Spring		lec	lab	sem.hrs
MATH482	STATISTICS PRACTICUM (CAPSTONE) (STAT Capstone)	3.0		3.0
MATH	MATHEMATICS-DS ELECTIVE ²			3.0
MATH	MATHEMATICS-DS ELECTIVE ²			3.0
CAS ELECTIVE	Culture and Society 400-level			3.0
FREE	FREE ELECTIVE	3.0		3.0

15.0**Total Semester Hrs: 120.0**

¹ May be satisfied by CSCI220, CSCI403, CSCI441, CSCI474, or CSCI478

² The AMS Electives list can be found at the end of this page (after the DS Electives List).

³ The Mathematics-DS Electives list can be found immediately below.

Mathematics-DS elective list. DS students must choose at least 2 electives from this list

MATH432	SPATIAL STATISTICS	3.0
MATH433	TIME SERIES AND ITS APPLICATIONS	3.0
MATH436	ADVANCED STATISTICAL MODELING	3.0
MATH437	MULTIVARIATE ANALYSIS	3.0
MATH438	STOCHASTIC MODELS	3.0
MATH440	PARALLEL SCIENTIFIC COMPUTING	3.0
MATH443	INTRODUCTION TO BAYESIAN STATISTICS	3.0
MATH560	INTRODUCTION TO KEY STATISTICAL LEARNING METHODS I	3.0
MATH561	INTRODUCTION TO KEY STATISTICAL LEARNING METHODS II	3.0
CSCI403	DATA BASE MANAGEMENT	3.0
CSCI404	ARTIFICIAL INTELLIGENCE	3.0
CSCI406	ALGORITHMS	3.0
CSCI423	COMPUTER SIMULATION	3.0
CSCI475	INFORMATION SECURITY AND PRIVACY	3.0
DSCI560	INTRODUCTION TO KEY STATISTICAL LEARNING METHODS I	3.0
DSCI561	INTRODUCTION TO KEY STATISTICAL LEARNING METHODS II	3.0
MATH	Department approval required for courses not on this list.	

AMS Electives List

AMS Elective List. Students may choose up to 4 electives from this list that are not already required by their emphasis to satisfy AMS Elective requirements.²

MATHxxx	Any 3-credit hour 300-, 400-, or 500- level MATH course other than MATH530 that is not already required by your AMS major track.	
CSCI403	DATA BASE MANAGEMENT	3.0
CSCI406	ALGORITHMS	3.0
DSCI403	INTRODUCTION TO DATA SCIENCE	3.0
DSCI560	INTRODUCTION TO KEY STATISTICAL LEARNING METHODS I	3.0
DSCI561	INTRODUCTION TO KEY STATISTICAL LEARNING METHODS II	3.0

Major GPA

The following list details the courses that are included in the major GPA for this degree:

- CSCI100 through CSCI799 inclusive
- MACS100 through MACS799 inclusive (Previous subject code)
- MATH100 through MATH799 inclusive

COURSES

MATH1XX. MATH ELECTIVE. 1-6 Semester Hr.

MATH100. INTRODUCTORY TOPICS FOR CALCULUS. 3.0 Semester Hrs.

This summer course for the MEP Challenge program is an introduction and/or review of topics which are essential to the background of an undergraduate student at Mines. This course serves as a preparatory course for the Calculus curriculum and includes material from Algebra,

Trigonometry, Mathematical Analysis, and Calculus. Topics include basic algebra and equation solving, solutions of inequalities, trigonometric functions and identities, functions of a single variable, continuity, and limits of functions. This course does not apply toward undergraduate degree or GPA. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- Simplify expressions and/or solve equations of algebraic and/or transcendental functions.
- Demonstrate a graphical understanding of limits and continuity.
- Use limit rules to evaluate limits of algebraic and transcendental functions.

MATH111. CALCULUS FOR SCIENTISTS AND ENGINEERS I. 4.0 Semester Hrs.

This is the first course in the calculus sequence. Topics include elements of plane geometry, functions, limits, continuity, derivatives and their application, definite and indefinite integrals; 4 hours lecture; 4 semester hours. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-MA1. Prerequisites: precalculus.

Course Learning Outcomes

- Recall derivatives and antiderivatives of algebraic, trigonometric, exponential, and log functions.
- Compute limits using algebraic techniques and L'Hôpital's rule. Compute derivatives using the power, product, quotient, and chain rule. Compute integrals using the Fundamental Theorem of Calculus, power rule, and u-substitution.
- Interpret the meaning of a limit, derivative, and integral in both geometric and physical contexts.
- Approximate functions, derivatives, and integrals using tangent lines, secant lines, and Riemann sums.
- Apply definitions and theorems to draw mathematical conclusions and justify computational results.
- Identify and apply techniques to solve problems from science, engineering, and economics.
- Communicate written mathematical arguments and statements that use standard notation and terminology, are logically ordered, and are clear and complete.

