MATHEMATICS

http://www.pacific.edu/Academics/Schools-and-Colleges/College-of-the-Pacific/Academics/Departments-and-Programs/Mathematics.html
Phone: (209) 946-2347
Location: Main Office in CR 106
Christopher Goff, Chair

Degrees Offered

Bachelor of Arts
Bachelor of Science

Majors Offered

Mathematics (BA, BS)
Mathematics with Departmental Honors (BS)
Applied Mathematics (BS)
Applied Mathematics with Departmental Honors (BS)
Applied Mathematics (BS)/**Master of Science in Data Science Pathway Program**

Minors Offered

Mathematics
Applied Mathematics
Statistics

The Mathematics Department shares the University mission of providing a superior, student-centered education. Education in mathematics assists students in developing, to their fullest potential, their mathematical reasoning, communication and problem solving skills. Students who choose to major in mathematics are provided opportunities to develop strong problem solving skills that use quantitative methods and appropriate technology. They understand the strengths, limitations and wide applicability of mathematical modeling in a variety of disciplines. Students develop an appreciation for the discipline and esthetics of mathematics, effectiveness in problem solving, and an appropriate understanding of theory. Graduates who major in mathematics are prepared for the many careers in which mathematics plays an important role, for further study in Mathematics at the graduate level, or for careers in teaching mathematics.

Students who prepare for careers in mathematics, mathematics teaching, or for graduate study in mathematics elect the Bachelor of Science degree. Students interested in applied areas or majoring in a discipline which uses mathematics elect the Bachelor of Science in Applied Mathematics. Students interested in mathematics primarily as a component of a liberal education or as a second major may elect the Bachelor of Arts degree. Minors in Mathematics, Applied Mathematics and Statistics are available to students who wish to add this component to their college experience. Students who choose to double major or minor in mathematics or who choose to study mathematics as part of their liberal arts education learn the major methods, applicability, and spirit of the mathematical sciences.

The Department of Mathematics also provides courses offering opportunities for students from other disciplines and professional programs to develop the quantitative skills necessary for success in their chosen field.

Preparation for Studying Mathematics

Since many degree programs within the University require courses in mathematics, students are encouraged to complete four years of high school mathematics. In general this would include two years of algebra, a year of geometry and a year of Math Analysis that includes Trigonometry. Four years of IMP or CPM mathematics are usually equivalent to these traditional courses. Students with Advanced Placement AB credit (score of 4 or 5) or Math IB Higher Level (score of 5, 6, or 7) start college mathematics in Calculus II while students with AP BC credit (score of 4 or 5) start in Calculus III. AP credit in Statistics (score of 4 or 5) is equivalent to MATH 037. A quantitative fundamental skills requirement is part of the general education program and requires passing an Intermediate Algebra or higher level test during orientation or completing a college level Statistics or College Algebra course. In order to enroll in mathematics department courses numbered MATH 033, MATH 035, MATH 041, MATH 045, MATH 051, MATH 053, or MATH 161, students must take and pass a mathematics placement examination appropriate to the course prerequisite. Some courses in Economics, Chemistry, Physics, Computer Science, Psychology, Political Science, and fundamental skills also have mathematics placement requirements.

For students who need additional preparation before entering introductory college mathematics courses, the College of the Pacific offers developmental skill courses in the areas of fundamental mathematics.

Pre-Professional Education Courses for Single Subject Mathematics

Students who plan to earn a degree and a teaching credential through the University of the Pacific simultaneously are required to take certain professional education courses during their undergraduate years. Contact Dennis Parker in the Mathematics Department for details about these course requirements.

Departmental Honors

The honors programs in mathematics and applied mathematics gives students the chance to work with a faculty supervisor on an advanced project, possibly related to current research in mathematics. It is ideal preparation for students interested in graduate study in math, applied math or a related field.

In order to be admitted into the Mathematics with Departmental Honors program, students must have a major GPA of at least 3.5, have completed MATH 101, and have completed or currently enrolled in two of the following: MATH 141, MATH 143, or MATH 155. In order to be admitted into the Applied Mathematics with Departmental Honors program, students must have a major GPA of at least 3.5, have completed MATH 055 and have completed or be currently enrolled in MATH 145. Junior or Senior class standing is recommended.

Students meeting the eligibility requirements may apply to graduate with Honors any time prior to the start of their final two semesters. To apply, a student must obtain the consent of a mathematics faculty member who is willing to supervise an honors project (typically completed during the student's senior year) and submit an application form to the Department Chair. ***Once approved, a Change of Program form must be submitted to the Office of the Registrar.***

Mathematics and Applied Mathematics
Proficiency in Calculus

- Students will be able to solve routine, non-routine, and applied problems in single and multivariable calculus.

Proficiency in Linear Algebra

- Students will be able to solve routine, non-routine, and applied problems involving matrices, linear transformations, eigenvalues, eigenvectors, vector spaces, and systems of linear equations.

Mathematical Writing

- Students will be able to convey the solutions to problems, providing the underlying logic and analysis in a way that is clear and unambiguous.

Research, Independent Learning

- Students will demonstrate the ability to research a topic, summarize, and report findings. Students will be able to learn on their own. They will recognize when additional information is needed. They will find it, if possible. They will cultivate good questions. Students will use appropriate means to find answers.

Problem Solving

- Students will be able to solve mathematical problems. They will be able to use prescribed methodology as well as adapt theory and methodology in new ways.

Modeling (Applied Math)

- Students will be able to apply mathematical structures and theory to real world problems. Students will be able to take a new problem given in words, translate it into a mathematical problem, investigate solutions using analytic techniques, and put the solution back into words.

Proof (Math)

- Students will demonstrate the ability to read, write, and assess the accuracy of mathematical proof.

Preparation for the Major

The first course in all Mathematics majors is Calculus I, II or III depending on the student's high school preparation in mathematics. Majors with AP Math AB or IB Math HL credit start in Calculus II. Majors with AP Math BC credit start in Calculus III. Students who are not able to start in Calculus I because of deficiencies in their algebra or Trig skills start in MATH 041, Precalculus. Students who place lower than MATH 041 discuss with their advisor how much extra time is required to complete their degree program because of the required developmental work. Mathematics majors are proficient with technology and consider taking elective courses that use quantitative skills in areas such as business, economics, computer science, science and engineering.

Bachelor of Arts Major in Mathematics

Students must complete a minimum of 120 units with a Pacific cumulative and major/program grade point average of 2.0 in order to earn the bachelor of arts degree with a major in mathematics.

I. General Education Requirements

For more details, see General Education (http://catalog.pacific.edu/stocktongeneral/generaleducationprogram/)

Minimum 28 units and 9 courses that include:

A. CORE Seminars (2 courses)

CORE 001	Problem Solving & Oral Comm	3
CORE 002	Writing and Critical Thinking	4

Note: 1) CORE Seminars cannot be taken for Pass/No Credit. *2)* Transfer students with 28 or more transfer credits taken after high school are exempt from both CORE seminars.

B. Breadth Requirement (7 courses, at least 3 units each)

At least one course from each of the following areas:

Artistic Process & Creation
Civic & Global Responsibility
Language & Narratives
Quantitative Reasoning
Scientific Inquiry
Social Inquiry
World Perspectives & Ethics

Note: 1) No more than 2 courses from a single discipline can be used to meet the Breadth Requirement.

C. Diversity and Inclusion Requirement

All students must complete Diversity and Inclusion coursework (at least 3 units)

Note: 1) Diversity and Inclusion courses can also be used to meet the breadth category requirements, or major or minor requirements.

D. Fundamental Skills

Students must demonstrate competence in:

Writing
Quantitative Analysis (Math)

Note: 1) Failure to satisfy the fundamental skills requirements by the end of four semesters of full-time study at the University is grounds for academic disqualification.

