

# MATHEMATICS AND STATISTICS

College of Natural Sciences and Mathematics

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General - John O. Brevik

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Students desiring information should contact the department office for referral to one of the faculty advisors.

## Career Possibilities

Mathematician • Statistician • Operations Research Analyst • Computer Programmer • Wage/Salary Analyst • Teacher • Systems Analyst • Financial Analyst • Corporate Accountant • Actuary • Surveyor • Information Scientist • Econometrist • Securities Analyst • Efficiency Engineer • Meteorologist • Technical Writer • Demographer (Some of these, and other careers, require additional education or experience. For more information, see [www.careers.csulb.edu](http://www.careers.csulb.edu).) Various entry-level trainee positions in business and industry are available for graduates regardless of academic discipline.

## Introduction

Mathematics is fundamental to all scientific knowledge, including not only the traditional natural sciences but increasingly the social and economic sciences. Mathematics is also a vital aid to critical and philosophical thinking.

The Department offers instruction for students at all levels beyond high school mathematics. Its courses provide the computational and analytic skills needed for a variety of majors, as well as the advanced theoretical topics for specialists in mathematics.

## Academic Advising and Facilitated Enrollment into Classes

All entering students who declare a major in a degree program offered by this department need to contact the College of Natural Sciences and Mathematics' (CNSM) Academic Advising Center (HSCI 164) and participate in the College's Science Safari to Success (for first time freshmen) or EONS (Enrollment and Orientation in the Natural Sciences and Mathematics for transfer students) Program. These programs are held in June-July for those starting in the Fall Semester and in January for those starting in the Spring Semester. Department advisors will be available to provide an overview of the students' chosen baccalaureate degree program, to assist with academic advisement, to provide information on the many career opportunities available, and to aid students in enrolling in classes. Contact the CNSM Academic Advising Center, Jensen Student Access to Sciences and Mathematics Center (HSCI 164), or department office for additional information.

## Concurrent and/or Summer Enrollment at Another College

Students who wish to take coursework at a community college or other college to meet curricular requirements while enrolled as undergraduates in the College of Natural Sciences and Mathematics must petition the appropriate department for prior approval to earn credit for specific courses. This policy applies to concurrent enrollment or summer enrollment. University policy must also be complied with; see 'Concurrent Enrollment' and 'Transfer of Undergraduate Credit' in this catalog. Courses not receiving prior approval will not be accepted for credit by the department.

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## Undergraduate Programs

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### Bachelor of Science in Mathematics (120 units)

This program requires a selection of fundamental courses in algebra, statistics, and analysis be taken. It is the most flexible program, in which the greatest number of electives may be chosen. Elective upper division mathematics courses are available which meet the needs of students preparing careers in industry and government, secondary teaching, and graduate study. Students who do not wish to complete the requirements for a declared option in applied mathematics or statistics may wish to elect courses in one or both of these areas as part of this degree program.

### Requirements

Lower Division:

Take all the following courses:

MATH 122 Calculus I (4)

Prerequisite: Appropriate MDPT placement or a grade of "C" or better in MATH 111 and 113, or a grade of "C" or better in MATH 117.

MATH 123 Calculus II (4)  
Prerequisite: A grade of "C" or better in MATH 122.

MATH 224 Calculus III (4)  
Prerequisite: A grade of "C" or better in MATH 123.

MATH 233 Fundamental Concepts for Adv Math (3)  
Prerequisite: A grade of "C" or better in MATH 123.

MATH 247 Introduction to Linear Algebra (3)  
Prerequisite: MATH 123.

CECS 174 Introduction to Programming and Problem Solving (3)  
Prerequisite: CECS 100 and MATH 113 (or equivalent).

PHYS 151 Mechanics and Heat (4)  
Prerequisite/Corequisite: MATH 122.

Take one of the following courses:

ENGL 101 Composition (3)  
Prerequisite: ENGL 100.

ENGL 317 Technical Communication (3)  
Prerequisites: GE Foundation requirements, upper-division standing, and a previous composition course, i.e., ENGL 100, 101, 102, 300, or equivalents.

Upper Division:

A minimum of 30 units of approved courses selected in consultation with a major advisor, to include the following:

Take one of the following courses:

MATH 341 Number Theory (3)  
Prerequisite: MATH 233.

MATH 347 Linear Algebra (3)  
Prerequisites: MATH 233 and 247.

Take all of the following courses:

MATH 361A Introduction to Mathematical Analysis I (3)  
Prerequisites: MATH 224, and MATH 233 or 247.

MATH 361B Introduction to Mathematical Analysis II (3)  
Prerequisite: MATH 361A.

MATH 364A Ordinary Differential Equations I (3)  
Prerequisites: MATH 224; Prerequisite/Corequisite: MATH 247.

MATH/STAT 380 Probability and Statistics (3)  
Prerequisite: MATH 224.

MATH 444 Introduction to Abstract Algebra (3)  
Prerequisites: MATH 233 and 247 and at least one of MATH 341 or 347.

(may not include MATH 303, 370A, 370B, or 409)

To allow flexibility, only 18 of the required 30 units are specified. Students should choose the remaining 12 units after discussing career goals and interests with an advisor.

## Option in Applied Mathematics (120 units)

This option emphasizes mathematics frequently used in applications. The student may choose one of two suboptions: the first is aimed at applications in science and engineering, the second at applications in economics and management. Students are prepared for careers in industry, business, and government and for graduate study in applied mathematics.

### Requirements

*Suboption I: Application in Science and Engineering*

Lower Division:

Take all the following courses:

MATH 122 Calculus I (4)  
Prerequisite: Appropriate MDPT placement or a grade of "C" or better in MATH 111 and 113, or a grade of "C" or better in MATH 117.

MATH 123 Calculus II (4)  
Prerequisite: A grade of "C" or better in MATH 122.

MATH 224 Calculus III (4)  
Prerequisite: A grade of "C" or better in MATH 123.

MATH 247 Introduction to Linear Algebra (3)  
Prerequisite: MATH 123.

CECS 174 Introduction to Programming and Problem Solving (3)  
Prerequisite: CECS 100 and MATH 113 (or equivalent).

PHYS 151 Mechanics and Heat (4)  
Prerequisite: None.

PHYS 152 Electricity and Magnetism (4)  
Prerequisite: PHYS 151; Prerequisite/Corequisite: MATH 123.

Take one of the following courses:

ENGL 101 Composition (3)  
Prerequisite: ENGL 100.

ENGL 317 Technical Communication (3)  
Prerequisites: GE Foundation requirements, upper-division standing, and a previous composition course, i.e., ENGL 100, 101, 102, 300, or equivalents.

Take one of the following courses:

PHYS 254 Applied Modern Physics (3)  
Prerequisite: PHYS 152 or EE 210; Prerequisite/Corequisite: MATH 224.

EE 211 Electric and Electronic Circuits (3)  
Prerequisites: (EE 210/210L or PHYS 152) and (MATH 123 or equivalent).

CE 205 Analytical Mechanics I (Statics) (3)  
Prerequisite: PHYS 151. Prerequisite/Corequisite: MATH 123.

Upper Division:

Take all the following courses:

MATH 323 Introduction to Numerical Analysis (4)  
Prerequisites: MATH 224, and a course in computer programming.

MATH 361A Introduction to Mathematical Analysis I (3)  
Prerequisites: MATH 224, and MATH 233 or 247.

MATH 361B Introduction to Mathematical Analysis II (3)  
Prerequisite: MATH 361A.

MATH 364A Ordinary Differential Equations I (3)  
Prerequisites: MATH 224, and prerequisite or corequisite MATH 247.

MATH 364B Ordinary Differential Equations II (3)  
Prerequisite: MATH 364A or 370A.

MATH/STAT 380 Probability and Statistics (3)  
Prerequisite: MATH 224.

MATH 470 Intro to Partial Differential Equations (3)  
Prerequisite: MATH 364A or 370A.

A minimum of 9 units from the following:

MATH 423, 461, 463, 472, 473, 474, 479, 485; STAT 381, 482.

A minimum of 9 units from one of the following groups:

A. PHYS 310, 340A, 340B, 350, 410, 422, 450;

B. EE 310, 370, 382, 411, 460, 482;

C. CE 335, 359, 437, 438, 458; MAE 371, 373

*Suboption II: Application in Economics and Management*

Lower Division:

Take all the following courses:

MATH 122 Calculus I (4)  
Prerequisite: Appropriate MDPT placement or a grade of "C" or better in MATH 111 and 113, or a grade of "C" or better in MATH 117.

- MATH 123 Calculus II (4)  
Prerequisite: A grade of "C" or better in MATH 122.
- MATH 224 Calculus III (4)  
Prerequisite: A grade of "C" or better in MATH 123.
- MATH 247 Introduction to Linear Algebra (3)  
Prerequisite: MATH 123.
- CECS 174 Introduction to Programming and Problem Solving (3)  
Prerequisite: CECS 100 and MATH 113 (or equivalent).

Take one of the following courses:

- ENGL 101 Composition (3)  
Prerequisite: ENGL 100.
- ENGL 317 Technical Communication (3)  
Prerequisites: GE Foundation requirements, upper-division standing, and a previous composition course, i.e., ENGL 100, 101, 102, 300, or equivalents.

Take one of the following groups:

1. ECON 100 Principles of Macroeconomics (3)  
Prerequisites: MATH 103 or higher and one GE Foundation course.  
ECON 101 Principles of Microeconomics (3),  
Prerequisite/Corequisite: MATH 103 or higher.  
or
2. ECON 300 Fundamentals of Economics (3)  
Prerequisites: GE Foundation requirements.

Upper Division:

Take all the following courses:

- MATH 323 Introduction to Numerical Analysis (4)  
Prerequisites: MATH 224, and a course in computer programming.
- MATH 361A Introduction to Mathematical Analysis I (3)  
Prerequisites: MATH 224, and MATH 233 or 247.
- MATH 361B Introduction to Mathematical Analysis II (3)  
Prerequisite: MATH 361A.
- MATH 364A Ordinary Differential Equations I (3)  
Prerequisites: MATH 224, and prerequisite or corequisite MATH 247.
- MATH/STAT 380 Probability and Statistics (3)  
Prerequisite: MATH 224.
- MATH 485 Mathematical Optimization (3)  
Prerequisites: MATH 247 and at least one of MATH 323, 347 or 380.
- STAT 381 Mathematical Statistics (3)  
Prerequisites: MATH 247, and MATH 380 or STAT 380.
- STAT 482 Random Processes (3)  
Prerequisites: MATH 247, and MATH 380 or STAT 380.