MATH112. CALCULUS FOR SCIENTISTS AND ENGINEERS II. 4.0 Semester Hrs.

Equivalent with MATH122,

This is the second course in the calculus sequence. Topics include vectors, applications and techniques of integration, infinite series, and an introduction to multivariate functions and surfaces. 4 hours lecture; 4 semester hours. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-MA1. Prerequisites: Grade of C- or better in MATH111.

Course Learning Outcomes

- COMPUTATIONS: Perform computations with integrals, sequences, series, vectors, vector-valued functions, and polar coordinates.
- APPLICATIONS: Construct and interpret mathematical objects (integrals, sequences, series, vectors, vector-valued functions, parameterizations, and polar coordinate representations) to describe physical or mathematical quantities.
- REASONING: Apply definitions and theorems to draw mathematical conclusions and justify computational results.

- WRITING: Communicate written mathematical arguments and statements that are complete and logically ordered through the use of standard notation and terminology.

MATH122. CALCULUS FOR SCIENTISTS AND ENGINEERS II HONORS. 4.0 Semester Hrs.

Equivalent with MATH112,

This Honors version of Calculus II covers the same topics as those covered in MATH112 but with additional material and problems.

Prerequisites: Grade of B- or better in MATH111.

Course Learning Outcomes

- COMPUTATION: Perform computations with integrals, sequences, series, vectors, vector-valued functions, and polar coordinates.
- APPLICATIONS: Construct and interpret mathematical objects (integrals, sequences, series, vectors, vector-valued functions, parameterizations, and polar coordinate representations) to describe physical or mathematical quantities.
- REASONING: Apply definitions and theorems to draw mathematical conclusions and justify computational results.
- WRITING: Communicate written mathematical arguments and statements that are complete and logically ordered through the use of standard notation and terminology.

MATH198. SPECIAL TOPICS. 0-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MATH199. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MATH199. INDEPENDENT STUDY. 1-6 Semester Hr.

MATH199. INDEPENDENT STUDY. 1-6 Semester Hr.

MATH199. INDEPENDENT STUDY. 1-6 Semester Hr.

MATH201. INTRODUCTION TO STATISTICS. 3.0 Semester Hrs.

Equivalent with MATH323,

This course is an introduction to probability and statistics, including fundamentals of experimental design and data collection, the summary and display of data, propagation of error, interval estimation, hypothesis testing, and linear regression with emphasis on applications to science and engineering. Prerequisite: MATH111.

Course Learning Outcomes

- Choose appropriate descriptive statistics and graphical displays to summarize a data set.
- Distinguish between commonly used random variables and sampling distributions in order to identify the appropriate statistical tools based on the context of a given problem.
- Identify, formulate, and evaluate appropriate tools for statistical inference based on the context of a given problem.
- Disseminate/Communicate statistical analysis.

MATH213. CALCULUS FOR SCIENTISTS AND ENGINEERS III. 4.0 Semester Hrs.

Equivalent with MATH223,

This is the third course in the calculus sequence, focused on multivariable calculus. Topics include partial derivatives, multiple integrals, and vector calculus. 4 hours lecture; 4 semester hours. Approved for Colorado Guaranteed General Education transfer. Equivalency for GT-MA1. Prerequisites: Grade of C- or better in MATH112 or MATH122. Corequisites: CSCI128 or CSCI102.

Course Learning Outcomes

- Graph functions of two variables in three-dimensions by using formulaic function knowledge, traces, and contour maps and extend this understanding to functions of three variables.
- Calculate partial derivatives and use them to solve applied problems.
- Construct and evaluate multiple integrals in appropriate coordinate systems such as rectangular, polar, cylindrical and spherical coordinates and apply them to solve problems involving volume, surface area, flux, density, and/or center of mass.
- Identify and use key theorems from vector calculus such as the Fundamental Theorem for Line Integrals, Green's Theorem, Stokes' Theorem, and/or the Divergence Theorem as appropriate to solve applied problems.

MATH223. CALCULUS FOR SCIENTISTS AND ENGINEERS III HONORS. 4.0 Semester Hrs.

This Honors version of Calculus III cover the same topics as those covered in MATH213 but with additional material and problems. Prerequisites: MATH112 with a grade of B- or higher or MATH122 with a grade of B- or higher.