II. College of the Pacific BA Requirement

Students must complete one year of college instruction or equivalent training in a language other than English.

Note: Transfer students with sophomore standing are exempt from this requirement.

III. Breadth Requirement

Students complete 60 units outside the primary discipline of the first major, regardless of the department who offers the course(s) in that discipline. (This includes general education courses, transfer courses, CPCE/EXTN units, internships, etc.)

IV. Major Requirements

Minimum 38 units and 12 courses that include:

MATH 011	Chair's Seminar	1
MATH 051	Calculus I	4
MATH 053	Calculus II	4
MATH 075	Introduction to Linear Algebra	4
MATH 101	Introduction to Abstract Mathematics	4
Select one of the following:		1
MATH 081	Writing Math Problems	
MATH 095	Problem Solving Seminar	

Select one of the following:		4
MATH 037	Introduction to Statistics and Probability	
MATH 131	Probability and Mathematical Statistics I	
Select two of the following:		8
MATH 143	Abstract Algebra I	
MATH 145	Applied Linear Algebra	
MATH 155	Real Analysis I	
Three MATH Electives (excluding MATH 005, MATH 033, MATH 035, MATH 041, MATH 045, MATH 161, and MATH 162) Minimum 3 units each.		

Note: Electives must be approved by a mathematics advisor.

Bachelor of Science Major in Mathematics

Students must complete a minimum of 120 units with a Pacific cumulative and major/program grade point average of 2.0 in order to earn the bachelor of science degree with a major in mathematics.

I. General Education Requirements

For more details, see General Education (http://catalog.pacific.edu/stocktongeneral/generaleducationprogram/)

Minimum 28 units and 9 courses that include:

A. CORE Seminars (2 courses)

CORE 001	Problem Solving & Oral Comm	3
CORE 002	Writing and Critical Thinking	4

Note: 1) CORE Seminars cannot be taken for Pass/No Credit. *2)* Transfer students with 28 or more transfer credits taken after high school are exempt from both CORE seminars.

B. Breadth Requirement (7 courses, at least 3 units each)
At least one course from each of the following areas:

Artistic Process & Creation
Civic & Global Responsibility
Language & Narratives
Quantitative Reasoning
Scientific Inquiry
Social Inquiry
World Perspectives & Ethics

Note: 1) No more than 2 courses from a single discipline can be used to meet the Breadth Requirement.

C. Diversity and Inclusion Requirement
All students must complete Diversity and Inclusion coursework (at least 3 units)

Note: 1) Diversity and Inclusion courses can also be used to meet the breadth category requirements, or major or minor requirements.

D. Fundamental Skills
Students must demonstrate competence in:

Writing
Quantitative Analysis (Math)

Note: 1) Failure to satisfy the fundamental skills requirements by the end of four semesters of full-time study at the University is grounds for academic disqualification.

II. Breadth Requirement

Students complete 60 units outside the primary discipline of the first major, regardless of the department who offers the course(s) in that discipline. (This includes general education courses, transfer courses, CPCE/EXTN units, internships, etc.)

III. Major Requirements

Minimum 46 units and 13 courses that include:

MATH 011	Chair's Seminar	1
MATH 051	Calculus I	4
MATH 053	Calculus II	4
MATH 055	Calculus III	4
MATH 075	Introduction to Linear Algebra	4
MATH 101	Introduction to Abstract Mathematics	4
MATH 141	Linear Algebra	4
MATH 143	Abstract Algebra I	4
MATH 155	Real Analysis I	4
Select one of the following two courses:		1
MATH 081	Writing Math Problems	
MATH 095	Problem Solving Seminar	
MATH Electives (Two courses with any number, excluding MATH 005, MATH 033, MATH 035, MATH 041, MATH 045, MATH 161 and MATH 162, minimum 3 units each)		6-9
MATH Upper Division Electives (Three courses numbered MATH 072 or higher excluding MATH 161, and MATH 162, minimum 3 units each)		9-12

Bachelor of Science Major in Mathematics with Departmental Honors

Students must complete a minimum of 120 units with a Pacific cumulative grade point average of 3.3 and major/program grade point average of 3.5 in order to earn the bachelor of science degree with a major in mathematics with departmental honors.

I. General Education Requirements

For more details, see General Education (http://catalog.pacific.edu/stocktongeneral/generaleducationprogram/)

Minimum 28 units and 9 courses that include:

A. CORE Seminars (2 courses)

CORE 001	Problem Solving & Oral Comm	3
CORE 002	Writing and Critical Thinking	4

Note: 1) CORE Seminars cannot be taken for Pass/No Credit. *2)* Transfer students with 28 or more transfer credits taken after high school are exempt from both CORE seminars.

B. Breadth Requirement (7 courses, at least 3 units each)
At least one course from each of the following areas:

Artistic Process & Creation
Civic & Global Responsibility
Language & Narratives
Quantitative Reasoning
Scientific Inquiry
Social Inquiry
World Perspectives & Ethics

Note: 1) No more than 2 courses from a single discipline can be used to meet the Breadth Requirement.

C. Diversity and Inclusion Requirement

All students must complete Diversity and Inclusion coursework (at least 3 units)

Note: 1) Diversity and Inclusion courses can also be used to meet the breadth category requirements, or major or minor requirements.

D. Fundamental Skills

Students must demonstrate competence in:

Writing	
Quantitative Analysis (Math)	

Note: 1) Failure to satisfy the fundamental skills requirements by the end of four semesters of full-time study at the University is grounds for academic disqualification.

II. Breadth Requirement

Students complete 60 units outside the primary discipline of the first major, regardless of the department who offers the course(s) in that discipline. (This includes general education courses, transfer courses, CPCE/EXTN units, internships, etc.)

III. Major Requirements

Minimum 46 units and 13 courses that include:

MATH 011	Chair's Seminar	1
MATH 051	Calculus I	4
MATH 053	Calculus II	4
MATH 055	Calculus III	4
MATH 075	Introduction to Linear Algebra	4
MATH 101	Introduction to Abstract Mathematics	4
MATH 141	Linear Algebra	4
MATH 143	Abstract Algebra I	4
MATH 155	Real Analysis I	4
Select one of the following two courses:		1
MATH 081	Writing Math Problems	
MATH 095	Problem Solving Seminar	
MATH Electives (Two courses with any number, excluding MATH 005, MATH 033, MATH 035, MATH 041, MATH 045, MATH 161 and MATH 162, minimum 3 units each)		6-9
MATH Upper Division Electives (Three courses numbered MATH 110 or higher excluding MATH 161, and MATH 162, minimum 3 units each)		9-12
MATH 197	Undergraduate Research [*]	2-4
Honors Thesis [*]		

Note: 1) Two semesters of MATH 197 under the direction of their chosen faculty supervisor. The second semester may focus on writing the Honors Thesis.

CSET Preparation (Future High School Math Teachers)

Students earning degrees with a Math or an Applied Math major are **not** required to pass the CSET exams (to demonstrate subject matter competence) for the California Single Subject Math credential. Please

contact Dr. Dennis Parker at dparker@pacific.edu for additional credential requirements.

a. BA for Single Subject Math with CSET (California Subject Exams for Teachers)

Core		
MATH 051	Calculus I	4
MATH 053	Calculus II	4
MATH 055	Calculus III	4
MATH 101	Introduction to Abstract Mathematics	4
MATH 141	Linear Algebra	4
MATH 143	Abstract Algebra I	4
Select one of the following Probability and Statistics course:		4
MATH 037	Introduction to Statistics and Probability	
MATH 131	Probability and Mathematical Statistics I	
Recommended Electives		
MATH 164	Topics in History of Mathematics	
MATH 166	Mathematical Concepts for Secondary Education	
MATH 168	Modern Geometries	

b. BS for Single Subject Math with CSET

Core		
MATH 051	Calculus I	4
MATH 053	Calculus II	4
MATH 055	Calculus III	4
MATH 101	Introduction to Abstract Mathematics	4
MATH 141	Linear Algebra	4
MATH 143	Abstract Algebra I	4
MATH 155	Real Analysis I	4
Recommended Electives		
MATH 037	Introduction to Statistics and Probability	
MATH 072	Operations Research Models	
MATH 074	Discrete and Combinatorial Mathematics	
MATH 164	Topics in History of Mathematics	
MATH 166	Mathematical Concepts for Secondary Education	
MATH 168	Modern Geometries	

Students who do not major in mathematics, but wish to earn a California mathematics or foundational-level mathematics teaching credential, may consider earning a minor in mathematics to help prepare them for the CSET exams. Below are minor coursework options recommended for mathematics teacher preparation.