Take a minimum of 6 units from the following courses:

MATH 364B, 423, 463, 470, 473, 474, 479; STAT 410

Take a minimum 15 units from one of the following groups:

A. Take both of the following courses:

ECON 310 Microeconomic Theory (3)  
Prerequisites: ECON 100, ECON 101, and either MATH 115 or MATH 122, with grades of "C" or better in all prerequisite courses.

ECON 311 Macroeconomic Theory (3)  
Prerequisites: ECON 100, ECON 101, and either MATH 115 or MATH 122, with grades of "C" or better in all prerequisite courses.

Take 9 units selected from the following  
ECON 333, 410, 411, 420, 485, 486

B. Take both of the following courses:

ECON 333 Managerial Economics (3)  
Prerequisites: ECON 100, 101 and either MATH 115 or 122.

SCM 410 Logistics Management (3)  
Prerequisites: MGMT 300, IS 301.

Take 9 units selected from the following:

SCM 411, 414; MGMT 412, 413, 426

### Option in Statistics (120 units)

This option provides a foundation in statistical methods. The courses required ensure that the student understands how the techniques are mathematically derived and how they are applied. Statistical analysis is an essential part of any scientific investigation and is a vital tool in monitoring the quality of products and services and in forecasting.

#### Requirements

Lower Division:

Take all the following courses:

MATH 122 Calculus I (4)  
Prerequisite: Appropriate MDPT placement or a grade of "C" or better in MATH 111 and 113, or a grade of "C" or better in MATH 117.

MATH 123 Calculus II (4)  
Prerequisite: A grade of "C" or better in MATH 122.

MATH 224 Calculus III (4)  
Prerequisite: A grade of "C" or better in MATH 123.

MATH 247 Introduction to Linear Algebra (3)  
Prerequisite: MATH 123.

CECS 174 Introduction to Programming and Problem Solving (3)  
Prerequisite: CECS 100 and MATH 113 (or equivalent).

Take one of the following courses:

ENGL 101 Composition (3)  
Prerequisite: ENGL 100.

ENGL 317 Technical Communication (3)  
Prerequisites: GE Foundation requirements, upper-division standing, and a previous composition course, i.e., ENGL 100, 101, 102, 300, or equivalents.

Upper Division:

Take a minimum of 34 units of MATH or STAT courses to include the following (but not MATH 303, 370A or 370B):

MATH 323 Introduction to Numerical Analysis (4)  
Prerequisites: MATH 224, and a course in computer programming.

MATH 361A Introduction to Mathematical Analysis I (3)  
Prerequisites: MATH 224, and MATH 233 or 247.

STAT 380 Probability and Statistics (3)  
Prerequisite: MATH 224.

STAT 381 Mathematical Statistics (3)  
Prerequisites: MATH 247, and MATH 380 or STAT 380.

STAT 410 Regression Analysis (3)  
Prerequisite: STAT 381.

STAT 450 Multivariate Statistical Analysis (3)  
Prerequisite: STAT 381; Prerequisite/Corequisite STAT 410.

STAT 475 Data Analysis with SAS (3)  
Prerequisite: STAT 381 or consent of instructor.

Three units of the elective upper-division MATH or STAT courses may be replaced by MATH 233.

## Option in Mathematics Education (120 units)

This option is for students preparing to teach mathematics at the secondary school level. Completion of this option meets subject matter competence requirements for the Single Subject Teaching Credential Mathematics. Consult the department's Mathematics Education Advisor early to plan the program.

### Requirements

#### Lower Division:

Take all the following courses:

MATH 122 Calculus I (4)

Prerequisite: Appropriate MDPT placement or a grade of "C" or better in MATH 111 and 113, or a grade of "C" or better in MATH 117.

MATH 123 Calculus II (4)

Prerequisite: A grade of "C" or better in MATH 122.

MATH 224 Calculus III (4)

Prerequisite: A grade of "C" or better in MATH 123.

MATH 233 Fundamental Concepts for Adv Math (3)

Prerequisite: A grade of "C" or better in MATH 123.

MATH 247 Introduction to Linear Algebra (3)

Prerequisite: MATH 123.

Take one of the following courses:

ENGL 101 Composition (3)

Prerequisite: ENGL 100.

ENGL 300 Advanced Composition (3)

Prerequisites: GE Foundation requirements and upper-division standing.

ENGL 317 Technical Communication (3)

Prerequisites: GE Foundation requirements, upper-division standing, and a previous composition course, i.e., ENGL 100, 101, 102, 300, or equivalents.

Take one of the following sequences:

PHYS 151 Mechanics and Heat (4)

Prerequisite: None

PHYS 152 Electricity and Magnetism (4)

Prerequisite: PHYS 151; Prerequisite/Corequisite: MATH 123.

or

PHIL 170 Critical Reasoning (3)

Prerequisite/Corequisite: GE Foundation requirements Category A.1 (Written English).

PHIL 270 Symbolic Logic I (3)

Prerequisite: None.

or

Eight units of a foreign language.

#### Upper Division:

Take all the following courses:

MATH 310 History of Early Mathematics (3)

Prerequisite/Corequisite: A 200-level mathematics course.

MATH 341 Number Theory (3)

Prerequisite: MATH 233.

MATH 355 College Geometry (3)

Prerequisite: MATH 247.

MATH/STAT 380 Probability and Statistics (3)

Prerequisite: MATH 224.

MATH 410 History of Modern Mathematics (3)

Prerequisites: MATH 247, 310 and at least three of the following: MATH 233, 341, 355, 361A, 380.

MATH 444 Introduction to Abstract Algebra (3)

Prerequisites: MATH 233 and 247 and at least one of MATH 341 or 347.

STAT 381 Mathematical Statistics (3)

Prerequisites: MATH 247, and MATH 380 or STAT 380.

MTED 301 Computer Applications in Mathematics for Teachers (3)

Prerequisites: One year of high school geometry and one of MTED 110 or MATH 122.

MTED 411 Topics and Issues in Secondary School Mathematics (3)

Prerequisites: MATH 310, 341, 355, 380, 410, 444; EDSS 300M or consent of the instructor.

EDSS 300M. Introduction to Teaching - Mathematics (3)

Prerequisite: Advanced sophomore or junior standing.

Take one of the following courses:

MATH 361A Introduction to Mathematical Analysis I (3)

Prerequisites: MATH 224, and MATH 233 or 247.

MATH 364A Ordinary Differential Equations I (3)

Prerequisites: MATH 224, and prerequisite or corequisite MATH 247.

Take 3 additional upper division mathematics units *excluding*: MATH 303, 370A, 370B, 409.

### Single Subject Teaching Credential Mathematics

In addition to meeting the subject matter competence requirement for the Teaching Credential, prospective Math teachers are also required to complete 45 units of professional preparation in the Single Subject Credential Program, including student teaching. Students may begin the professional preparation courses as early as the junior year. With careful planning, it is possible to complete all of the credential program courses, except for student teaching, as an undergraduate. Courses may also be completed as a post-baccalaureate student. Refer to the Single Subject Teacher Education section of this catalog or the Single Subject Credential Program website ([www.ced.csulb.edu/single-subject](http://www.ced.csulb.edu/single-subject)) for a description of the professional preparation requirements, courses, and application procedures.

### Honors in Mathematics

Students majoring in the B.S. in Mathematics (all options) who would like an enriched academic program that includes a thesis may complete the Honors in the Major program described here. May also complete General Honors through the University Honors Program, in which case the thesis requirement may be met through the Honors in the Major.

### Admission Requirements

Admission to the Honors in the Major program will be determined by the Honors in the Major Advisor.

1. Junior or senior standing with at least one year remaining before graduation.
2. Declared major of B.S. in Mathematics or any of its options.
3. Completion of the following:

MATH 122 Calculus I (4)

Prerequisite: Appropriate MDPT placement or a grade of "C" or better in MATH 111 and 113, or a grade of "C" or better in MATH 117.

MATH 123 Calculus II (4)

Prerequisite: A grade of "C" or better in MATH 122.

MATH 224 Calculus III (4)

Prerequisite: A grade of "C" or better in MATH 123.

MATH 247 Introduction to Linear Algebra (3)

Prerequisite: MATH 123.

And at least two upper division MATH courses at the time of entry with grades of at least "C" in each course. Students may apply during the semester in which they expect to complete these courses.

- GPA's of at least 3.500 in all courses in the major and in all upper division courses in the major at the time of application.
- Submission of an application describing the student's academic background, reasons for applying, and willingness to commit to completion of the requirements, including a thesis.
- Letter of recommendation from a CSULB faculty member familiar with the student's work and abilities.

### Graduation Requirements

- GPA of at least 3.500 in all upper division courses in the major and in all courses in Items 3, 4, and 5, below.
- Completion of all requirements for the chosen option of the B.S. in Mathematics.
- Completion of at least one of the following courses: MATH 347, 423, 451, 461, 463, 472, 479.  
These courses may be included among the upper division units for the major, in item 2, if allowed in the student's major.
- Completion of at least three units of any combination of: MATH 491 and/or MATH 496.
- Completion of 3 units of MATH 498H, Senior Thesis-Honors.
- It is a requirement for this Honors in the Major program that the 6 units of MATH 491, 496, and 498H be in addition to the Department of Mathematics and Statistics course requirements for the B.S.
- Presentation of thesis results in a public forum. This forum could be at a meeting of a scientific or professional organization or a campus or departmental forum, subject to the approval of the Honors in the Major Advisor.  
Substitutions to this program must be approved by the Honors in the Major Advisor.

## Minor in Mathematics

### Requirements

The Minor in Mathematics is available to any student not majoring in Mathematics or Applied Mathematics.

The student must complete 23 or more semester units as follows:

- MATH 122 Calculus I (4)  
Prerequisite: Appropriate MDPT placement or a grade of "C" or better in MATH 111 and 113, or a grade of "C" or better in MATH 117.
- MATH 123 Calculus II (4)  
Prerequisite: A grade of "C" or better in MATH 122.
- MATH 224 Calculus III (4)  
Prerequisite: A grade of "C" or better in MATH 123.
- MATH 247 Introduction to Linear Algebra (3)  
Prerequisite: MATH 123.

And take 9 units of upper-division MATH or STAT courses to include MATH 361A but not MATH 370A.