Course Learning Outcomes

- Graph functions of two variables in three-dimensions by using formulaic function knowledge, traces, and contour maps and extend this understanding to functions of three variables.
- Calculate partial derivatives, apply them to solve problems associated with instantaneous rates of change, linear approximations, extreme values, and constrained optimization, and extend these applications to design solution techniques for similar problems in higher-dimensional spaces.
- Construct and evaluate multiple integrals in appropriate coordinate systems such as rectangular, polar, cylindrical and spherical coordinates and apply them to solve problems involving volume, surface area, flux, density, and/or center of mass.
- Distinguish between single and multivariate differential/integral calculus and, when applicable, interpret the consequences of these differences.
- Interpret the operators of multivariate differential/integral calculus and use this to solve problems associated with summation, extreme values, constrained optimization and instantaneous rates of change.
- List the operators of vector analysis, apply them to solve problems related to the fundamental theorem of calculus for vector-valued multivariate functions and interpret them in the context of physical applications.
- Investigate and use key theorems from vector calculus such as the Fundamental Theorem for Line Integrals, Green's Theorem, Stokes' Theorem, and/or the Divergence Theorem and select them as appropriate to solve applied problems and develop key physical relationships.

MATH225. DIFFERENTIAL EQUATIONS. 3.0 Semester Hrs.

Equivalent with MATH235,
This course is an introduction to ordinary differential equations. Topics include classical techniques for first and higher order equations and

systems of equations. Laplace transforms, phase-plane and stability analysis of non-linear equations and systems, applications from physics, mechanics, electrical engineering, and environmental sciences. 3 hours lecture; 3 semester hours. Prerequisites: Grade of C- or better in MATH112 or MATH122. Co-requisites: CSC128 or CSCI102.

Course Learning Outcomes

- Investigate the models of physical systems such as exponential and logistic growth, Newton's Law of Heating/Cooling, Mixing (Tank) problems, spring mass systems, LRC circuits, and predator/prey models using first and second order differential equations.
- Apply classical techniques such as Separation of Variables, Integrating Factors, the Method of Undetermined Coefficients, Bernoulli substitutions, and Laplace Transforms to solve first and second order ordinary differential equations.
- Use eigenvalues and eigenvectors to solve 2x2 linear, constant-coefficient, homogeneous systems of differential equations; interpret the corresponding phase portraits for linear systems; use linearization to analyze the stability of critical points for nonlinear two dimensional systems.
- Apply the concepts of linearity, superposition, existence, and uniqueness of solutions to solve linear differential equations.

MATH235. DIFFERENTIAL EQUATIONS HONORS. 3.0 Semester Hrs.

Equivalent with MATH225,
This Honors version of Differential Equations covers the same topics as those covered in MATH225 but with additional material and problems. 3 hours lecture; 3 semester hours. Prerequisite: Grade of B- or better in MATH112 or MATH 113 or MATH122.

Course Learning Outcomes

- Construct models associated with natural/physical phenomenon such as biological populations, classical/quantum oscillators. Analyze and explain their predictions. Summarize and critique the models. Recommend and support modifications.
- Solve first and second-order linear ordinary differential equations using classical techniques such as Integrating Factors, the Method of Undetermined Coefficients, power series and Laplace Transforms, eigenvalues and eigenvectors and interpret the solutions in both phase and state space.
- Apply the concepts of linearity, superposition, and existence and uniqueness of solutions to solve linear differential equations.
- Apply the apparatus of linearization, nullclines, conservation, and dissipation to analyze linear and nonlinear differential equations.

MATH298. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MATH298. SPECIAL TOPICS. 1-6 Semester Hr.

MATH299. INDEPENDENT STUDY. 1-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MATH300. FOUNDATIONS OF ADVANCED MATHEMATICS. 3.0 Semester Hrs.

This course is an introduction to communication in mathematics. This writing intensive course provides a transition from the Calculus sequence to theoretical mathematics curriculum in CSM. Topics include logic and recursion, techniques of mathematical proofs, reading and writing proofs. 3 hours lecture; 3 semester hours. Prerequisite: MATH112 or MATH122.

Course Learning Outcomes

- Apply the rules of logic in order to construct proofs. In particular, students should be able to work symbolically with connectives and quantifiers to produce logically valid, correct and clear arguments.
- Apply abstract definitions and previous results (from areas such as set theory, discrete mathematics, introductory analysis, or introductory abstract algebra) as well as create intuition-forming examples or counterexamples in order to prove or disprove a conjecture.
- Construct direct and indirect proofs and proofs by induction and determine the appropriateness of each type in a particular setting (such as set theory, discrete mathematics, introductory analysis, or introductory abstract algebra).
- Write solutions to problems and proofs of theorems that meet rigorous standards based on content, organization and coherence, argument and support, and style and mechanics.
- Analyze and critique proofs with respect to logic and correctness.

MATH301. INTRODUCTION TO ANALYSIS. 3.0 Semester Hrs.

Equivalent with MATH401,

This course is a first course in real analysis that lays out the context and motivation of analysis in terms of the transition from power series to those less predictable series. The course is taught from a historical perspective. It covers an introduction to the real numbers, sequences and series and their convergence, real-valued functions and their continuity and differentiability, sequences of functions and their pointwise and uniform convergence, and Riemann-Stieltjes integration theory. 3 hours lecture; 3 semester hours. Prerequisites: MATH300 or CSCI358.