MATH 037	Introduction to Statistics and Probability	4
MATH 051	Calculus I	4
MATH 053	Calculus II	4
MATH 101	Introduction to Abstract Mathematics	4
MATH 141	Linear Algebra	4
MATH 166	Mathematical Concepts for Secondary Education	3
MATH 168	Modern Geometries	4

Bachelor of Science Major in Applied Mathematics

Students must complete a minimum of 120 units with a Pacific cumulative and major/program grade point average of 2.0 in order to earn the bachelor of science degree with a major in applied mathematics.

I. General Education Requirements

For more details, see General Education (http://catalog.pacific.edu/stocktongeneral/generaleducationprogram/)

Minimum 28 units and 9 courses that include:

A. CORE Seminars (2 courses)

CORE 001	Problem Solving & Oral Comm	3
CORE 002	Writing and Critical Thinking	4

Note: 1) CORE Seminars cannot be taken for Pass/No Credit. *2)* Transfer students with 28 or more transfer credits taken after high school are exempt from both CORE seminars.

B. Breadth Requirement (7 courses, at least 3 units each)

At least one course from each of the following areas:

Artistic Process & Creation
Civic & Global Responsibility
Language & Narratives
Quantitative Reasoning
Scientific Inquiry
Social Inquiry
World Perspectives & Ethics

Note: 1) No more than 2 courses from a single discipline can be used to meet the Breadth Requirement.

C. Diversity and Inclusion Requirement

All students must complete Diversity and Inclusion coursework (at least 3 units)

Note: 1) Diversity and Inclusion courses can also be used to meet the breadth category requirements, or major or minor requirements.

D. Fundamental Skills

Students must demonstrate competence in:

Writing
Quantitative Analysis (Math)

Note: 1) Failure to satisfy the fundamental skills requirements by the end of four semesters of full-time study at the University is grounds for academic disqualification.

II. Breadth Requirement

Students complete 60 units outside the primary discipline of the first major, regardless of the department who offers the course(s) in that discipline. (This includes general education courses, transfer courses, CPCE/EXTN units, internships, etc.)

III. Major Requirements

Minimum 46 units and 13 courses that include:

MATH 011	Chair's Seminar	1
MATH 051	Calculus I	4
MATH 053	Calculus II	4
MATH 055	Calculus III	4
MATH 075	Introduction to Linear Algebra	4
MATH 145	Applied Linear Algebra	4
Select one of the following:		1
MATH 081	Writing Math Problems	
MATH 095	Problem Solving Seminar	
Select one of the following:		4
COMP 051	Introduction to Computer Science	
COMP 061	Introduction to Programming for Data Science	
Select one of the following:		4
MATH 057	Applied Differential Equations I: ODEs	
MATH 101	Introduction to Abstract Mathematics	
Select three of the following (minimum 3 units per course):		9-12
MATH 037	Introduction to Statistics and Probability	
MATH 057	Applied Differential Equations I: ODEs	
MATH 072	Operations Research Models	
MATH 074	Discrete and Combinatorial Mathematics	
MATH 110	Numerical Analysis	
MATH 121	Financial Mathematics I	
MATH 122	Financial Mathematics II	
MATH 130	Topics in Applied Statistics	
MATH 131	Probability and Mathematical Statistics I	
MATH 132	Probability and Mathematical Statistics II	
MATH 133	Statistical Learning Methods	
MATH 148	Cryptography	
MATH 152	Vector Analysis	
MATH 157	Applied Differential Equations II	
MATH 174	Graph Theory	
MATH 193 Special Topics (to be approved by advisor)		

Three further electives chosen from a list of approved courses available in the mathematics department or math electives numbered MATH 072 or higher (excluding MATH 081, MATH 095, MATH 161, MATH 162, and MATH 166.) At most one elective may be numbered lower than 100. — 9-12

Note: 1) Electives are to be chosen in consultation of a major advisor. *2)* At most one elective may be numbered lower than 110. *3)* One elective may be chosen from the following experiences: independent study, undergraduate research, internship, and practicum.

Bachelor of Science Major in Applied Mathematics with a concentration in Actuarial Science

Students must complete a minimum of 120 units with a Pacific cumulative and major/program grade point average of 2.0 in order to earn the bachelor of science degree with a major in applied mathematics with a concentration in actuarial science.

I. General Education Requirements

For more details, see General Education (http://catalog.pacific.edu/stocktongeneral/generaleducationprogram/)

Minimum 28 units and 9 courses that include:

A. CORE Seminars (2 courses)

CORE 001	Problem Solving & Oral Comm	3
CORE 002	Writing and Critical Thinking	4

Note: 1) CORE Seminars cannot be taken for Pass/No Credit. *2)* Transfer students with 28 or more transfer credits taken after high school are exempt from both CORE seminars.

B. Breadth Requirement (7 courses, at least 3 units each)

At least one course from each of the following areas:

Artistic Process & Creation
Civic & Global Responsibility
Language & Narratives
Quantitative Reasoning
Scientific Inquiry
Social Inquiry
World Perspectives & Ethics

Note: 1) No more than 2 courses from a single discipline can be used to meet the Breadth Requirement.

C. Diversity and Inclusion Requirement

All students must complete Diversity and Inclusion coursework (at least 3 units)

Note: 1) Diversity and Inclusion courses can also be used to meet the breadth category requirements, or major or minor requirements.

D. Fundamental Skills

Students must demonstrate competence in:

Writing
Quantitative Analysis (Math)

Note: 1) Failure to satisfy the fundamental skills requirements by the end of four semesters of full-time study at the University is grounds for academic disqualification.

II. Breadth Requirement

Students complete 60 units outside the primary discipline of the first major, regardless of the department who offers the course(s) in that discipline. (This includes general education courses, transfer courses, CPCE/EXTN units, internships, etc.)

III. Major Requirements

Minimum 50 units and 13 courses that include:

MATH 011	Chair's Seminar	1
COMP 051	Introduction to Computer Science	4
or COMP 061	Introduction to Programming for Data Science	
MATH 051	Calculus I	4
MATH 053	Calculus II	4
MATH 055	Calculus III	4
MATH 057	Applied Differential Equations I: ODEs	4
MATH 075	Introduction to Linear Algebra	4
MATH 081	Writing Math Problems	1
or MATH 095	Problem Solving Seminar	
MATH 121	Financial Mathematics I	3
MATH 131	Probability and Mathematical Statistics I	4
MATH 145	Applied Linear Algebra	4
Select two of the following:		7-8

MATH 037	Introduction to Statistics and Probability	
MATH 122	Financial Mathematics II	
MATH 124	Advanced Financial Mathematics	
MATH 125	Actuarial Models I	
MATH 126	Actuarial Models II	
MATH 127	Models of Life Contingencies I	
MATH 128	Models of Life Contingencies II	
MATH 130	Topics in Applied Statistics	
MATH 132	Probability and Mathematical Statistics II	
MATH 133	Statistical Learning Methods	
Select two of the following:		8
BUSI 104	Operations Management	
BUSI 105	Financial Management	
BUSI 123	Investment Analysis	
BUSI 125	Intermediate Financial Management	
BUSI 188	Data and Decisions	
COMP 047	Discrete Math for Computer Science	
COMP 137	Parallel Computing	
COMP 147	Computing Theory	
COMP 151	Artificial Intelligence	
ECON 160	Mathematical Economics	
ECON 161	Empirical Methods	
ECON 190	Econometrics	

Bachelor of Science Major in Applied Mathematics with Departmental Honors

Students must complete a minimum of 120 units with a Pacific cumulative grade point average of 3.3 and minimum major/program grade point average of 3.5 in order to earn the bachelor of science degree with a major in applied mathematics with departmental honors.