The student may replace MATH 123 and 224 by an additional 3 units of upper division MATH or STAT (excluding MATH 370A) not used to meet the above upper-division requirements.

## Minor in Applied Mathematics

### Requirements

The Minor in Applied Mathematics is available to any student not majoring in Mathematics or Applied Mathematics.

The student must complete 27 or more semester units as follows:

Lower Division:

Take all of the following courses:

- MATH 122 Calculus I (4)  
Prerequisite: Appropriate MDPT placement or a grade of "C" or better in MATH 111 and 113, or a grade of "C" or better in MATH 117.
- MATH 123 Calculus II (4)  
Prerequisite: A grade of "C" or better in MATH 122.
- MATH 224 Calculus III (4)  
Prerequisite: A grade of "C" or better in MATH 123.
- MATH 247 Introduction to Linear Algebra (3)  
Prerequisite: MATH 123.

Upper Division:

Take all of the following courses:

- MATH 323 Introduction to Numerical Analysis (4)  
Prerequisites: MATH 224, and a course in computer programming.
- MATH/STAT 380 Probability and Statistics (3)  
Prerequisite: MATH 224.

Take one of the following courses:

- MATH 364A Ordinary Differential Equations I (3)  
Prerequisites: MATH 224, and prerequisite or corequisite MATH 247.
- MATH 370A Applied Mathematics I (3)  
Prerequisites: MATH 123. Not open to Freshmen.

Take one course from the following:

- MATH 364B, 423, 470, STAT 381, or 482.

The student may replace MATH 123 and 224 by an additional course from MATH 364B, 423, 470, STAT 381, 482 not used to meet the above upper division requirements.

## Minor in Statistics

### Requirements

The Minor in Statistics is available to any non-Mathematics major. The student must complete 26 or more semester units by following one of two sequences:

*Sequence One:*

Take all of the following courses:

- MATH 122 Calculus I (4)  
Prerequisite: Appropriate MDPT placement or a grade of "C" or better in MATH 111 and 113, or a grade of "C" or better in MATH 117.
- MATH 123 Calculus II (4)  
Prerequisite: A grade of "C" or better in MATH 122.
- MATH 247 Introduction to Linear Algebra (3)  
Prerequisite: MATH 123.
- MATH 380 Probability and Statistics (3)  
Prerequisite: MATH 224.
- STAT 381 Mathematical Statistics (3)  
Prerequisites: MATH 247, and MATH 380 or STAT 380.

Take any three of the following:

- MATH 323, STAT 410, 450, 475, 482, 484, and/or 485

### Sequence Two:

Take all of the following courses:

MATH 122 Calculus I (4)

Prerequisite: Appropriate MDPT placement or a grade of "C" or better in MATH 111 and 113, or a grade of "C" or better in MATH 117.

MATH 123 Calculus II (4)

Prerequisite: A grade of "C" or better in MATH 122.

MATH 224 Calculus III (4)

Prerequisite: A grade of "C" or better in MATH 123.

MATH 247 Introduction to Linear Algebra (3)

Prerequisite: MATH 123.

MATH 380 Probability and Statistics (3)

Prerequisite: MATH 224.

STAT 381 Mathematical Statistics (3)

Prerequisites: MATH 247, and MATH 380 or STAT 380.

Take any two of the following:

MATH 323, STAT 410, 450, 475, 482, 484, and/or 485

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## Graduate Programs

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### How to Apply

See department's website: [www.csulb.edu/depts/math/](http://www.csulb.edu/depts/math/)

To apply for admission to a graduate program in the Department of Mathematics and Statistics, you must apply to the department and to the university.

To apply to the department, send one of the following appropriate prerequisite worksheet (available online at above website or from the department office) to the Graduate Advisor by June 1 for fall admission or December 1 for spring admission:

- Pure Mathematics Prerequisite Worksheet;
- Applied Mathematics Prerequisite Worksheet;
- Applied Statistics Prerequisite Worksheet;
- Mathematics Education for Secondary Teachers Prerequisite Worksheet.

### Master of Science in Mathematics

#### Prerequisites

1. A bachelor's degree in mathematics, or a bachelor's degree with a minimum of 24 upper division units in mathematics from an accredited college or university;
2. A grade of "C" or better in MATH 247, 361A-B, 364A and 444, or their equivalents. Deficiencies will be determined by the Graduate Advisor.

#### Advancement to Candidacy

The regulations governing the master's degree are those in effect at the time of advancement to candidacy. In addition to University requirements, the student must have completed all prerequisite courses listed above with no grade less than "C". Students must have fulfilled the Graduation Writing Assessment Requirement (GWAR) and should file for Advancement upon completion of at least six units (and no more than nine units) on the Program, with at least a 3.0 GPA. Program of study must be approved by the appropriate Graduate Advisor, Department of Mathematics and Statistics Chair, Associate Dean in the College of Natural Sciences and Mathematics, and Dean of Graduate Studies.

### Requirements

1. A minimum of 30 graduate and approved upper-division units in mathematics including:
  - A. Three of the following courses: MATH 540A, 550A, 561A, or 562A.
  - B. Two additional courses selected from MATH 540B, 550B, 561B, or 562B.
  - C. An additional 3 units of 500-level mathematics courses.
2. Complete one of the following:
  - A. Pass a comprehensive written examination in two areas of Pure Mathematics. Specific requirements for passing of the comprehensive examinations can be found on the Department of Mathematics and Statistics website at [www.csulb.edu/depts/math](http://www.csulb.edu/depts/math).
  - B. Subject to the approval of the Pure Mathematics Committee in the Department of Mathematics and Statistics, write a thesis in mathematics and defend it orally.

### Option in Applied Mathematics

#### Prerequisites

1. A bachelor's degree in mathematics, physics, or engineering, or a bachelor's degree with at least 24 upper division units in mathematics from an accredited college or university.
2. A grade of "C" or better in MATH 247, 323, 361A/B, 364A, and MATH/STAT 380, or their equivalents. Deficiencies will be determined by the Graduate Advisor.

#### Advancement to Candidacy

The regulations governing the master's degree are those in effect at the time of advancement to candidacy. In addition to University requirements, the student must have completed all prerequisite courses listed above, with no grade less than "C". Students must have fulfilled the Graduation Writing Assessment Requirement (GWAR) and should file for Advancement upon completion of at least six units (and no more than nine units) on the program, with at least a 3.0 GPA. Program of study must be approved by the appropriate Graduate Advisor, Department of Mathematics and Statistics Chair, Associate Dean in the College of Natural Sciences and Mathematics.

#### Requirements

1. A minimum of 30 graduate and upper division units approved by the Graduate Advisor, and including:
  - A. Three of the following courses: MATH 563, 570, 576 and 579.
  - B. Three additional courses selected from: MATH 520, 521, 564, 573, 574, 575, 577, 578, and the course in 1.A not used to satisfy that requirement.
2. Complete one of the following:
  - A. Pass a comprehensive written examination in two subjects of Applied Mathematics. Specific requirements for passing of the comprehensive examinations can be found on the Department of Mathematics and Statistics website at [www.csulb.edu/depts/math](http://www.csulb.edu/depts/math).
  - B. Subject to the approval of the Applied Mathematics Committee in the Department of Mathematics and Statistics, write a thesis in applied mathematics and defend it orally.

C. Subject to the approval of the Applied Mathematics Committee in the Department of Mathematics and Statistics, complete a non-proprietary applied mathematics thesis project with a local company under the guidance of a faculty advisor in applied mathematics and a project leader from the company. Write a final report on the thesis project and its outcomes, and defend it orally. Specific requirements for completion of the thesis project can be found on the Department of Mathematics and Statistics website at [www.csulb.edu/depts/math](http://www.csulb.edu/depts/math).

### Option in Mathematics Education for Secondary School Teachers

Option in Mathematics Education for Secondary School Teachers is designed for people holding a California Single Subject Teaching Credential in Mathematics and teaching in middle, junior high, or high schools. This option will give students greater expertise in mathematics and mathematics education (curriculum, teaching, learning, assessment and research). The program includes a blend of courses from pure and applied mathematics, statistics, mathematics education, and also may include coursework from the College of Education.

#### Prerequisites

1. A bachelor's degree in mathematics or mathematics education, or a bachelor's degree with at least 24 upper division units in mathematics from an accredited college or university.
2. A California Single Subject Credential in Mathematics.
3. Course work in mathematics should include MATH 247, 310, 341, 355, 361A or 364A, and MATH/STAT 380 or equivalent with a grade of "C" or better.

#### Advancement to Candidacy

The regulations governing the master's degree are those in effect at the time of advancement to candidacy. In addition to University requirements stated elsewhere in this catalog, must have completed prerequisites above and must have satisfied the Graduation Writing Assessment Requirement (GWAR). Must file for Advancement to Candidacy after completion of at least 6 units (and recommend filing before completing 9 units) on Program of Study, with an overall 3.0 grade-point average. Program of Study must be approved by Mathematics Education Graduate Advisor, Department of Mathematics and Statistics Chair and Associate Dean in the College of Natural Sciences and Mathematics.

#### Requirements

1. A minimum of 30 units of graduate level or approved upper division coursework which includes the following:
  - A. A minimum of 9 graduate or approved upper-division units of mathematics, including at least one 500-level mathematics course. If not previously taken for BS or credential, this course of study must include:
    - MATH 410 History of Modern Mathematics (3)  
Prerequisites: MATH 247, 310 and at least three of the following: MATH 233, 341, 355, 361A, 380.
    - MATH 444 Introduction to Abstract Algebra (3)  
Prerequisites: MATH 233 and 247 and at least one of MATH 341 or 347.

B. A minimum of 15 graduate units of mathematics education including:

1) Take both of the following:

MTED 511 Mathematics Teaching and Learning (3)  
Prerequisite: Consent of instructor.

MTED 512 Curriculum and Assessment in Math (3)  
Prerequisite: MTED 511 or consent of instructor.

2) At least 9 units in mathematics education chosen in consultation with the Mathematics Education Graduate Advisor from the following courses:

MTED 540, 550, 560, 580, 590

C. A minimum of 6 units of approved upper division or graduate electives from mathematics, mathematics education, or approved College of Education courses, chosen in consultation with the Mathematics Education Graduate Advisor. If the student plans to teach at the Community College level, she/he must take at least 18 units of graduate or approved upper division mathematics from Parts A and C. If the student intends to do a thesis he/she must take EDP 520 or the equivalent.