Course Learning Outcomes

- Master basic properties of real numbers and sets of real numbers. Use these to prove statements about real numbers and sets of real numbers.
- Cardinality: Distinguish between finite, countably infinite, and uncountable sets. Prove that a given set has one of these properties.
- Prove and use properties of sequences.
- Limits and continuity: State and prove properties about limits and continuity using ϵ - δ definitions; Use the Bolzano-Weierstrass theorem to prove facts about continuous functions.
- Applications of limits: Properties of continuous functions, intermediate value theorem, extreme value theorem, derivatives, and mean value theorem.
- Integration: Riemann integrability, estimation of integrals, interchange of limits with integration.

MATH307. INTRODUCTION TO SCIENTIFIC COMPUTING. 3.0 Semester Hrs.

Equivalent with CSCI407, MATH407,

This course is designed to introduce scientific computing to scientists and engineers. Students in this course will be taught various numerical methods and programming techniques to solve basic scientific problems. Emphasis will be made on implementation of various numerical and approximation methods to efficiently simulate several applied

mathematical models. 3 hours lecture; 3 semester hours. Prerequisite: MATH213 or MATH223; CSCI102 or CSCI128 or CSCI200. Co-requisite: MATH225 or MATH235.

Course Learning Outcomes

- Implement algorithms in Matlab to approximate solutions to problems.
- Select appropriate algorithms for specific problems.
- Calculate error bounds on certain numerical approximations.

MATH310. INTRODUCTION TO MATHEMATICAL MODELING. 3.0 Semester Hrs.

An introduction to modeling and communication in mathematics. A writing intensive course providing a transition from the core math sequence to the upper division AMS curriculum. This course will include methods for building, solving, and analyzing discrete mathematical models. Other mathematical and statistical modeling techniques will also be introduced. Students will formulate and solve applied problems and will present results orally and in writing. In addition, students will be introduced to the mathematics software that will be used in upper division courses. Prerequisite: MATH201, MATH213, MATH225.

Course Learning Outcomes

- Formulate and investigate mathematical and statistical models
- Identify multiple types of models and techniques
- Communicate the results of a modeling study in writing and orally

MATH324. STATISTICAL MODELING. 3.0 Semester Hrs.

This course is an introduction to applied statistical modeling. Topics include linear regression, analysis of variance, and design of experiments, focusing on the construction of models and evaluation of their fit. Techniques covered will include stepwise and best subsets regression, variable transformations, and residual analysis. Emphasis will be placed on the analysis of data with statistical software. Prerequisite: MATH201.

Course Learning Outcomes

- Intro to tools and R
- Linear Regression
- Analysis of Variance
- Random effects and mixed models

MATH332. LINEAR ALGEBRA. 3.0 Semester Hrs.

Systems of linear equations, matrices, determinants and eigenvalues. Linear operators. Abstract vector spaces. Applications selected from linear programming, physics, graph theory, and other fields. Prerequisite: CSCI128; MATH112, MATH122, or PHGN100.

Course Learning Outcomes

- Perform basic matrix and vector operations, including row reducing matrices, adding/multiplying matrices, calculating determinants, determining eigenvalues/eigenvectors, computing orthogonal projections, and computing matrix decompositions.
- Recall/restate basic definitions and theorems of linear algebra to determine properties of matrices and sets of vectors.
- Communicate linear algebra concepts using proper terminology and notation.
- Utilize matrix and vector operations to solve applied problems including least squares approximation and orthogonal projection.
- Compute a singular value decomposition and use the result to solve an applied problem and determine properties of a matrix.

MATH334. INTRODUCTION TO PROBABILITY. 3.0 Semester Hrs.

This course is an introduction to the theory of probability essential for problems in science and engineering. Topics include axioms of probability, combinatorics, conditional probability and independence, discrete and continuous probability density functions, expectation, jointly distributed random variables, Central Limit Theorem, laws of large numbers. 3 hours lecture, 3 semester hours. Prerequisites: CSC1128 or CSC1102. Co-requisites: MATH213, MATH223.

Course Learning Outcomes

- Understand and apply key axioms, definitions, and theorems including the 3 axioms of probability, counting and combinatorial methods, conditional probability and Bayes Theorem, the definition and mathematical role of random variables, jointly distributed random variables.
- Identify and apply common distributions (Normal, binomial, etc.)
- Understand the Central Limit Theorem and use it to approximate appropriate distributions.
- Define distributions associated with random sample from normal populations (for use in inference in MATH335 and beyond).
- Use R to simulate and analyze synthetic and real-world data to apply the theory discussed in LOs above to data examples, check pen-and-paper calculations through simulation, connect the theory learned in this class with data analysis skills to be expanded in subsequent AMS courses.