I. General Education Requirements

For more details, see General Education (http://catalog.pacific.edu/stocktongeneral/generaleducationprogram/)

Minimum 28 units and 9 courses that include:

A. CORE Seminars (2 courses)

CORE 001	Problem Solving & Oral Comm	3
CORE 002	Writing and Critical Thinking	4

Note: 1) CORE Seminars cannot be taken for Pass/No Credit. *2)* Transfer students with 28 or more transfer credits taken after high school are exempt from both CORE seminars.

B. Breadth Requirement (7 courses, at least 3 units each)

At least one course from each of the following areas:

Artistic Process & Creation
Civic & Global Responsibility
Language & Narratives
Quantitative Reasoning
Scientific Inquiry
Social Inquiry
World Perspectives & Ethics

Note: 1) No more than 2 courses from a single discipline can be used to meet the Breadth Requirement.

C. Diversity and Inclusion Requirement

All students must complete Diversity and Inclusion coursework (at least 3 units)

> *Note: 1)* Diversity and Inclusion courses can also be used to meet the breadth category requirements, or major or minor requirements.

D. Fundamental Skills

Students must demonstrate competence in:

Writing	
Quantitative Analysis (Math)	

> *Note: 1)* Failure to satisfy the fundamental skills requirements by the end of four semesters of full-time study at the University is grounds for academic disqualification.

II. Breadth Requirement

Students complete 60 units outside the primary discipline of the first major, regardless of the department who offers the course(s) in that discipline. (This includes general education courses, transfer courses, CPCE/EXTN units, internships, etc.)

III. Major Requirements

Minimum 50 units and 15 courses that include:

MATH 011	Chair's Seminar	1
MATH 051	Calculus I	4
MATH 053	Calculus II	4
MATH 055	Calculus III	4
MATH 075	Introduction to Linear Algebra	4
MATH 145	Applied Linear Algebra	4
COMP 051	Introduction to Computer Science	4
or COMP 061	Introduction to Programming for Data Science	
MATH 081	Writing Math Problems	1
or MATH 095	Problem Solving Seminar	
Select one of the following:		4
MATH 057	Applied Differential Equations I: ODEs	
MATH 101	Introduction to Abstract Mathematics	
Select three of the following (minimum 3 units per course):		9-12
MATH 037	Introduction to Statistics and Probability	
MATH 072	Operations Research Models	
MATH 074	Discrete and Combinatorial Mathematics	
MATH 110	Numerical Analysis	
MATH 121	Financial Mathematics I	
MATH 122	Financial Mathematics II	
MATH 130	Topics in Applied Statistics	
MATH 131	Probability and Mathematical Statistics I	
MATH 132	Probability and Mathematical Statistics II	
MATH 133	Statistical Learning Methods	
MATH 148	Cryptography	
MATH 152	Vector Analysis	
MATH 157	Applied Differential Equations II	
MATH 174	Graph Theory	
MATH 193	Special Topics (to be approved by advisor)	
MATH 197	Undergraduate Research (Honors Thesis)	2-4

Three further electives chosen from a list of approved courses available in the mathematics department or math electives numbered MATH 072 or higher (excluding MATH 081, MATH 095, MATH 161, MATH 162, and MATH 166.) At most one elective may be numbered lower than 100.		9-12

> *Note: Note: 1)* Electives are to be chosen in consultation of a major advisor. *2)* At most one elective may be numbered lower than 110. *3)* One elective may be chosen from the following experiences: independent study, undergraduate research, internship, and practicum. *4)* Two semesters of MATH 197 under the direction of their chosen faculty supervisor. The second semester may focus on writing the Honors Thesis.

Bachelor of Science in Applied Mathematics/Master of Science in Data Science Pathway Program

Students must complete a minimum of 120 units with a Pacific undergraduate cumulative and major/program grade point average of 3.0 in order to earn the Bachelor of Science in Applied Mathematics degree. The Master of Science in Data Science degree will be awarded after completion of the 30 graduate units required for this program. Eight units will count towards both the undergraduate and graduate degree requirements.

> **Note**: Acceptance into the graduate portion of this pathway program is conditional on (a) completion of all undergraduate program requirements by the end of the seventh semester at Pacific and (b} a minimum 3.0 cumulative Pacific undergraduate GPA.

I. General Education Requirements

For more details, see General Education (http://catalog.pacific.edu/stocktongeneral/generaleducationprogram/)

Minimum 28 units and 9 courses that include:

A. CORE Seminars (2 courses)

CORE 001	Problem Solving & Oral Comm	3
CORE 002	Writing and Critical Thinking	4

> *Note: 1)* CORE Seminars cannot be taken for Pass/No Credit. *2)* Transfer students with 28 or more transfer credits taken after high school are exempt from both CORE seminars.

B. Breadth Requirement (7 courses, at least 3 units each)

At least one course from each of the following areas:

Artistic Process & Creation
Civic & Global Responsibility
Language & Narratives
Quantitative Reasoning
Scientific Inquiry
Social Inquiry
World Perspectives & Ethics

> *Note: 1)* No more than 2 courses from a single discipline can be used to meet the Breadth Requirement.

C. Diversity and Inclusion Requirement

All students must complete Diversity and Inclusion coursework (at least 3 units)

D. Fundamental Skills

Students must demonstrate competence in:

Writing
Quantitative Analysis (Math)

Note: 1) Failure to satisfy the fundamental skills requirements by the end of four semesters of full-time study at the University is grounds for academic disqualification.

II. Breadth Requirement

Students complete 60 units outside the primary discipline of the first major, regardless of the department who offers the course(s) in that discipline. (This includes general education courses, transfer courses, CPCE/EXTN units, internships, etc.)

III. Major Requirements

Minimum 46 units and 13 courses that include:

MATH 011	Chair's Seminar	1
MATH 051	Calculus I	4
MATH 053	Calculus II	4
MATH 055	Calculus III	4
MATH 075	Introduction to Linear Algebra	4
MATH 081	Writing Math Problems	1
or MATH 095	Problem Solving Seminar	
MATH 145	Applied Linear Algebra	4
COMP 051	Introduction to Computer Science	4
or COMP 061	Introduction to Programming for Data Science	
Select one of the following:		4
MATH 057	Applied Differential Equations I: ODEs	
MATH 101	Introduction to Abstract Mathematics	
Select three of the following (minimum 3 units per course):		9-12
MATH 037	Introduction to Statistics and Probability	
MATH 057	Applied Differential Equations I: ODEs	
MATH 072	Operations Research Models	
MATH 074	Discrete and Combinatorial Mathematics	
MATH 101	Introduction to Abstract Mathematics	
MATH 110	Numerical Analysis	
MATH 121	Financial Mathematics I	
MATH 122	Financial Mathematics II	
MATH 130	Topics in Applied Statistics	
MATH 131	Probability and Mathematical Statistics I	
MATH 132	Probability and Mathematical Statistics II	
MATH 133	Statistical Learning Methods	
MATH 148	Cryptography	
MATH 152	Vector Analysis	
MATH 157	Applied Differential Equations II	
MATH 174	Graph Theory	
MATH 193 Special Topics (to be approved by advisor)		
Three further electives chosen from a list of approved courses available in the mathematics department or math electives numbered MATH 072 or higher (excluding MATH 081, MATH 095, MATH 161, MATH 162, and MATH 166.) At most one elective may be numbered lower than 100.		9-12

V. Master of Science in Data Science Requirements

Master of Science in Data Science

Students must complete a minimum of 32 units with a Pacific cumulative grade point average of 3.0 to earn the master of science in data science degree.