2. Complete one of the following two options:

A. Pass two comprehensive written examinations in mathematics education (one representing MTED 511/512 and one in a selected area - MTED 540, 550, 560, or 580);

B. Subject to the approval of the Mathematics Education Committee of the Department of Mathematics and Statistics, write a thesis in mathematics education and defend it orally (MTED 698).

#### Mathematics Education Thesis

Students choosing the thesis option must consult with the Mathematics Education Graduate Advisor to select a thesis advisor. A proposal is then written in consultation with the mathematics education faculty advisor who will guide the student in choosing the thesis topic and supervise the writing process. After a thesis topic is chosen, it must be approved by the Mathematics Education Committee. A thesis committee of three faculty members, including the thesis advisor, is then chosen to approve the final work. During the writing of the thesis report, students must enroll in MTED 698.

#### Master of Science in Applied Statistics

##### Prerequisites

1. A bachelor's degree from an accredited college or university.
2. A grade of "B" or better in MATH 247, MATH/STAT 380, and STAT 381 or their equivalents.

##### Advancement to Candidacy

In addition to University requirements, the student must have completed all prerequisite courses listed above, with no grade less than "B". Students must have satisfied the Graduation Writing Assessment Requirement (GWAR) and should file for Advancement upon completion of at least six units (and no more than nine units) of the Program, with at least a 3.0 GPA. Program of study must be approved by the appropriate Graduate Advisor, Department of Mathematics and Statistics Chair, Associate Dean in the College of Natural Sciences and Mathematics.

## Requirements

1. A minimum of 30 graduate and 400 level units in statistics (STAT) and could include upper division/graduate non-statistics units approved by the statistics graduate advisor, and including:
  - A. STAT 510, 520, 530.
  - B. Four additional courses selected from 500 level STAT courses or 400 level STAT courses.
  - C. A minimum of 18 units at the 500/600 level, including at least 15 units of graduate courses in statistics (STAT) other than STAT 697 or 698.
2. Complete one of the following:
  - A. Pass two comprehensive written examinations in Statistical Inference (STAT 520) and Experimental Design (STAT 530).
  - B. Subject to the approval of the Statistics Committee in the Department of Mathematics and Statistics, write a thesis in statistics and defend it orally.
  - C. Subject to the approval of the Statistics Committee in the Department of Mathematics and Statistics, complete a non-proprietary statistical project with an industrial company under the guidance of a faculty advisor in statistics. Write a final report and give an oral presentation of the project and its outcomes to the department. Specific requirements for completion of the project can be found on the department's statistics webpage at [www.csulb.edu/depts/math](http://www.csulb.edu/depts/math).

## Single Subject Teaching Credential in Mathematics

For information, refer to the undergraduate section in this department.

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## Early Start Mathematics Courses (ESM)

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### 1. Early Start Basic Algebra (1)

Prerequisite: ELM score of 38 or less.

Arithmetic review, elementary algebra and geometry.

This course will satisfy the Early Start Program requirement for CSULB bound students. Cannot be taken for credit toward a university degree. Not open to students who are exempt from the ELM.

Credit/No Credit grading only. (Seminar 15 hrs)

### 3. Elem Algebra-Geometry (3)

Prerequisite: Prerequisite: ELM Score of 38 or less.

Arithmetic review, elementary algebra, and some basic geometry concepts. Cannot be taken for credit toward a university degree. Credit/No Credit grading only. Not open to students who are exempt from the ELM or who have not yet taken the ELM but are required to do so.

Credit/No Credit grading only. (Seminar 45 hrs).

### 11. Early Start Enhanced Algebra (1)

Prerequisite: ELM score between 40 and 48 inclusive.

Intermediate algebra and geometry.

This course is designed to satisfy the Early Start Program requirement for CSULB bound students. Cannot be taken for credit toward a university degree. Not open to students who are exempt from the ELM

Credit/No Credit grading only. (Seminar 15 hrs).

### 21. Basic Intermediate Algebra (3)

Prerequisite: Prerequisite: MAPB 1 or ELM Score between 40 and 48 inclusive.

Linear functions, their graphs, applications; proportions and percent change, applications to geometry and life; operations on radicals; rational exponents and scientific notation; dimensional analysis; sets, Venn diagrams, basic counting principles; combinations, permutations, probability; elementary data analysis; logarithmic, exponential functions, applications.

For students who will not need to take MATH 113, 114 or 115 or MTED 110. Cannot be taken for credit toward a university degree. Not open to students who are exempt from the ELM or who have not yet taken the ELM but are required to do so. Credit/No Credit grading only. (Lecture 3 hrs.)

### 33. Enhanced Intermediate Algebra (3)

Prerequisite: Prerequisite: MAPB 1 or ELM Score between 40 and 48 inclusive.

Polynomial, rational, radical expressions, equations; rational exponents, complex numbers; solutions, graphs of linear, quadratic equations, functions; linear systems; graphs of and operations on functions; including the difference quotient and inverses; logarithmic and exponential functions. Applications to science and business emphasized.

For students that intend to take MATH 113 or 115. Cannot be taken for credit toward a university degree. Not open to students who are exempt from the ELM or who have not yet taken the ELM but are required to do so. Credit/No Credit grading only. (Lecture 4 hrs)

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## Mathematics Prebaccalaureate Courses (MAPB)

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### 1. Elementary Algebra and Geometry (4)

Prerequisite: Appropriate ELM Score.

Arithmetic review, elementary algebra, and some basic geometry concepts. Cannot be taken for credit toward a university degree.

Not open to students who are exempt from the ELM or who have not yet taken the ELM but are required to do so. Credit/No Credit grading only. (Lecture 4 hrs.)

### 7. Basic Intermediate Algebra (3)

Prerequisite: MAPB 1 or appropriate ELM Score.

Linear functions, their graphs, applications; proportions and percent change, applications to geometry and life; operations on radicals; rational exponents and scientific notation; dimensional analysis; sets, Venn diagrams, basic counting principles; combinations, permutations, probability; elementary data analysis; logarithmic, exponential functions, applications.

Cannot be taken for credit toward a university degree. Not open to students who are exempt from the ELM or who have not yet taken the ELM but are required to do so. For students who will not need to take MATH 113, 115 or 117. Credit/No Credit grading only. (Lecture 3 hrs.)

### 11. Enhanced Intermediate Algebra (4)

Prerequisite: MAPB 1 or appropriate ELM Score.

Polynomial, rational, radical expressions, equations; rational exponents, complex numbers; solutions, graphs of linear, quadratic equations, functions; linear systems; graphs of and operations on functions, including the difference quotient and inverses; logarithmic and exponential functions. Applications to science and business emphasized.

Cannot be taken for credit toward a university degree. Not open to students who are exempt from the ELM or who have not yet taken the ELM but are required to do so. For students that intend to take MATH 113, 115 or 117. Credit/No Credit grading only. (Lecture 2 hrs., activity 2 hrs.)

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## Mathematics Courses (MATH)

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Satisfying the Entry-Level Math (ELM) requirement (see "Undergraduate Programs" section of this catalog) is a prerequisite for all mathematics courses and mathematics education courses. Please contact the ELM Coordinator in the Department of Mathematics and Statistics for details regarding the ELM test score.

### LOWER DIVISION

#### 103. Mathematical Ideas (3)

Prerequisite: Appropriate ELM score, ELM exemption, or MAPB 7 or 11.

Surveys variety of concepts in undergraduate mathematics. Includes elementary logic, numeration systems, rational and real numbers, modular number systems, elementary combinatorics, probability and statistics, using real world examples.

Not open for credit to students with credit in any MATH or MTED course numbered greater than 103, or the equivalent. (Lecture 3 hrs.)

#### 109. Modeling with Algebra (3)

Prerequisite: Appropriate ELM score, ELM exemption, or MAPB 7 or 11.

Data, functions, domain, range, representations of functions (verbal, numerical, graphical, algebraic), visualizing functions (increasing, decreasing, maximum, minimum, concave up, concave down). Linear functions, rate of change, slope, modeling data, systems of linear equations, linear inequalities. Exponentials, logs, growth decay, semi log plots for modeling.

Not open for credit to students with credit in any MATH or MTED course numbered greater than 103, or the equivalent. (Lecture 3 hrs.)

#### 111. Precalculus Trigonometry (3)

Prerequisite: Appropriate ELM score, ELM exemption, or MAPB 11. Trigonometric functions and applications. Arithmetic and graphical representation of complex numbers, polar form, DeMoivre's Theorem.

Not open for credit to students with credit in MATH 101, 117 or 122. (Lecture 3 hrs.)

#### 113. Precalculus Algebra (3)

Prerequisite: Appropriate ELM score, ELM exemption, or MAPB 11. Equations, inequalities. Functions, their graphs, inverses, transformations. Polynomial, rational functions, theory of equations. Exponential, logarithmic functions, modeling. Systems of equations, matrices, determinants. Sequences, series.

Not open for credit to students with credit in MATH 112, 115, 117, 119A, 120, or 122. For students who will continue to MATH 115, 117, 119A, or 122. (Lecture 3 hrs.)

#### 114. Finite Mathematics (3)

Prerequisite: Appropriate ELM score, ELM exemption, or MAPB 11. Combinatorial techniques and introduction to probability. Equations of lines and systems of linear equations, matrices, introduction to linear programming.

Not open for credit to students with credit in MATH 233 or 380. (Lecture 3 hrs.)

#### 115. Calculus for Business (4)

Prerequisite: Appropriate ELM score, ELM exemption, or MAPB 11. Functions, derivatives, optimization problems, graphs, partial derivatives. Lagrange multipliers, intergration of functions of one variable. Applications to business and economics. Emphasis on problem-solving techniques.

(Lecture 3 hrs, activity 1 hr) Not open for credit to students with credit in MATH 119A, 120, or 122.

#### 117. Precalculus Mathematics (4)

Prerequisite: Appropriate MDPT placement or a grade of "C" or better in MAPB 11.

Polynomial, rational, exponential, logarithmic, and trigonometric functions. Complex numbers, conic sections, graphing techniques.

Not open for credit to students with credit in MATH 122. (Lecture 3 hrs., problem session 2 hrs.)

#### 119A. Survey of Calculus I (3)

Prerequisite: Appropriate MDPT placement or a grade of "C" or better in MATH 113.

Functions, limits and continuity, differentiation and integration of functions of one variable including exponential, logarithmic, and trigonometric functions. Graphing, optimization, parametric equations, integration by substitution and by parts, numerical integration. Applications to the life sciences. Emphasis on problem solving.