MATH335. INTRODUCTION TO MATHEMATICAL STATISTICS. 3.0 Semester Hrs.

An introduction to the theory of statistics essential for problems in science and engineering. Topics include sampling distributions, methods of point estimation, methods of interval estimation, significance testing for population means and variances and goodness of fit, linear regression, analysis of variance. 3 hours lecture, 3 semester hours. Prerequisite: MATH334.

MATH342. HONORS LINEAR ALGEBRA. 3.0 Semester Hrs.

Same topics as those covered in MATH332 but with additional material and problems as well as a more rigorous presentation. 3 hours lecture; 3 semester hours. Prerequisite: MATH213, MATH223.

Course Learning Outcomes

- Perform basic matrix and vector operations, including row reducing matrices, adding/multiplying matrices, calculating determinants, determining eigenvalues/eigenvectors, computing orthogonal projections, and computing matrix decompositions.
- Recall/restate basic definitions and theorems of linear algebra to determine properties of matrices and sets of vectors.
- Communicate linear algebra concepts using proper terminology and notation.
- Utilize matrix and vector operations to solve applied problems including least squares approximation and orthogonal projection.
- Compute a singular value decomposition and use the result to solve an applied problem and determine properties of a matrix.

MATH398. SPECIAL TOPICS. 0-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MATH398. SPECIAL TOPICS. 0-6 Semester Hr.**MATH399. INDEPENDENT STUDY. 0.5-6 Semester Hr.**

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MATH399. INDEPENDENT STUDY. 1-6 Semester Hr.**MATH399. INDEPENDENT STUDY. 1-6 Semester Hr.****MATH399. INDEPENDENT STUDY. 1-6 Semester Hr.****MATH408. COMPUTATIONAL METHODS FOR DIFFERENTIAL EQUATIONS. 3.0 Semester Hrs.**

This course is designed to introduce computational methods to scientists and engineers for developing differential equations based computer models. Students in this course will be taught various numerical methods and programming techniques to simulate systems of nonlinear ordinary differential equations. Emphasis will be on implementation of various numerical and approximation methods to efficiently simulate several systems of nonlinear differential equations. Prerequisite: MATH307. 3 hours lecture, 3 semester hours.

Course Learning Outcomes

- Analyze the stability, consistency, and convergence of several computational methods for solving initial value problems.
- Analyze and implement techniques for stiff systems.
- Analyze and implement techniques for boundary value problems.
- Analyze and implement techniques for simple partial differential equations.
- Utilize MATLAB tools for solving differential equations.

MATH431. MATHEMATICAL BIOLOGY. 3.0 Semester Hrs.

This is the second modeling course in the Computational and Applied Mathematics sequence. This course will include methods for building, solving, and analyzing continuous mathematical models. Other mathematical modeling techniques will also be introduced. These methods will be applied to population dynamics, epidemic spread, pharmacokinetics and modeling of physiologic systems. Students will formulate and solved applied problems and will present results orally and in writing. Prerequisite: MATH307, MATH310 or BIOL300, and MATH332 or MATH342.

Course Learning Outcomes

- Describe the assumptions and implementations of some of the classical models of mathematical biology in your own words.
- Derive models for biological phenomena including both discrete and continuous classes of models.
- Solve models using both analytical and numerical techniques.
- Apply techniques for model analysis and interpret results.
- Generate and professionally communicate novel results in mathematical biology.

MATH432. SPATIAL STATISTICS. 3.0 Semester Hrs.

Modeling and analysis of data observed in a 2- or 3-dimensional region. Random fields, variograms, covariances, stationarity, nonstationarity, kriging, simulation, Bayesian hierarchical models, spatial regression, SAR, CAR, QAR, and MA models, Geary/Moran indices, point processes, K-function, complete spatial randomness, homogeneous and inhomogeneous processes, marked point processes. Prerequisite: MATH324, MATH332, MATH335.

Course Learning Outcomes

- Use graphical techniques to visualize a spatial data set.
- Select and apply appropriate covariance functions to model spatial dependence.
- Simulate Gaussian Processes (GP) using relevant computational algorithms.
- Identify the components of an additive spatial model.
- Manipulate the likelihood function for a GP and estimate parameters using maximum likelihood.
- Given a spatial data set fit a spatial model, find predictions and prediction uncertainty.
- Assess the limitations of exact spatial computations for large data sets.
- Generate a professional pdf document of a spatial data analysis that includes figures, equations and tables (e.g. using R Markdown).
- Characterize a spatial data set as suitable for a GP model, a non-Gaussian model, an inverse problem, or as a point process.

MATH433. TIME SERIES AND ITS APPLICATIONS. 3.0 Semester Hrs.