ANLT 201	Linear Algebra for Data Science	1
ANLT 202	Frequentist Statistics	1
ANLT 203	Bayesian Statistics	1
ANLT 208	Research Methods for Data Science	1
ANLT 210	Software Methods for Data Science	1
ANLT 212	Analytics Computing for Data Science	1
ANLT 214	Data Engineering for Data Science	1
ANLT 222	Machine Learning for Data Science	1
ANLT 224	Data Wrangling	1
ANLT 232	Introduction to Data Visualization	1
ANLT 233	Dynamic Visualization	1
ANLT 234	Analytics Storytelling for Data Science	1
ANLT 242	Relational Databases	1
ANLT 243	NoSQL Databases	1
ANLT 272	Healthcare Case Studies	1
ANLT 276	Emphasis Case Studies	1
ANLT 282	Capstone Project	6
ANLT 283	Weekly Hot Topics [*]	3
Select three of the following:		3
ANLT 205	Consumer Analytics	
ANLT 206	Sentiment Analysis and Opinion Mining	
ANLT 207	Time Series Analysis	
ANLT 223	Advanced Machine Learning	
ANLT 273	Fraud Detection	
ANLT 274	Customer Analytics	
ANLT 275	Text Mining	

* Students will take three semesters of ANLT 283.

The MS Data Science program here (https://engineering.pacific.edu/ engineering/academics/ms-data-science/)

Note: 1) A total of twelve graduate units can count towards the BS degree.

Minors

The study of mathematics is a process that develops important modes of critical thinking. Because quantitative problem solving is a desirable skill, a minor in mathematics can be a beneficial addition to the program of any student at Pacific irrespective of his/her major. Mathematics minors may also benefit students who plan on further graduate education in related areas. Minors in mathematics are designed to offer a measure of breadth and some depth in the student's mathematical experience. Only courses passed with a C- or better grade are used to meet the minor requirements. A minimum of 12 of the minor units must be completed at

Pacific. Students who plan to minor in mathematics contact the chair of the Mathematics Department and are assigned a minor advisor.

Minor in Mathematics

Students must complete a minimum of 23 units with a Pacific minor grade point average of 2.0 in order to earn a minor in Mathematics.

Minor Requirements:

MATH 101	Introduction to Abstract Mathematics	4
MATH 051	Calculus I	4
MATH 053	Calculus II	4
MATH 075	Introduction to Linear Algebra	4
Select one of the following:		4
MATH 141	Linear Algebra	
MATH 143	Abstract Algebra I	
MATH 155	Real Analysis I	
Select one MATH elective		3-4

Minor in Statistics

Students must complete a minimum of 25 units with a Pacific minor grade point average of 2.0 in order to earn a minor in statistics.

Minor Requirements:

Select one of the following:		4
MATH 035	Elementary Statistical Inference	
MATH 037	Introduction to Statistics and Probability	
MATH 051	Calculus I	4
MATH 053	Calculus II	4
MATH 130	Topics in Applied Statistics	3
MATH 131	Probability and Mathematical Statistics I	4
Two additional courses relevant to statistics (at least 3 units each)		6-8

Note: Electives are to be chosen in consultation of a minor advisor.

Minor in Applied Mathematics

Students must complete a minimum of 20 units with a Pacific minor grade point average of 2.0 in order to earn a minor in applied mathematics.

Minor Requirements:

MATH 051	Calculus I	4
MATH 053	Calculus II	4
MATH 075	Introduction to Linear Algebra	4
MATH 145	Applied Linear Algebra	4
Three MATH Electives (see notes below)		9-12

Note: 1) Electives are to be chosen in consultation of a minor advisor. 2) Units earned for MATH 033, MATH 035, MATH 041, MATH 045, MATH 161, or MATH 162 do not count as elective units toward the minor in applied mathematics.

Mathematics Courses

MATH 001. Pre-algebra and Lab. 3 Units.
This course is designed for students whose Mathematics Placement Test score indicates a need to review arithmetic skills and Pre-algebra material. Topics covered include fractions, decimals, percents, basic area and volume formulas, signed numbers, use of variables in mathematical statements, translating statements in English to mathematical equations, solving linear equations and ratio and proportion. The course is taught using a Personalized System of Instruction. Neither the course credit nor course grade applies towards graduation. Prerequisite is an appropriate test score or permission of instructor.

MATH 003. Elementary Algebra and Lab. 3 Units.
Topics covered include signed numbers, linear equations, polynomials, factoring, algebraic fractions, radicals, quadratic equations, inequalities and systems of linear equations. This is an introductory course for students with limited high school background in mathematics. This course is taught using a Personalized System of Instruction. This course is inappropriate for students who have passed the Elementary Algebra placement exam or any higher level placement exam. Neither the course credit nor course grade applies towards graduation. Prerequisite: MATH 001 with a "C" or better or an appropriate test score or permission of instructor.

MATH 004. Math Literacy for College. 3 Units.
This course is designed to help students develop mathematical reasoning skills and the foundational algebra skills needed to be successful in an introductory statistics or intermediate algebra course. The topics in the course are selected around the central goals for developing numeracy, proportional reasoning, algebraic reasoning, and an understanding of functions. An emphasis is placed on performing, explaining, and applying relevant skills to new situations. Problems are generally presented in context of real world situations. The course is not appropriate for students who have placed into MATH 005 or above. There is no prerequisite for this course. Students passing this course with a C- or better are eligible to take MATH 005, 005E, 035, or 161.

MATH 005. Intermediate College Algebra. 3 Units.
This course is taught in a traditional lecture format. Topics covered in this course include the real number system, solution of linear equations and inequalities, word problems, factoring, algebraic equations, exponents and radicals, quadratic equations, relations, functions, graphs, systems of equations and logarithmic and exponential functions. This course is not appropriate for students who have passed the Intermediate Algebra placement test of any higher level test. Pass/No Credit (P/NC) grading option is not allowed for this course. A grade of C- or better is required to satisfy the University's Fundamental Skills requirement in quantitative analysis/math. Prerequisite: MATH 003 with a "C-" or better or an appropriate test score or permission of instructor. **(MATH)**

MATH 005E. Intermediate College Algebra and Lab. 3 Units.
This course is taught using the emporium model in which students use technology to drive their learning in a lab setting with on-demand support from the instructor and tutors. Topics covered in this course include the real number system, solution of linear equations and inequalities, word problems, factoring, algebraic equations, exponents and radicals, quadratic equations, relations, functions, graphs, systems of equations and logarithmic and exponential functions. This course is not appropriate for students who have passed the Intermediate Algebra placement test of any higher level test. Pass/No Credit (P/NC) grading option is not allowed for this course. A grade of C- or better is required to satisfy the University's Fundamental Skills requirement in quantitative analysis/math. Prerequisite: MATH 003 with a "C-" or better or an appropriate test score or permission of instructor. **(MATH)**

MATH 007. Trigonometry and Lab. 2 Units.
Topics in this course include angle measure, trigonometric functions, applications of trigonometry, graphs of trigonometric functions, trigonometric identities, inverse functions and complex numbers. This course is designed for students who have not studied trigonometry in high school. Prerequisites include a satisfactory score on the Intermediate Algebra placement test. This course is taught using a Personalized System of Instruction and meets three hours per week. Pass/No credit (P/NC) grading option is not allowed for this course. Students who complete MATH 005 and MATH 007 with a C- or better may enroll in MATH 051. Prerequisite: MATH 005 with a "C-" or better, an appropriate test score, or permission of instructor. **(MATH)**

MATH 011. Chair's Seminar. 1 Unit.
The learning objective of this course is for students to gain insight into the Math department and university resources. Throughout the semester students will be exposed to various facets of the Math department and the university. Math professors will make presentations, introducing students to their research areas and upper division math courses they teach. Some of these presentations will introduce students to opportunities to get involved in undergraduate research. Students will also be exposed to university resources including, but not limited to, the Math Tutoring Center, Career Resource Center, Counselling and Psychological Services.