Not open for credit to students with credit in MATH 115, 120 or 122. (Lecture 3 hrs.)

#### 119B. Survey of Calculus II (3)

Prerequisite: MATH 119A or 122.

Functions of several variables, partial derivatives, optimization. First order differential equations, second order linear homogeneous differential equations, systems of differential equations. Probability, random variables, difference equations. Introduces matrices, Gaussian elimination, determinants. Life science applications. Emphasis on problem solving.

Not open for credit to students with credit in MATH 123 or 224. (Lecture 3 hrs.)

#### 122. Calculus I (4)

Prerequisite: Appropriate MDPT placement or a grade of "C" or better in MATH 111 and 113, or a grade of "C" or better in MATH 117.

Continuous functions. Derivatives and applications including graphing, related rates, and optimization. Transcendental functions. L'Hospital's Rule. Antiderivatives. Definite integrals. Area under a curve.

(Lecture 3 hrs., problem session 2 hrs.)

#### 123. Calculus II (4)

Prerequisite: A grade of "C" or better in MATH 122.

Applications of the integral. Techniques of integration. Infinite series including convergence tests and Taylor series. Parametric equations. Polar coordinates. Introduces differential equations.

Not open for credit to students with credit in MATH 222. (Lecture 3 hrs., problem session 2 hrs.)

#### 173. Programming in Mathematical Software (3)

Prerequisite: MATH 113 or equivalent.

Introduction to basic concepts and fundamental techniques for solving mathematical and scientific problems by using software MatLab and Maple. Structured problem solving and programming. (Lecture 2 hrs, problem session, 2 hrs.) Letter grade only (A-F).

#### 224. Calculus III (4)

Prerequisite: MATH 123 with a grade of "C" or better.

Vectors and three-dimensional analytic geometry. Partial derivatives and Lagrange multipliers. Multiple integrals. Vector calculus, line and surface integrals. Green's Theorem, Stokes' Theorem, and the Divergence Theorem.

(Lecture 3 hrs., problem session 2 hrs.)

#### 233. Fundamental Concepts for Advanced Mathematics (3)

Prerequisite: MATH 123 with a grade of "C" or better.

Fundamentals of logic and set theory, counting principles, functions and relations, induction and recursion, introduction to probability, elementary number theory, congruences. Introduces writing proofs.

(Lecture 3 hrs.)

### **247. Introduction to Linear Algebra (3)**

Prerequisite: MATH 123.

Matrix algebra, solution of systems of equations, determinants, vector spaces including function spaces, inner product spaces, linear transformations, eigenvalues, eigenvectors, quadratic forms, and applications. Emphasis on computational methods.

(Lecture 3 hrs.)

### **297. Directed Study (1-3)**

Prerequisite: Consent of instructor.

For students who wish to undertake special study, at the lower division level, which is not a part of any regular course, under the direction of a faculty member. Individual investigation, studies or surveys of selected problems.

## **UPPER DIVISION**

### **303. Reflections in Space and Time (3)**

Prerequisites: GE Foundation requirements, at least one GE Exploration course, upper-division standing.

An experimentally-driven investigation of the mathematical nature of symmetry and patterns. Considers the pervasive appearance and deep significance of symmetry and patterns in art and science.

(Lecture 3 hrs.)

### **310. History of Early Mathematics (3)**

Prerequisite/Corequisite: A 200-level mathematics course.

History of mathematics through seventeenth century, including arithmetic, geometry, algebra, and beginnings of calculus. Interconnections with other branches of mathematics. Writing component; strongly recommended students enrolling have completed the G.E. A.1 requirement.

(Lecture 3 hrs.)

### **323. Introduction to Numerical Analysis (4)**

Prerequisites: MATH 224, and a course in computer programming.

Numerical solution of nonlinear equations, systems of linear equations, and ordinary differential equations. Interpolating polynomials, numerical differentiation, and numerical integration. Computer implementation of these methods.

(Lecture-discussion 3 hrs., problem session 2 hrs.)

### **341. Number Theory (3)**

Prerequisite: MATH 233

Divisibility, congruences, number theoretic functions, Diophantine equations, primitive roots, continued fractions. Writing proofs.

(Lecture 3 hrs.)

### **347. Linear Algebra (3)**

Prerequisites: MATH 233 and 247.

In-depth study of linear transformations, vector spaces, inner product spaces, quadratic forms, similarity and the rational and Jordan canonical forms. Writing proofs.

(Lecture 3 hrs.)

### **355. College Geometry (3)**

Prerequisite: MATH 247.

Transformations, motions, similarities, geometric objects, congruent figures, axioms of geometry and additional topics in Euclidean and non-Euclidean geometry. Writing proofs.

(Lecture 3 hrs.)

### **361A. Introduction to Mathematical Analysis I (3)**

Prerequisites: MATH 224, and MATH 233 or 247.

Rigorous study of calculus and its foundations. Structure of the real number system. Sequences and series of numbers. Limits, continuity and differentiability of functions of one real variable. Writing proofs.

(Lecture 3 hrs.)

### **361B. Introduction to Mathematical Analysis II (3)**

Prerequisite: MATH 361A.

Riemann integration. Topological properties of the real number line. Sequences of functions. Metric spaces. Introduction to calculus of several variables. Writing proofs.

(Lecture 3 hrs.)

### **364A. Ordinary Differential Equations I (3)**

Prerequisites: MATH 224.

Prerequisite/Corequisite: MATH 247.

First order differential equations; undetermined coefficients and variation of parameters for second and higher order differential equations, series solution of second order linear differential equations; systems of linear differential equations; applications to science and engineering.

(Lecture 3 hrs.)

### **364B. Ordinary Differential Equations II (3)**

Prerequisite: MATH 364A or 370A.

Existence-uniqueness theorems; Laplace transforms; difference equations; nonlinear differential equations; stability, Sturm-Liouville theory; applications to science and engineering.

(Lecture 3 hrs.)

### **370A. Applied Mathematics I (3)**

Prerequisites: MATH 123. Not open to Freshmen.

First order ordinary differential equations, linear second order ordinary differential equations, numerical solution of initial value problems, Laplace transforms, matrix algebra, eigenvalues, eigenvectors, applications.

Not open for credit to mathematics majors. (Lecture 3 hrs.)

### **370B. Applied Mathematics II (3)**

Prerequisite: MATH 370A.

Arithmetic of complex numbers, functions of a complex variable, contour integration, residues, conformal mapping; Fourier series, Fourier transforms; separation of variables for partial differential equations. Applications.

Not open for credit to mathematics majors. (Lecture 3 hrs.)

### **380. Probability and Statistics (3)**

Prerequisite: MATH 224.

Frequency interpretation of probability. Axioms of probability theory. Discrete probability and combinatorics. Random variables. Distribution and density functions. Moment generating functions and moments. Sampling theory and limit theorems.

Letter grade only (A-F). (Lecture 3 hrs.) Same course as STAT 380. Not open for credit to student with credit in STAT 380.

### **409. Strategies for Graduate Admission (1)**

Prerequisite: Senior or graduate standing.

The nature and expectations of doctoral programs in Mathematics and related fields. Intensive preparation for GRE mathematics subject exams.

Credit/No Credit grading only. Does not satisfy Mathematics major requirements. (Lecture-discussion 1 hr.)

### **410. History of Modern Mathematics (3)**

Prerequisites: MATH 247, 310 and at least three of the following: MATH 233, 341, 355, 361A, 380.

History of mathematics from seventeenth century onward. Development of calculus, analysis, and geometry during this time period. Other topics discussed may include history of probability and statistics, algebra and number theory, logic, and foundations.

(Lecture 3 hrs.)

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## Mathematics Courses (MATH)

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### 423. Intermediate Numerical Analysis (3)

Prerequisites: MATH 247 and 323.

Numerical solutions of systems of equations, calculation of eigenvalues and eigenvectors, approximation of functions, solution of partial differential equations. Computer implementation of these methods.

(Lecture 3 hrs.)

### 444. Introduction to Abstract Algebra (3)

Prerequisites: MATH 233 and 247 and at least one of MATH 341 or 347.

Groups, subgroups, cyclic groups, symmetric groups, Lagrange's theorem, quotient groups. Homomorphisms and isomorphisms of groups. Rings, integral domains, ideals, quotient rings, homomorphisms of rings. Fields. Writing proofs.

(Lecture 3 hrs.)

### 451. Differential Geometry (3)

Prerequisite: MATH 364A or 370A.

Structure of curves and surfaces in space, including Frenet formulas of space curves; frame fields and connection forms; geometry of surfaces in Euclidean three space; Geodesics and connections with general theory of relativity.

(Lecture 3 hrs.)

### 456. Dynamics and Geometry of Chaos (3)

Prerequisites: MATH 247, 361A, or consent of instructor.

An introduction to discrete dynamical systems in one and two dimensions. Theory of iteration: attracting and repelling periodic points, symbolic dynamics, chaos, and bifurcation. May include a computer lab component.

(Lecture 3 hrs)

### 461. Introduction to Complex Analysis (3)

Prerequisite: MATH 361A.

Theory and applications of complex variables. Analytic functions, integrals, power series and applications.

Not open for credit to students with credit in MATH 562A. (Lecture 3 hrs.)

### 463. Multivariable Calculus (3)

Prerequisites: MATH 224, 247, and 361B.

Topology of Euclidean spaces. Partial derivatives. Derivatives as linear transformations. Inverse and implicit function theorems. Jacobians, vector calculus, Green's and Stokes' theorems. Variational problems.

(Lecture 3 hrs.)

### 470. Introduction to Partial Differential Equations (3)

Prerequisite: MATH 364A or 370A.

First and second order equations, characteristics, Cauchy problems, elliptic, hyperbolic, and parabolic equations. Introduction to boundary and initial value problems and their applications.

(Lecture 3 hrs.)

### 472. Fourier Analysis (3)

Prerequisite: MATH 364A or 370A.

Theory of Fourier series and Fourier transforms. Physics and engineering applications. Parseval's and Plancherel's identities. Convolution. Multi-dimensional transforms and partial differential equations. Introduction to distributions. Discrete and fast Fourier transforms.

(Lecture 3 hrs.)

### 473./573. Scientific Computing (3)

Prerequisites: MATH 323 and either 364A or 370A.

(Undergraduates register in MATH 473; graduates in MATH 573.)

Introduction to programming languages, implementations of numerical algorithms for solution of linear algebraic equations, interpolation and extrapolation, integration and evaluation of functions, root finding and nonlinear equations, fast Fourier transforms, minimization and maximization of functions, numerical solutions of differential equations.