Equivalent with BELS331, BELS433, MACS433, MATH331, Exploratory Analysis of Time Series, Stationary Time Series, Autocorrelation and Partial Autocorrelation, Autoregressive Moving Average (ARMA) Models, Forecasting, Estimation, ARIMA Models for Nonstationary Data, Multiplicative Seasonal ARIMA Models, The Spectral Density, Periodogram and Discrete Fourier Transform, Spectral Estimation, Multiple Series and Cross-Spectra, Linear Filters, Long Memory ARMA and Fractional Differencing, GARCH Models, Threshold Models, Regression with Autocorrelated Errors, Lagged Regression, Multivariate ARMAX Models. Prerequisite: MATH324, MATH335.

Course Learning Outcomes

- Select, implement, and interpret appropriate statistical methods for describing and analyzing time series data sets in the context of your own research interests.
- Apply a variety of methods for analyzing time series data and evaluate their suitability and limitations in a research context.
- Critically examine critically your own and other researchers' use of methods of analysis for time series data.
- Use the R software to perform time series analysis of real data sets.

MATH436. ADVANCED STATISTICAL MODELING. 3.0 Semester Hrs.

Modern methods for constructing and evaluating statistical models. Topics include generalized linear models, generalized additive models, hierarchical Bayes methods, and resampling methods. Time series models, including moving average, autoregressive, and ARIMA models, estimation and forecasting, confidence intervals. 3 hours lecture; 3 semester hours. Prerequisite: MATH324, MATH332, and MATH 334.

Course Learning Outcomes

- Fit and interpret standard and weighted linear models
- Fit and interpret ANOVA models
- Fit and interpret generalized linear models
- Fit models to time series data
- Perform diagnostic tests on statistical models

MATH437. MULTIVARIATE ANALYSIS. 3.0 Semester Hrs.

This course is an introduction to applied multivariate techniques for data analysis. Topics include principal components, cluster analysis, MANOVA and other methods based on the multivariate Gaussian distribution,

discriminant analysis, classification with nearest neighbors. 3 hours lecture; 3 semester hours. Prerequisite: MATH324, MATH335, and MATH332 or MATH342.

Course Learning Outcomes

- Explain fundamental theory of random matrices and use relevant linear algebra techniques to represent multiple random variables including theory of the multivariate normal distribution.
- Apply and evaluate the fitness for purpose of multivariate techniques including MANOVA, regression, factor methods, and clustering.
- Visualize multivariate data using R and use visualizations to inform model selection and fit.
- Communicate the goal, methodology, and findings of a statistical study.

MATH438. STOCHASTIC MODELS. 3.0 Semester Hrs.

An introduction to stochastic models applicable to problems in engineering, physical science, economics, and operations research. Markov chains in discrete and continuous time, Poisson processes, and topics in queuing, reliability, and renewal theory. Prerequisite: MATH332, MATH334.

Course Learning Outcomes

- Derive fundamental properties of discrete-time Markov processes.
- Develop properties of Poisson processes from first principles.
- Describe continuous-time Markov processes in terms of infinitesimal generators.
- Calculate occupancy times and limiting distributions.
- Use the reflection principle to compute first passage times of Brownian paths.

MATH439. SURVIVAL ANALYSIS. 3.0 Semester Hrs.

Basic theory and practice of survival analysis. Topics include survival and hazard functions, censoring and truncation, parametric and non-parametric inference, hypothesis testing, the proportional hazards model, model diagnostics. 3 hours lecture; 3 semester hours. Prerequisite: MATH335.

Course Learning Outcomes

- Define and understand the notions of survival and hazard.
- Identify and understand types of censoring and truncation.
- Compute and apply the Kaplan-Meier and Nelson-Aalen estimators.
- Perform the logrank test.
- Formulate and apply the Cox proportional hazards model.
- Formulate and apply the Accelerated Failure Time model.

MATH440. PARALLEL SCIENTIFIC COMPUTING. 3.0 Semester Hrs.

Equivalent with CSCI440,

This course is designed to facilitate students' learning of high-performance computing concepts and techniques to efficiently perform large-scale mathematical modelling and data analysis using modern high-performance architectures (e.g. multi-core processors, multiple processors, and/or accelerators). Emphasis will be placed on analysis and implementation of various scientific computing algorithms in high-level languages using their interfaces for parallel or accelerated computing. Use of scripting to manage HPC workflows is included. Prerequisite: MATH307, CSCI200.

Course Learning Outcomes

- Apply best practices in scientific computing including style, documentation, version control for collaboration, and testing.

- Describe and apply concepts of shared-memory parallelism, distributed-memory parallelism, and accelerator-based computing.
- Analyze the parallelizability of algorithms, both theoretically and experimentally, and perform scalability tests.
- Design parallel algorithms to fit various parallel programming models.
- Implement parallel algorithms with modern hardware.

MATH443. INTRODUCTION TO BAYESIAN STATISTICS. 3.0 Semester Hrs.