MATH 033. Elements of Calculus. 4 Units.
This course covers polynomial, rational, exponential and logarithmic functions as well as differentiation, integration and maxima/minima of functions of several variables. Elementary differential equations are studied and applications to natural sciences, social sciences and other fields are covered. Credit is not given for this course if a students has received credit for MATH 051 or AP credit in Calculus. Prerequisites: Two years of high school algebra and an appropriate score on either the Intermediate Algebra placement test or the Pre-Calculus placement test; or MATH 005 or MATH 041 with a "C-" or better. **(GE3B, GEQR, MATH)**

MATH 035. Elementary Statistical Inference. 3 Units.
Sampling, simple experimental designs, descriptive statistics, confidence intervals & hypothesis tests for means and proportions, Chi-square tests, linear & multiple regression, analysis of variance. Use of statistical software and/or online statistical calculators. Credit is not given for this course if a student has received credit for MATH 037 or MATH 131 or has AP credit in statistics. Prerequisite: MATH 004 or exemption by placement. GE IIIB. **(GE3B, GEQR, MATH, PLAW)**

MATH 037. Introduction to Statistics and Probability. 4 Units.
Students will develop mathematical tools for collecting, summarizing, analyzing, and drawing inferences from data. Topics covered include elements of descriptive statistics, such as graphs, tables, measures of central tendency and dispersion; discrete and continuous probability models for experiments and sampling distributions including the normal, t-, and chi-square distributions; and basic concepts of inferential statistics including confidence intervals, p-values, hypothesis tests for both one-and two-sample problems, ANOVA, and linear regression. The use of statistical software is required. This course is not recommended for first semester freshmen. Credit will not given for this course if a student has received credit for MATH 035 or has AP credit in Statistics. Prerequisites: MATH 033 or MATH 041 or MATH 045 or MATH 051 or MATH 053 with a "C-" or better or appropriate score on the calculus placement test. **(GE3B, GEQR, MATH, PLAW)**

MATH 039. Probability with Applications to Statistics. 4 Units.
Probability concepts in discrete and continuous spaces is explored in some depth as well as important probability models (e.g., binomial, Poisson, exponential, normal, etc.), mathematical expectation and generating functions. Applications to statistical inference includes maximum likelihood, moment and least squares estimation. Confidence intervals and hypothesis testing is also covered. Credit is not given for both MATH 039 and MATH 131. Prerequisite: MATH 053 with a "C-" or better. **(GE3B)**

MATH 041. Pre-calculus. 4 Units.
The algebraic and trigonometric concepts which are necessary preparation for Calculus I are studied. Topics include the real number system, algebraic, trigonometric, exponential and logarithmic functions. Emphasis is on the function concept; graphing functions; solving equations, inequalities and linear systems; and applied problems. Credit for this course is not given if a student has AP Calculus credit. Prerequisite: MATH 005 with a "C-" or better or an appropriate score on either the Intermediate Algebra placement test, the Pre-calculus placement test or the calculus placement test. **(GE3B, GEQR, MATH)**

MATH 045. Introduction to Finite Mathematics and Calculus. 3 Units.
Applications of finite math & calculus to problems in business, economics, and related fields through the study of systems of equations, elementary functions, elementary linear programming, the derivative, and the integral. Credit for this course is not given if a student has credit for MATH 051 or AP Calculus credit. Prerequisites: One of the following: (1) MATH 005 or MATH 041 with a grade of C- or higher (2) Math Placement (3) Exemption from Math Placement. **(GE3B, GEQR, MATH)**

MATH 051. Calculus I. 4 Units.
Students study differential calculus of algebraic and elementary transcendental functions, anti-derivatives, introductory definite integrals, and the Fundamental Theorem of Calculus. Applications include the first and second derivative tests and optimization. Credit is not given for this course if a student has AP Calculus I credit. Prerequisites: MATH 007 or MATH 041 with a "C-" or better, a score of 3 on either AP Calculus AB or BC exam, or an appropriate score on the placement test for calculus. **(GE3B, GEQR, MATH)**

MATH 053. Calculus II. 4 Units.
This course covers techniques and applications of integration, sequences and series, convergence of series, and Taylor Polynomials. Credit is not given for this course if a student has AP Calculus II credit. Prerequisites: MATH 051 with a "C-" or better, AP Calculus AB credit, or an appropriate score on the calculus placement test. **(GE3B, GEQR, MATH)**

MATH 055. Calculus III. 4 Units.
This course introduces multivariable calculus. Topics covered include vector geometry of the plane and Euclidean 3-space; differential calculus of real-valued functions of several variables, as well as partial derivatives, gradient, max-min theory, quadratic surfaces, and multiple integrals. Prerequisite: MATH 053 with a "C-" or better or AP Math BC credit.

MATH 057. Applied Differential Equations I: ODEs. 4 Units.
Students study ordinary differential equations, first-order equations, separable and linear equations. Also covered are direction fields, second order linear equations with constant coefficients, method of undetermined coefficients, laplace transforms, and unit impulse response and convolutions. Homogeneous systems of first order linear equations and matrix algebra determinants, eigenvalues, eigenvectors are also studied. Existence and uniqueness theorems are discussed and calculators or computers are used to display solutions and applications. Prerequisites: MATH 055 with a "C-" or better, or MATH 053 and MATH 075, both with a "C-" or better, or permission of instructor.

MATH 064. Ancient Arithmetic. 4 Units.
This course traces mathematical and historical developments throughout the ancient world, ending with the Scientific Revolution. Students will gain mathematical knowledge through the analysis of historical problems and solution methods, while contextualizing these endeavors into a larger historical context. Students will read mathematical primary sources, and will learn to think about the development of mathematical primary sources, and will learn to think about the development of mathematics as an intellectual pursuit over time. This course is cross-listed with HIST 066. Prerequisite: Fundamental Skills.

MATH 072. Operations Research Models. 4 Units.
Operations Research (OR) is concerned with scientific design and operation of systems which involve the allocation of scarce resources. This course surveys some of the quantitative techniques used in OR. Linear Programs are solved using graphical techniques and the simplex algorithm. Among the other models studied is the transportation, assignment, matching, and knapsack problems. Prerequisite: MATH 033 or MATH 045 or MATH 051 with a "C-" or better or the appropriate score on the calculus placement test.

MATH 074. Discrete and Combinatorial Mathematics. 4 Units.
The fundamental principles of discrete and combinatorial mathematics are covered. Topics include the fundamental principles of counting, the Binomial Theorem, generating functions, recurrence relations and introductory graph theory, that includes trees and connectivity. Prerequisite: MATH 033 or MATH 045 or MATH 051 with a "C-" or better, or an appropriate score on the calculus placement test.