Not open for credit to students with credit in MATH 573.

### 474. Mathematics of Financial Derivatives (3)

Prerequisites: MATH 364A or MATH 370A, MATH 380, or consent of instructor.

Options, futures, and other financial derivatives; arbitrage; risk-neutral valuation; binomial trees; the log-normal hypothesis; the Black-Scholes-Merton formula and applications; the Black-Scholes-Merton partial differential equation; American options; exotic options; bond models and interest rate derivatives; credit risk and credit derivatives.

### 479./579. Mathematical Modeling (3)

Prerequisites: MATH 247, 323; 364A or 370A; one additional mathematics course, or consent of instructor. (Undergraduates register in MATH 479; graduates in MATH 579.)

Application of mathematics to develop models of phenomena in science, engineering, business, and other disciplines. Evaluation of benefits and limitations of mathematical modeling.

Letter grade only (A-F). (Lecture 3 hrs.)

### 485. Mathematical Optimization (3)

Prerequisites: MATH 247 and at least one of MATH 323, 347 or 380.

Linear and nonlinear programming: simplex methods, duality theory, theory of graphs, Kuhn-Tucker theory, gradient methods and dynamic programming.

(Lecture 3 hrs.)

### 491. Honors Seminar in Problem Solving (1)

Prerequisite: Consent of instructor.

Challenging problems from many fields of mathematics, taken largely from national and worldwide collegiate and secondary school competitions. Students required to participate in at least one national competition.

May be repeated to a maximum of 3 units. (Lecture-discussion 1 hr.)

### 495. Topics in Modern Mathematics (3)

Prerequisite: Consent of instructor.

Topics of current interest from mathematics literature.

### 496. Special Problems (1-3)

Prerequisite: Consent of instructor.

Student investigations in mathematics, applied mathematics, mathematics education, or statistics. May include reports and reviews from the current literature, as well as original investigations.

May be repeated to a maximum of 3 units. Letter grade only (A-F).

### 497. Directed Studies (1-3)

Prerequisites: Junior or senior standing and consent of instructor.

Readings in areas of mutual interest to student and instructor which are not a part of any regular course. A written report or project may be required.

May be repeated to a maximum of 3 units.

### 498H. Senior Thesis - Honors (3)

Prerequisites: Admission to Honors in the Major in Mathematics or to the University Honors Program, and consent of instructor.

Planning, preparation, completion, and oral presentation of a written thesis in mathematics, applied mathematics, mathematics education, or statistics.

Not available to graduate students. Letter grade only (A-F).

## GRADUATE LEVEL

### 520. Finite Element Method (3)

Prerequisite: MATH 323, 361A, 364A. Recommended: MATH 470.

Variational forms and weak solutions of partial differential equations, Galerkin method, construction of elements, numerical algorithms for matrix equations and for one-dimensional and two-dimensional problems. Convergence analysis and error estimate. Numerical implementations of algorithms.

Letter grade only (A-F). (Lecture 3 hrs.)

### 521. Matrix Method in Data Analysis and Pattern Recognition (3)

Prerequisite: MATH 423 or 576.

Vector spaces and linear transformations, optimal orthogonal projections, eigenvalues, eigenvectors, SVD, generalized SVD, Fourier and wavelet transforms, convolution, tangent distance. Implementations include object recognition, handwritten digit classification, digital image processing, feature extraction, image deblurring, text mining.

Letter grade only (A-F). (Lecture 3 hrs.)

### 540A. Abstract Algebra I (3)

Prerequisite: MATH 444.

Group theory including symmetric groups; group actions on sets; Sylow theorems and finitely generated abelian groups; ring theory including polynomial rings, division rings, Euclidean domains, principal ideal domains, and unique factorization domains.

Letter grade only (A-F). (Lecture 3 hrs.)

### 540B. Abstract Algebra II (3)

Prerequisite: MATH 540A.

Modules; Field extensions; Finite fields; Splitting fields, Galois theory. Commutative ring theory including chain conditions and primary ideals. Topics of current interest.

Letter grade only (A-F). (Lecture 3 hrs.)

### 541. Elliptic Curves (3)

Prerequisites: MATH 341, 444 and consent of instructor. Recommended: MATH 461 and 540A.

Fermat's method of descent; finite fields; Weierstrass normal form; integer, rational points on elliptic curves; group structures of rational points; Mordell's Theorem; computation examples. May include congruent numbers, Certicom's public cryptography challenges, Lenstra's factorization method, Birch/Swinnerton-Dyer Conjecture

Letter grade only (A-F). (Lecture 3 hrs.)

### 542. Algebraic Geometry (3)

Prerequisite: MATH 540A or consent of instructor.

An introduction to algebraic geometry: Algebraic sets; affine and projective varieties. Additional topics at the discretion of the instructor may include: Algebraic Curves; Intersection Theory; Invariant Theory; Computational Approaches.

Letter grade only (A-F). (Lecture 3 hrs.)

### 550A. Topology I (3)

Prerequisite: MATH 361B.

Fundamentals of point-set topology: metric spaces and topological spaces; bases and neighborhoods; continuous functions; subspaces, product spaces and quotient spaces; separation properties, countability properties, compactness, connectedness; convergence of sequences, nets and filters.

Letter grade only (A-F). (Lecture 3 hrs.)

### 550B. Topology II (3)

Prerequisite: MATH 550A.

Further topics in point-set topology: local compactness, paracompactness, compactifications; metrizable; Baire category theorem; homotopy and the fundamental group. Topics may also include uniform spaces, function spaces, topological groups or topics from algebraic topology.

Letter grade only (A-F). (Lecture 3 hrs.)

### 560A. Functional Analysis I (3)

Prerequisites: MATH 247, 361B.

Linear spaces, metric and topological spaces, normed linear spaces; four principles of functional analysis: Hahn-Banach, Open Mapping, Uniform Boundedness, and Closed Graph theorems; adjoint spaces; normed space convergence, conjugate spaces, and operator spaces; Banach Fixed Point theorem; Hilbert spaces.

Letter grade only (A-F). (Lecture 3 hrs.)

### 560B. Functional Analysis II (3)

Prerequisite: MATH 560A or consent of instructor.

Spectral theory of operators on normed spaces; special operators; elementary theory of Banach algebras; selected topics from applied functional analysis.

(Lecture 3 hrs.)

### 561A. Real Analysis I (3)

Prerequisite: MATH 361B.

Theory of measure and integration, focusing on the Lebesgue integral on Euclidean space, particularly the real line. Modes of convergence. Fatou's Lemma, the monotone convergence theorem and the dominated convergence theorem. Fubini's theorem.

Letter grade only (A-F). (Lecture 3 hrs.)

### 561B. Real Analysis II (3)

Prerequisite: MATH 561A or consent of instructor.

$L_p$  spaces of functions. Holder's inequality. Minkowski's inequality. Norm convergence, weak convergence and duality in  $L_p$ . Further topics from convergence of Fourier series, measure-theoretic probability, the Radon-Nikodym theorem; other topics depending on time and interest.

Letter grade only (A-F). (Lecture 3 hrs.)

### 562A. Complex Analysis I (3)

Prerequisite: MATH 361B. Recommended: MATH 461.

Axiomatic development of real and complex numbers; elements of point set theory; differentiation and analytic functions, classical integral theorems; Taylor's series, singularities, Laurent series, calculus of residues.

Letter grade only (A-F). (Lecture 3 hrs.)

### 562B. Complex Analysis II (3)

Prerequisite: MATH 562A.

Multiple-valued functions, Riemann surfaces; analytic continuation; maximum modulus theorem; conformal mapping with applications, integral functions; gamma function, zeta function, special functions.

Letter grade only (A-F). (Lecture 3 hrs.)

### 563. Applied Analysis (3)

Prerequisites: MATH 361B and either 364A or 370A.

Hilbert Spaces,  $L_p$  spaces, Distributions, Fourier Transforms, and applications to differential and integral equations from physics and engineering.

Letter grade only (A-F). (Lecture 3 hrs.)

### 564. Applied Nonlinear Ordinary Differential Equations (3)

Prerequisites: MATH 361B; 364A or 370A.

Stability and asymptotic analysis, Perturbation methods, Phase plane analysis, Bifurcation, Chaos, Applications to science and engineering.

(Lecture 3 hrs.)

### 570. Partial Differential Equations (3)

Prerequisites: MATH 364A and 463.

Cauchy's problem; classification of second order equations; methods of solution of hyperbolic, parabolic, and elliptic equations.

Letter grade only (A-F). (Lecture 3 hrs.)

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## Mathematics Courses (MATH)

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### 573./473. Scientific Computing (3)

Prerequisites: MATH 323 and either 364A or 370A. (Undergraduates register in MATH 473; graduates in MATH 573.)

Introduction to programming languages, implementations of numerical algorithms for solution of linear algebraic equations, interpolation and extrapolation, integration and evaluation of functions, root finding and nonlinear equations, fast Fourier transforms, minimization and maximization of functions, numerical solutions of differential equations.

Letter grade only (A-F). (Lecture 3 hrs.) Not open for credit to students with credit in MATH 473.

### 574. Stochastic Calculus and Applications (3)

Prerequisites: MATH 361B, 364A or 370A, 380.

Review of probability theory. Markov processes. Wiener processes. Stochastic integrals. Stochastic differential equations. Applications to Finance and Engineering.

(Lecture 3 hrs.)

### 575. Calculus of Variations (3)

Prerequisites: MATH 361B and either 364A or 370A

Solution methods for variational problems. First variation, Euler-Lagrange equation, variational principles, problems with constraints, boundary conditions, applications to physics and geometry. May include multiple integral problems, eigenvalue problems, convexity, and second variation.

Letter grade only (A-F). (Lecture 3 hrs.)

### 576. Numerical Analysis (3)

Prerequisites: MATH 323, 361B, 364A.

Advanced numerical methods. Introduction to error analysis, convergence, and stability of numerical algorithms. Topics may include solution of ordinary differential equations, partial differential equations, systems of linear and nonlinear equations, and optimization theory.

Letter grade only (A-F). (Lecture 3 hrs.)

### 577. Numerical Solution of Partial Differential Equations (3)

Prerequisite: MATH 423 or MATH 576 or consent of instructor.