The course Bayesian Statistics will introduce students to Bayesian thinking. It will cover conjugate families of distributions, the notion of posterior distributions, and rely heavily on the tools of simulation and Markov Chain Monte Carlo methods. Applications of Bayesian modeling may include: Bayesian regression, classification, and hierarchical Bayesian models. Use of R and RStan will be required. Prerequisite: MATH334.

Course Learning Outcomes

- Apply Bayes Rule for events, understanding the role of conditional probabilities.
- Specify a data model and an appropriate prior distribution for the model parameters, then derive the correct posterior distribution for those parameters.
- Identify and use conjugate priors for specific data models for single-parameter models.
- Write a metropolis hastings algorithm in R to generate a markov chain monte carlo that approximates a posterior distribution.
- Use stan to generate posterior approximations.
- Use stan to fit Bayesian regression models, including Poisson and binomial models, and hierarchical Gaussian models.

MATH454. COMPLEX ANALYSIS. 3.0 Semester Hrs.

The complex plane. Analytic functions, harmonic functions. Mapping by elementary functions. Complex integration, power series, calculus of residues. Conformal mapping. Prerequisite: MATH225 or MATH235 and MATH213 or MATH223. 3 hours lecture, 3 semester hours.

Course Learning Outcomes

- Identify and manipulate analytic functions, including the elementary functions and functions with branch cuts.
- Investigate and manipulate infinite series, including Taylor and Laurent expansions.
- Employ Cauchy's theorems to solve and analyze problems in complex analysis.
- Evaluate integrals using contour integral methods.

MATH455. PARTIAL DIFFERENTIAL EQUATIONS. 3.0 Semester Hrs.

Linear partial differential equations, with emphasis on the classical second-order equations: wave equation, heat equation, Laplace's equation. Separation of variables, Fourier methods, Sturm-Liouville problems. Prerequisites: MATH225 or MATH235 and MATH213 or MATH223. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- Construct and analyze Fourier series.
- Use the method of separation of variables to solve boundary-value and initial-value problems.
- Solve fundamental Sturm–Liouville problems.
- Use the method of Frobenius to solve second-order ODEs.

MATH457. INTEGRAL EQUATIONS. 3.0 Semester Hrs.

This is an introductory course on the theory and applications of integral equations. Abel, Fredholm and Volterra equations. Fredholm theory: small kernels, separable kernels, iteration, connections with linear algebra and Sturm-Liouville problems. Applications to boundary-value problems for Laplace's equation and other partial differential equations. Prerequisites: MATH332 or MATH342, and MATH455. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- Solve integral equations using appropriate methods.
- Use integral equations for boundary value problems.

MATH458. ABSTRACT ALGEBRA. 3.0 Semester Hrs.

This course is an introduction to the concepts of contemporary abstract algebra and applications of those concepts in areas such as physics and chemistry. Topics include groups, subgroups, isomorphisms and homomorphisms, rings, integral domains and fields. Prerequisites: MATH300. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- Students will read, interpret, and use the vocabulary, symbolism, and basic definitions used in abstract algebra, including binary operations, relations, groups, subgroups, homomorphisms, rings, and ideals.
- Students will develop and apply the fundamental properties of abstract algebraic structures, their substructures, their quotient structure, and their mappings. Students will also prove basic theorems such as Lagrange's theorem, Cayley's theorem, and the fundamental theorems for groups and rings.
- Students will use the facts, formulas, and techniques learned in this course to prove theorems about the structure, size, and nature of groups, subgroups, quotient groups, rings, subrings, and the associated mappings. Students will also solve problems about the size and composition of subgroups and quotient groups; the orders of elements; and isomorphic groups and rings.
- Students will acquire a level of proficiency in the fundamental concepts and applications necessary for further study, including graduate work, in academic areas requiring abstract algebra as a prerequisite, or for work in occupational fields requiring a background in abstract algebra or other highly abstract mathematics. These fields might include the physical sciences and engineering as well as mathematics.

MATH459. ASYMPTOTICS. 3.0 Semester Hrs.

Equivalent with MATH559,

Asymptotic methods are used to find approximate solutions to problems when exact solutions are unavailable or too complicated to be useful.

A broad range of asymptotic methods is developed, covering algebraic problems, integrals and differential equations. Prerequisites: MATH213 and MATH225. 3 hours lecture; 3 semester hours.

Course Learning Outcomes

- Use asymptotic methods to solve algebraic problems.
- Use asymptotic methods to estimate integrals
- Use asymptotic methods to solve differential equations.

MATH470. MATHEMATICAL MODELING OF SPATIAL PROCESSES IN BIOLOGY. 3.0 Semester Hrs.