MATH 075. Introduction to Linear Algebra. 4 Units.
Linear algebra is the generalized study of solutions to systems of linear equations. The study of such systems dates back over 2000 years and now is foundational in the design of computational algorithms for many modern applications. This course will serve as an introduction to basic computational tools in linear algebra including the algebra and geometry of vectors, solutions to systems of linear equations, matrix algebra, linear transformations, determinants, eigenvalue-eigenvector problems, and orthogonal bases. Prerequisite: MATH 051 with a "C-" or better.

MATH 081. Writing Math Problems. 1 Unit.
This course is an introduction to LaTeX math typesetting software commonly used by mathematicians including document creation, special document classes, mathematics commands and terminology. Writing problems for contests in multiple content areas and proofreading math problems. Practicum aspect: students will provide the content and grading for Pacific's Avinash Raina High School Math Competition. Prerequisite may be taken concurrently: MATH 051. (Spring).

MATH 093. Special Topics. 1-4 Units.

MATH 093E. Math Literacy for College. 3 Units.

MATH 093F. Special Topics. 4 Units.

MATH 095. Problem Solving Seminar. 1 Unit.
The objective of this course is to learn mathematics through problem solving. Students in mathematics courses are often given the impression that to solve a problem, one must imitate the solution to a similar problem that has already been solved. This course will attempt to develop student creativity in solving problems by considering problems not commonly encountered in other mathematics courses. Students enrolled in this course are expected to participate in the William Lowell Putnam Mathematical Competition on the first Saturday in December. Students may take this course for credit at most four times. Prerequisite: MATH 053 with a "C-" or better.

MATH 101. Introduction to Abstract Mathematics. 4 Units.
An introduction to the spirit and rigor of mathematics is the focus of the course. The content may vary with instructor, but the objective is to develop the skills required to read and write mathematics and prove theorems. Concepts include elementary logic, sets and functions, cardinality, direct and indirect proofs, mathematical induction. Prerequisites: MATH 053 with a "C-" or better or permission of the instructor.

MATH 110. Numerical Analysis. 4 Units.
Numerical analysis deals with approximation of solutions to problems arising from the use of mathematics. The course begins with a necessary but brief discussion of floating point arithmetic, and then proceeds to discuss the computer solution of linear algebraic systems by elimination and iterative methods, the algebraic eigenvalue problem, interpolation, numeric integration, that includes a discussion of adaptive quadrature, the computation of roots of nonlinear equations and the numerical solution of initial value problems in ordinary differential equations. Prerequisite: MATH 055 with a "C-" or better.

MATH 121. Financial Mathematics I. 3 Units.
This course provides understanding of fundamental concepts in financial mathematics and how those concepts are applied in calculating present and accumulated values for various streams of cash flows as a basis for future use in reserving, valuation, pricing, asset/liability management, investment income, capital budgeting, and valuing contingent cash flows. Topics include interest rates, determinants of interest rates, and interest-related concepts, annuities involving both level and varying payments, and varying interest rates, projects appraisal evaluation, loans and loan payment methods, bonds and bond evaluations. This course, together with MATH 122, prepares students for the Society of Actuaries Financial Mathematics examination. Prerequisite: MATH 053 with a "C-" or better or permission of instructor.

MATH 122. Financial Mathematics II. 3 Units.
This course is the second semester of one-year financial mathematics. The course starts with reviewing bonds and bond evaluations. New topics include: discount model in common stock evaluation, analysis of term structure of interest rates, concepts of duration and convexity, and using and convexity to approximate bond price changes with respect to interest rate change, cash flow matching, immunization (including full immunization), Redington immunization, interest rate swaps. This course, together with MATH 121, prepares students for the Society of Actuaries Financial Mathematics examination. Prerequisite: MATH 121 with a "C-" or better or permission of instructor.

MATH 122P. Problem Solving in Financial Mathematics. 1 Unit.
This 1 unit course is designed to prepare students for actuarial professional Exam FM. The course will review basic concepts in theory of interest and interest rate swaps (material covered in both MATH 121 and MATH 122). The course is entirely problem driven. Prerequisite: MATH 122 with a "C-" or better.

MATH 124. Advanced Financial Mathematics. 4 Units.
This course is designed to develop student's knowledge of the theoretical basis of certain actuarial models and the application of those models to insurance and other financial risks. The primary topics are: Option relations, binomial option pricing, Black-Scholes equation, market-making and delta hedging, exotic options, and Lognormal Distribution. Prerequisites: BUSI 123 and MATH 131 with a "C-" or better.

MATH 125. Actuarial Models I. 3 Units.
Actuaries put a price on risk, and this course considers constructing and analyzing actuarial loss models (risk theory, severity and ruin models). This is the first part of a two-course series that covers the theory and applications of actuarial modeling. Actuarial Models I covers topics in probability theory relevant to the construction of actuarial models. After a review of random variables and basic probability distributional properties, the course examines severity and frequency loss models. Aggregate loss models, risk measures and the impact of coverage modifications on both frequency and severity will also be discussed. Finally, we will explore various ways of simulating random variables. Prerequisite: MATH 132 with a "C-" or better or Permission of Instructor.

MATH 126. Actuarial Models II. 3 Units.
This course is the second part of a two-course series that covers the theory and applications of actuarial modeling. The course continues a study of the loss modeling processes introduced in Actuarial Models I. The primary topics the course cover are: (1) Estimation for complete data: empirical distributions for complete, individual data and grouped data. (2) Estimation for modified data: point estimation, Mean, variance, and interval estimation, kernel density models, approximations for large data sets. (3) Frequentist estimation: method of moments and percentile matching, maximum likelihood estimation, variance and interval estimation, Bayesian estimation, estimation for discrete distribution. (4) Frequentist estimation for discrete distribution. (5) Model selection: representations of the data and model, hypothesis tests, two types of selection criteria, extreme value models, copula models, models with covariates. (6) Simulation. Prerequisite: MATH 125 with a "C-" or better or Permission of Instructor.

MATH 127. Models of Life Contingencies I. 4 Units.
This course is an introduction to life contingencies as applied in actuarial practice. This course is the first semester of two-semester course sequence, and it is designed to develop knowledge of the theoretical basis of life-contingent actuarial models and the application of those models to insurance and other financial risks. It covers the mathematical and probabilistic topics that underlie life contingent financial instruments like life insurance, pensions and lifetime annuities. Topics include life tables, present value random variables for contingent annuities and insurance, their distributions and actuarial present values, equivalence principle, and other principles for determining premiums and reserves. Prerequisites: MATH 122; MATH 131 with a "C-" or better or Permission of Instructor.

MATH 128. Models of Life Contingencies II. 4 Units.
This course is a continuation of the study of life contingencies. It is designed to develop the student's knowledge of the theoretical basis of life-contingent actuarial models and the application of those models to insurance and other financial risks. Topics include insurance and annuity reserves, characterization of discrete and continuous multiple decrement models in insurance, employee benefits, benefit reserves, and multiple life models. Prerequisite: MATH 127 with a "C-" or better or Permission of Instructor.

MATH 130. Topics in Applied Statistics. 3 Units.
This course covers topics in applied statistics not normally covered in an introductory course. Students study multiple regression and correlation, analysis of variance of one- and two-way designs and other topics selected from non-parametric methods, time series analysis, discriminant analysis, factor analysis, that depend upon student interest. There is extensive use of packaged computer programs. Prerequisites: MATH 035 or MATH 037 with a "C-" or better.

MATH 131. Probability and Mathematical Statistics I. 4 Units.
This course covers counting techniques, discrete and continuous random variables, distribution functions, special probability densities such as binomial, hypergeometric, geometric, negative binomial, Poisson, Uniform, Gamma, Exponential, Weibull, and Normal. Students study joint distributions, marginal and conditional distributions, mathematical expectations, moment generating functions, functions of random variables, sampling distribution of the mean, and the Central Limit Theorem. Credit is not given for both MATH 039 and MATH 131. Prerequisite: MATH 053 with a "C-" or better.