Finite difference methods solving hyperbolic, parabolic, elliptic PDE'S; accuracy, convergence, and stability analysis. Selected initial-value boundary-value problems, characteristics, domain of dependence, matrix and von Neumann's methods of stability analysis. Solutions of large sparse linear systems. Finite element method.

(Lecture 3 hrs.)

### 578. Numerical Linear Algebra (3)

Prerequisites: MATH 247 and 323 or consent of instructor.

Numerical solutions of linear systems, least squares problems, eigenvalue problems. Matrix factorization: LU, QR, SVD, iterative methods. Error analysis. Applications with attention to linear algebra problems arising in numerical solutions of partial differential equations. Numerical implementation of algorithms.

Letter grade only (A-F). (Lecture 3 hrs.)

### 579./479. Mathematical Modeling (3)

Prerequisites: MATH 247, 364A or 370A, 323; one additional upper-division mathematics course, or consent of instructor. (Undergraduates register in MATH 479; graduates in MATH 579.)

Application of mathematics to develop models of phenomena in science, engineering, business, and other disciplines. Evaluation of benefits and limitations of mathematical modeling.

Letter grade only (A-F). (Lecture 3 hrs.)

### 590. Selected Topics in Mathematics (3)

Prerequisite: Consent of Instructor

Specialized and advanced topics in mathematics.

May be repeated to a maximum of 9 units in different or same semester. (3 hours lecture)

### 695. Seminar in Mathematics (3)

Prerequisite: Consent of instructor.

Presentation and discussion of advanced work, including original research by faculty and students. Topics announced in the *Schedule of Classes*.

May be repeated to a maximum of 6 units. Letter grade only (A-F).

### 697. Directed Studies (1-3)

Prerequisite: Consent of instructor.

Research on a specific area in mathematics. Topics for study to be approved and directed by faculty advisor in the Department of Mathematics and Statistics.

Letter grade only (A-F).

### 698. Thesis or Project (1-6)

Prerequisite: Advancement to candidacy.

Formal report of research or project in mathematics.

May be repeated to a maximum of six units. Letter grade only (A-F).

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## Mathematics Education Courses (MTED)

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Satisfying the Entry-Level Math (ELM) requirement (see "Undergraduate Programs" section of this catalog) is a prerequisite for all mathematics education courses.

### LOWER DIVISION

#### 110. The Real Number System for Elementary and Middle School Teachers (3)

Prerequisite: ELM or ELM exemption or MAPB 11.

Introduction to problem solving processes and strategies. Development and analysis of structure, properties, and operations of real number system. Concept and process development using appropriate models, manipulatives, and activities.

Not open for credit to Mathematics majors. (Lecture 2 hrs., activity 2 hrs.)

#### 205. Activity Based Probability and Statistics for Elementary and Middle School Teachers (3)

Prerequisites: ELM or ELM exemption or MAPB 11 and MTED 110.

Activity-based exploration of randomization, data representation, measures of central tendency and dispersion. Analysis of experiments requiring hypothesizing, experimental design and data gathering. Basic laws of probability and set theory, combinations, permutations, and simulations.

Letter grade only (A-F). (Lecture 2 hrs., activity 2 hrs.) Not open for credit to mathematics (all options) and statistics majors or for students with credit in MTED 105.

#### 211. Geometry and Measurement for Elementary Teachers (3)

Prerequisites: MTED 110 with a grade of "C" or better and one year of high school geometry.

Problem solving and hands-on modeling of real-world geometry situations focusing on patterning, informal geometry, congruence, similarity, constructions, transformations, tessellations, measurement in 1, 2, and 3 dimensions (English and Metric units). Computer applications are integrated into the course.

Not open for credit to Mathematics majors or any student with credit in MTED 312. (Lecture 2 hrs., activity 2 hrs.)

## UPPER DIVISION

### 301. Computer Applications in Mathematics for Teachers (3)

Prerequisites: One year of high school geometry and one of MTED 110 or MATH 122.

Designed for pre-service or inservice teachers. Software evaluation; teacher tools (spreadsheets, databases, email, collaborative tools, and applications); mathematics using technology; programming; technology use issues in schools.

Satisfies California Level I teaching credential computer technology standard. Open for credit to pre-service or in-service teaching credential students only. (Lecture 2 hrs., activity 2 hrs.)

### 303. Number Systems, Probability and Statistics for Elementary and Middle School Teachers (3)

Prerequisite: California Teaching Credential.

Introduction to problem solving, development, analysis of the structure, properties and operations of the real number system. Concept and process development using appropriate models, manipulatives, and activities. Statistics including data representation, measures of central tendency and dispersion. Basic laws of probability and set theory, combinations, permutations, and simulations.

Letter grade only (A-F). (Lecture 2 hours, Activity 2 hours)

### 312. Geometry and Measurement for Mathematics Specialists in Elementary and Middle Schools (4)

Prerequisites: MTED 110 and one year of high school geometry.

Exploration, conjecture, justification of geometric relationships, applications relevant to teaching geometry (K-10). Problem solving, informal geometry, proof, non-Euclidean geometry, congruency, similarity, constructions, transformations, tessellations, measurement (English and Metric) in 1, 2, and 3 dimensions. Computer construction utility used.

Not open for credit to Mathematics majors. Letter grade only (A-F). (Lecture 2 hrs., activity 2 hrs.)

### 402. Problem Solving Applications in Mathematics for Elementary and Middle School Teachers (3)

Prerequisites: "C" or better in both MTED 110, and either MTED 211 or 312 or the equivalent and a course in Critical Thinking.

Problem solving processes and strategies; interrelates and applies content from many mathematics areas (real number system, algebra, number theory, geometry, measurement, probability and statistics); develops questioning strategies, fostering understanding of algebra and geometry. Technology integrated throughout.

Not open for credit to Mathematics majors. (Lecture 2 hrs., activity 2 hrs.)

### 411. Topics and Issues in Secondary School Mathematics (3)

Prerequisites: MATH 310, 341, 355, 380, 410, 444; EDSS 300M or consent of the instructor.

Analysis of topics and issues in secondary school mathematics curriculum. Problem solving, mathematical connections, communication, structures, conjecture, proof, manipulatives, technology, assessment. Observations/interview experiences and portfolio assemblage required. Intended for students preparing to enter Single Subject Credential Program in mathematics.

(Lecture 2 hrs., laboratory 3 hrs.)

### 415. History of Mathematics for Elementary and Middle School Teachers (4)

Prerequisite: MTED 312 with a grade of "C" or better.

Mathematics ideas throughout history with orientation toward various civilizations and cross-cultural views. Covers origins and interrelationships of areas of K-9 mathematics curriculum, including arithmetic, algebra, geometry, statistics and probability, cryptography, and other mathematics topics.

Not open for credit to mathematics (all options) or statistics majors or for students with credit in MATH 310 or MTED 315. Letter grade only (A-F). (Lecture 2 hrs; activity 2 hrs.)

### 420. Number Theory for Elementary and Middle School Teachers (4)

Prerequisite: MTED 312 with a grade of "C" or better.

Concepts and justification involving basic properties of natural numbers, mathematics induction, Euclidean algorithm, and the Fundamental Theorem of Arithmetic. Topics include proofs and problem-solving with divisibility, primes and composites, and prime factorization; congruences and other examples.

Not open for credit to mathematics (all options) or statistics majors or for students with credit in MATH 341 or MTED 320. Letter grade only (A-F). (Lecture 2 hrs; activity 2 hrs.)

### 424. Algebraic Structures for Elementary and Middle School Teachers (4)

Prerequisite: MTED 312 with a grade of "C" or better.

Properties of real and complex numbers, groups, rings, reals and complex fields; polynomial equations and inequalities; polynomial, rational, radical, absolute value, exponential, and logarithmic functions; matrices and vectors.

Not open for credit to mathematics (all options) or statistics majors or for students with credit in MATH 444 or MTED 324. Letter grade only (A-F). (Lecture 2 hrs; activity 2 hrs.)

### 425. Functions, Models and Concepts of Calculus for Elementary and Middle School Teachers (4)

Prerequisite: MTED 312 with a grade of "C" or better.

Numeric, symbolic, graphical, verbal representation of functions; sequences and sums. Intuitive development of concepts of limit, continuity, derivative, integral. Applications, including differential equations. Algebraic methods and technology emphasized in context of learning calculus. Not open for credit to mathematics (all options) or statistics majors or for students with credit in MTED 325. Letter grade only (A-F). (Lecture 2 hrs; activity 2 hrs.)

### 430. Connections, Integrations, and Reasoning in Mathematics for Teachers (4)

Prerequisites: "C" or better in MTED 205 or 300; MTED 312, 402, 415, 420, 424, and 425.

Examination, analysis, and integration of mathematics topics appropriate for elementary and middle school teachers. Topics will include problem solving, hypothesis and justification, and mathematics connections and communication.

Not open for credit to mathematics (all options) or statistics majors or for students with credit in MTED 403. Letter grade only (A-F). (Lecture 2 hrs; activity 2 hrs.)

### 495. Special Topics in Mathematics Education (1-3)

Prerequisite: Consent of instructor.

Topics of interest in Mathematics Education.

May be repeated to a maximum of 9 units with different topics in different semesters. Letter grade only (A-F).

## GRADUATE LEVEL

### 500. Advanced Perspectives of Concepts Foundational to Algebra for Teachers (3)

Prerequisite: Multiple Subjects Credential, or consent of instructor.

Analytic investigation of foundational algebra concepts using representations, reasoning and proof, and problem solving. Topics include: number theory, properties of real numbers, proportional reasoning, algebra, discrete mathematics, and functions.

This course will not count toward any M.S. degree options in the Department of Mathematics and Statistics. Letter grade only (A-F). (Lecture 3 hrs.)

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## Mathematics Education Courses (MTED)

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### 511. Mathematics Teaching and Learning (3)

Prerequisite: Consent of instructor.

Theories of mathematics teaching and learning. Key issues in mathematics and mathematics education. Historical development and contemporary views of various theoretical perspectives for teaching and learning mathematics, including the roles of standards and various mathematics and education organizations.

Letter grade only (A-F). (Lecture and Discussion, 3 hrs.)

### 512. Curriculum and Assessment in Mathematics (3)

Prerequisite: MTED 511 or consent of instructor.

Theories of mathematics curriculum and forms of assessment. Introduces major philosophies, issues, resources, and technologies pertaining to curricula and assessment of mathematics. Relevant histories and contemporary practices of design and implementation of curriculum and assessment of mathematics.

Letter grade only (A-F). (Lecture and Discussion, 3 hrs.)