This course is an introduction to mathematical modeling of spatial processes in biology. The emphasis is on partial differential equation models from a diverse set of biological topics such as cellular homeostasis, muscle dynamics, neural dynamics, calcium handling,

epidemiology, and chemotaxis. We will survey a variety of models and analyze their results in the context of the biology. Mathematically, we will examine the diffusion equation, advection equation, and combinations of the two that include reactions. There will be a significant computational component to the course including bi-weekly computational labs; students will solve the model equations and perform computations using MATLAB. Prerequisite: MATH431, MATH455 or equivalent courses and familiarity with MATLAB.

Course Learning Outcomes

- Describe classical spatial-temporal models in mathematical biology including diffusion-reaction, advection-reaction, and advection-diffusion-reaction
- Derive partial differential equations models for spatial-temporal phenomena
- Implement analytical and numerical techniques to solve and analyze spatial-temporal models
- Assimilate current literature, extend it in a final project that advances the field, and communicate results professionally and effectively

MATH472. MATHEMATICAL AND COMPUTATIONAL NEUROSCIENCE. 3.0 Semester Hrs.

This course will focus on mathematical and computational techniques applied to neuroscience. Topics will include nonlinear dynamics, hysteresis, the cable equation, and representative models such as Wilson-Cowan, Hodgkin-Huxley, and FitzHugh-Nagumo. Applications will be motivated by student interests. In addition to building basic skills in applied math, students will gain insight into how mathematical sciences can be used to model and solve problems in neuroscience; develop a variety of strategies (computational, theoretical, etc.) with which to approach novel mathematical situations; and hone skills for communicating mathematical ideas precisely and concisely in an interdisciplinary context. In addition, the strong computational component of this course will help students to develop computer programming skills and apply appropriate technological tools to solve mathematical problems. 3 hours lecture; 3 semester hours. Prerequisite: MATH431.

Course Learning Outcomes

- Describe the classical models of mathematical neuroscience including Hodgkin-Huxley, Wilson-Cowan, and FitzHugh-Nagumo
- Implement analytical and numerical techniques to analyze models at different spatial and temporal scales;
- Apply concepts from nonlinear dynamics including phase plane analysis, bifurcation theory, and model reduction techniques to analyze models in neuroscience.
- Assimilate current literature, extend it in a final project that advances the field, and communicate results professionally and effectively.

MATH482. STATISTICS PRACTICUM (CAPSTONE). 3.0 Semester Hrs.

This is the capstone course in the Statistics option. Students will apply statistical principles to data analysis through advanced work, leading to a written report and an oral presentation. Choice of project is arranged between the student and the individual faculty member who will serve as advisor. Prerequisite: MATH436.

Course Learning Outcomes

- Gain hands-on data analysis experience on a substantial problem seeing it all the way through.
- Communicate effectively with clients, who might have limited statistical background.

- Develop well-documented and reproducible code.
- Document results in a technical report and potentially co-author a scientific publication.

MATH484. MATHEMATICAL AND COMPUTATIONAL MODELING (CAPSTONE). 3.0 Semester Hrs.

This is the capstone course in the Computational and Applied Mathematics sequence. This course will include methods for building, solving, and analyzing spatial mathematical models. Other mathematical modeling techniques will also be introduced. Students will apply computational and applied mathematics modeling techniques to solve complex problems in biological, engineering and physical systems. Students will formulate and solve applied problems and will present results orally and in writing. Mathematical methods and algorithms will be studied within both theoretical and computational contexts. The emphasis is on how to formulate, analyze and use nonlinear modeling to solve typical modern problems. Prerequisite: MATH431, MATH455.

Course Learning Outcomes

- Construct, interpret, and critique fundamental models of physical, chemical, and biological systems throughout the fundamental and applied sciences.
- Utilize computational tools, such as MATLAB, to simulate behavior arising from mathematical models
- Describe and interpret, via oral and written means, pertinent information obtained from mathematical analysis and simulation in order to draw scientific conclusions concerning applied model

MATH491. UNDERGRADUATE RESEARCH. 1-3 Semester Hr.

Individual investigation under the direction of a department faculty member. Written report required for credit. Variable - 1 to 3 semester hours. Repeatable for credit to a maximum of 12 hours.

MATH498. SPECIAL TOPICS. 1-6 Semester Hr.

(I, II) Pilot course or special topics course. Topics chosen from special interests of instructor(s) and student(s). Usually the course is offered only once. Prerequisite: none. Variable credit; 1 to 6 credit hours. Repeatable for credit under different titles.

MATH498. SPECIAL TOPICS. 1-6 Semester Hr.

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MATH498. SPECIAL TOPICS. 1-6 Semester Hr.

MATH499. INDEPENDENT STUDY. 0.5-6 Semester Hr.

(I, II) Individual research or special problem projects supervised by a faculty member, also, when a student and instructor agree on a subject matter, content, and credit hours. Prerequisite: "Independent Study" form must be completed and submitted to the Registrar. Variable credit; 1 to 6 credit hours. Repeatable for credit.

MATH499. INDEPENDENT STUDY. 1-6 Semester Hr.
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