MATH 131P. Problem Solving in Probability. 1 Unit.
This course is designed to prepare students for actuarial professional Exam P. This course will review basic concepts in theory of probability. The primary focus is problem solving; applying fundamental probability tools in assessing risks. Prerequisite: MATH 131 or permission of instructor.

MATH 132. Probability and Mathematical Statistics II. 4 Units.
Sampling distributions such as Chi-square, t and F are studied as estimation methods such as methods of moments, maximum likelihood and least squares. The course covers properties of estimators such as unbiasedness, consistency, sufficiency, tests of hypothesis concerning means, difference between means, variances, proportions, one and two-way analysis of variance. Prerequisite: MATH 131 with a "C-" or better.

MATH 133. Statistical Learning Methods. 4 Units.
This course will describe, implement and compare statistical models for classification and regression problems including ordinary least squares regression, logistic regression, K-nearest neighbors, shrinkage methods, decision trees, random forests, clustering algorithms, principal component analysis, neural networks, random walks, and autoregressive models. Common methods for the selection and validation of models such as stepwise selection, cross-validation, training/testing sets and data visualization will also be discussed. The use of statistical software will be emphasized. An introductory background in programming is recommended. Prerequisites: MATH 037, DATA 051, or MATH 131 with a "C-" or better or permission of instructor.

MATH 141. Linear Algebra. 4 Units.
Fundamental linear algebra concepts from an abstract viewpoint, with the objective of learning the theory and writing proofs. Concepts include: vector spaces, bases, linear transformations, matrices, invertibility, eigenvalues, eigenvectors, invariant subspaces, inner product spaces, orthogonality, and the spectral theorem. Prerequisites: MATH 049, MATH 075 with a "C-" or better.

MATH 143. Abstract Algebra I. 4 Units.
This is an introductory course to groups, rings and fields, with an emphasis on number theory and group theory. Students study finite groups, permutation groups, cyclic groups, factor groups, homomorphisms, and the isomorphic theorem. The course concludes with an introduction to polynomial rings. Prerequisite: MATH 049 with a "C-" or better or permission instructor.

MATH 144. Abstract Algebra II. 4 Units.
This course is a continuation of MATH 143, and it emphasizes field theory and the application of groups to geometry and field extensions. Students study algebraic and separable field extensions, dimension, splitting fields, Galois theory, solvability by radicals, and geometric constructions. Prerequisite: MATH 143 with a "C-" or better or permission of instructor.

MATH 145. Applied Linear Algebra. 4 Units.
This is the second semester course in linear algebra with an emphasis on the theory and application of matrix decompositions. Topics include methods for solving systems of equations, QR factorization, the method of least squares, diagonalization of symmetric matrices, singular value decomposition, and applications. Prerequisites: MATH 053, MATH 075 with a "C-" or better.

MATH 148. Cryptography. 3 Units.
Cryptography and cryptanalysis from historical cryptosystems through the modern use of cryptology in computing are studied. Topics include public and symmetric key cryptosystems, digital signatures, modular arithmetic and other topics in number theory and algebra. Possible additional topics include error correcting codes, digital cash, and secret sharing techniques. Prerequisite: MATH 053 with a "C-" or better or permission of instructor.

MATH 152. Vector Analysis. 4 Units.
Vector analysis and topics for students of applied mathematics, physics and engineering are studied. Topics include vector fields, gradient, divergance and curl, parametiric surfaces, line integrals, surface integrals, and integral theorems. Formulations of vector analysis in cylindrical and spherical coordinates are also included. Prerequisites: MATH 055 with a "C-" or better.

MATH 154. Topology. 4 Units.
This course introduces general topology and its relation to manifold theory. Topics include metric spaces, general spaces, continuous functions, homeomorphisms, the separation axioms, connectedness, compactness, and product spaces. Prerequisite: MATH 049 with a "C-" or better.

MATH 155. Real Analysis I. 4 Units.
This course focuses on properties of real numbers, sequences and series of real numbers, limits, continuity and differentiability of real functions. Prerequisites: MATH 049 and MATH 055 with a "C-" or better.

MATH 156. Real Analysis II. 4 Units.
This course covers integration, series of real numbers, sequences and series of functions, and other topics in analysis. Prerequisite: MATH 155 with a "C-" or better.

MATH 157. Applied Differential Equations II. 4 Units.
This course covers partial differential equations, derivation and solutions of the Wave, Heat and Potential equations in two and three dimensions as well as Fourier series methods, Bessel functions and Legendre polynomials, and Orthogonal functions. Additional topics may include Fourier integral transform methods, the Fast Fourier Transform and Sturm-Liouville theory. Computer exercises that use MATLAB are included. Prerequisite: MATH 057 with a "C-" or better.

MATH 161. Elementary Concepts of Mathematics I. 3 Units.
Concepts and principles underlying elementary and middle school programs in mathematics. Laboratory materials will be used to reinforce understanding of concepts. Prerequisite: MATH 004, suitable score on placement test, or exemption from placement test. Not open to freshman. This course does not count as an elective for a B.S. degree.

MATH 162. Elementary Concepts of Mathematics II. 3 Units.
Continuation of MATH 161. Concepts and principles of elementary and middle school mathematics. Prerequisites: MATH 161 (concurrency allowed) or permission of instructor.

MATH 164. Topics in History of Mathematics. 3 Units.
Topics in mathematics are studied from a historical perspective. Topics are chosen from: numeration systems; mathematics of the ancient world, especially Greece; Chinese, Hindu and Arabic mathematics; the development of analytic geometry and calculus; and modern axiomatic mathematics. Students solve problems using historical and modern methods. Students read and report on the biography of a mathematician. Prerequisite: MATH 053 with a "C-" or better. Junior standing or permission of the instructor.

MATH 166. Mathematical Concepts for Secondary Education. 3 Units.
This course covers secondary school mathematics from an advanced viewpoint and pedagogical perspective. Content is aligned with the mathematics subject matter requirements from the California Commision on Teacher Credentialing. Prerequisite: MATH 053 with a "C-" or better.

MATH 168. Modern Geometries. 4 Units.
Selected topics in this course are from Euclidean, non-Euclidean and transformational geometry in additionto both analytic and synthetic methods. The history of the development of geometries and axiomatic systems is covered. The course uses laboratory materials and computer packages used to reinforce understanding of the concepts. The course is required for high school teacher candidates. Prerequisite: MATH 049 with a "C-" or better or permission of instructor.

MATH 174. Graph Theory. 4 Units.
This course is an in-depth consideration of discrete structures and their applications. Topics include connectivity, Eulerian and Hamiltonian paths, circuits, trees, Ramsey theory, digraphs and tournaments, planarity, graph coloring, and matching and covering problems. Applications of graph theory to fields such as computer science, engineering, mathematics, operations research, social sciences, and biology are considered. Prerequisites: MATH 051 or MATH 074 or COMP 047 with a "C-" or better or an appropriate score on the calculus placement test.

MATH 189A. Statistical Consulting Practicum. 2 Units.
While working under close faculty supervision, students gain valuable practical experience in applying statistical methods to problems presented by University researchers, business and industry. Students enrolled in MATH 189A ordinarily participate in more sophisticated projects and take a more responsible role than students in MATH 089A. Pass/No credit. Prerequisites: for MATH 089A, MATH 130 with a "C-" or better or permission of the instructor; for MATH 189A, 089A with a "C-" or better and permission of the instructor.

MATH 191. Independent Study. 2-4 Units.
Student-initiated projects cover topics not available in regularly scheduled corses. A written proposal that outlines the project and norms for evaluation must be approved by the department chairperson.

MATH 197. Undergraduate Research. 2-4 Units.