### 540. Algebra in the School Curriculum (3)

Prerequisite: MTED 511; prerequisite or corequisite: MTED 512 or consent of instructor.

Issues/topics concerning algebraic learning using curricular standards. Examining texts, curricula, algebraic thinking, and teaching research. Common errors and possible remedies, algebra for mathematizing situations. Relationship of K-12 algebra curriculum to modern algebra and its structures. Fundamental theorem of algebra.

Letter grade only (A-F). (Lecture and Discussion, 3 hrs.)

### 550. Geometry and Measurement in the School Curriculum (3)

Prerequisite: MTED 511; prerequisite or corequisite: MTED 512 or consent of instructor.

Content, curriculum, standards, and research in learning and teaching geometry, spatial sense and measurement in K-12. Justification and proof, applications and abstraction, tools and technology in geometry teaching and learning. Current issues in teaching and learning of geometry and measurement.

Letter grade only (A-F). (Lecture and Discussion, 3 hrs.)

### 560. Analysis in the Secondary Curriculum (3)

Prerequisites: MTED 511 and MATH 361A; prerequisite or corequisite: MTED 512 or consent of instructor.

Fundamental concepts of calculus, functions, mappings, related topics and proofs in real and complex analysis, relating mathematics analysis to secondary curriculum. Issues and techniques in teaching and learning of mathematical analysis. Examination of mathematics education research and mathematics frameworks.

Letter grade only (A-F). (Lecture and Discussion, 3 hrs.)

### 580. Probability and Statistics in the School Curriculum (3)

Prerequisite: MTED 511; prerequisite or corequisite: MTED 512 or consent of instructor.

Content, curriculum, and research in learning and teaching probability and statistics in K-12 schools. Includes role of applications, abstraction, tools and technology in probability and statistics teaching and learning.

Letter grade only (A-F). (Lecture and Discussion, 3 hrs.)

### 590. Special Topics in Mathematics Education (1-3)

Prerequisite: Consent of instructor.

Advanced study of special topics in the field of mathematics education.

May be repeated for a total of six units with different topics. Letter grade only (A-F). (Seminar 1-3 hrs.)

### 697. Directed Studies in Mathematics Education (1-3)

Prerequisites: MTED 511, 512; EDP 520; Advancement to Candidacy; consent of instructor.

Research project in mathematics education.

Letter grade only (A-F).

### 698. Thesis in Mathematics Education (1-4)

Prerequisites: MTED 511, 512; EDP 520; Advancement to Candidacy; consent of instructor.

Research in mathematics education culminating in a formal report.

Letter grade only (A-F).

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## Statistics Courses (STAT)

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### 108. Statistics for Everyday Life (3)

Exploratory data analysis, methods of visualizing data, descriptive statistics, misuse and manipulation of data in statistical analysis, probability, binomial and normal distributions, hypothesis testing, correlation and regression, contingency tables.

Not open for credit to students with credit in MATH 108, 180, 380; or MTED 105, 205. (Lecture 3 hrs.)

### 380. Probability and Statistics (3)

Prerequisite: MATH 224.

Frequency interpretation of probability. Axioms of probability theory. Discrete probability and combinatorics. Random variables. Distribution and density functions. Moment generating functions and moments. Sampling theory and limit theorems.

Letter grade only (A-F). Same course as MATH 380. Not open for credit to students with credit in MATH 380. (Lecture 3 hrs.)

### 381. Mathematical Statistics (3)

Prerequisites: MATH 247, and MATH 380 or STAT 380.

Estimation and hypothesis testing. Maximum likelihood and method of moments estimation. Efficiency, unbiasedness, and asymptotic distribution of estimators. Neyman-Pearson Lemma. Goodness-of-fit tests. Correlation and regression. Experimental design and analysis of variance. Nonparametric methods.

Letter grade only (A-F). (Lecture 3 hrs.) Not open for credit to students with credit in MATH 381.

### 410./510. Regression Analysis (3)

Prerequisite: STAT 381. (Undergraduates register in STAT 410; graduates enroll in STAT 510.)

Simple linear regression: estimation and inference, prediction, analysis of residuals, detection of outliers, use of transformations. Multiple linear regression: influence diagnostics, multi-collinearity, selection of variables, simultaneous estimation and inference, validation techniques. Statistical software for data analysis used.

Letter grade only (A-F). (Lecture 3 hrs.) Not open for credit to students with credit in MATH 480 or 590.

### 450./550. Multivariate Statistical Analysis (3)

Prerequisite: STAT 381; Prerequisite/Corequisite STAT 410. (Undergraduates register in STAT 450; graduates enroll in STAT 550.)

Discriminate analysis, principal components, factor analysis, cluster analysis, logistic regression, canonical correlation, multidimensional scaling, and some nonlinear techniques. Statistical software used.

Letter grade only (A-F). (Lecture 3 hrs.) Not open for credit to students with credit in MATH 483 or 593.

### 475. Data Analysis with SAS (3)

Prerequisite: STAT 381 or consent of instructor.

Topics include: Statistical analysis including extraction, presentation of data in graphical form, creation, modification of datasets, interpretation of output, writing of reports. Provides SAS programming techniques for aforementioned topics preparation for SAS base certification.

Letter grade only (A-F). (Lecture 3 hrs.) Not open for credit to students with credit in MATH 489.

### **482. Random Processes (3)**

Prerequisites: MATH 247, and MATH 380 or STAT 380.

Further topics in probability. Markov processes. Renewal theory. Random walks. Queueing theory. Poisson processes. Brownian motion.

Letter grade only (A-F). (Lecture 3 hrs.) Not open for credit to students with credit in MATH 382.

### **484. Actuarial Science: Models (3)**

Prerequisite: STAT 381 or consent of instructor.

Statistical techniques applied to risk management. Expected utility theory, individual risk models, compound Poisson distributions and processes, ruin probability and first surplus, stop-loss and proportional reinsurance, statistical survival distributions and life tables, life annuity, actuarial present values, and premiums determination.

Letter grade only (A-F). (Lecture 3 hrs.) Not open for credit to students with credit in MATH 484.

### **485. Actuarial Science: Financial Mathematics (3)**

Prerequisite: STAT 381.

Simple and compound interests, stochastic approaches to interest and annuities, stochastic models of stock, Black-Scholes arbitrage pricing of options and other derivative securities, Markowitz portfolio optimization theory, Ito financial calculus, filtrations and martingales.

Letter grade only (A-F). (Lecture 3 hrs.)

### **495./595. Topics in Modern Statistics (3)**

Prerequisite: Consent of instructor. (Undergraduates register in STAT 495; graduates enroll in STAT 595.)

Topics of current interest from statistics literature.

Letter grade only (A-F). Course may be repeated to a maximum of 6 units with different topics. (Lecture 3 hrs)

### **497. Directed Studies (1-3)**

Prerequisite: Consent of instructor.

Junior or senior standing and consent of instructor. Not open to graduate students.

Letter grade only (A-F).

## **GRADUATE LEVEL**

### **510./410. Regression Analysis (3)**

Prerequisite: STAT 381. (Undergraduates register in STAT 410; graduates enroll in STAT 510.)

Simple linear regression: estimation and inference, prediction, analysis of residuals, detection of outliers, use of transformations. Multiple linear regression: influence diagnostics, multi-collinearity, selection of variables, simultaneous estimation and inference, validation techniques. Statistical software for data analysis used.

Letter grade only (A-F). (Lecture 3 hrs.) Not open for credit to students with credit in MATH 480 or 590.

### **520. Statistical Inference (3)**

Prerequisite: STAT 381 or consent of instructor.

Properties of a random sample, convergence in probability, law of large numbers, sampling from the normal distribution, the central limit theorem, principles of data reduction, likelihood principle, point estimation, Bayesian estimation, methods of evaluating estimators, hypothesis testing, decision theory, confidence intervals.

Letter grade only (A-F). (Lecture 3 hrs.) Not open for credit to students with credit in MATH 580.

### **530. Experimental Design (3)**

Prerequisite: STAT 381 or consent of instructor.

Design of experiments to permit efficient analysis of sources of variation with application to quality assurance. Factorial and fractional factorial designs; block designs; confounding. Fixed and random effect models. Effects of departure from assumptions;

transformations. Response surface techniques. Taguchi methods.

Letter grade only (A-F). (Lecture 3 hrs.) Not open for credit to students with credit in MATH 581.

### **532. Statistical Quality Control (3)**

Prerequisite: STAT 381 or consent of instructor.

Introduction to methods of statistical quality control. Includes control charts, acceptance sampling, process capability analysis, and aspects of experimental design.

Letter grade only (A-F). (Lecture 3 hrs.) Not open for credit to students with credit in MATH 584.

### **540. Survey Sampling (3)**

Prerequisite: STAT 381 or consent of instructor.

Theory and practice of sampling from finite populations. Simple random sampling, stratified random sampling, systematic sampling, cluster sampling, properties of various estimators including ratio, regression, and difference estimators. Error estimation for complex samples.

Letter grade only (A-F). (Lecture 3 hrs.) Not open for credit to students with credit in MATH 583.

### **544. Statistical Consulting (3)**

Prerequisites: STAT 381 and STAT 410/510 or consent of instructor.

The methodology of statistical consulting: guidelines for client-consultant communications, presentations to clients, basics of writing final technical reports, thorough case studies involving advanced statistical analysis, invited client presentations, real-life projects, group discussions, written and oral statistical reports by students.

Letter grade only (A-F). (Lecture 3 hrs.)

### **550./450. Multivariate Statistical Analysis (3)**

Prerequisite: STAT 381; Prerequisite/Corequisite STAT 410. (Undergraduates register in STAT 450; graduates enroll in STAT 550.)

Discriminate analysis, principal components, factor analysis, cluster analysis, logistic regression, canonical correlation, multidimensional scaling, and some nonlinear techniques. Statistical software used.

Letter grade only (A-F). (Lecture 3 hrs.) Not open for credit to students with credit in MATH 483 or 593.

### **560. Nonparametric Statistics (3)**

Prerequisite: STAT 410 or 510, or consent of instructor.

Alternatives to normal-theory statistical methods, analysis of categorical and ordinal data, methods based on ranks, measures of association, goodness of fit tests, order statistics.

Letter grade only (A-F). (Lecture 3 hrs.) Not open for credit to students with credit in MATH 585.

### **570. Statistical Simulation (3)**

Prerequisite: STAT 381 or consent of instructor.

Simulation modeling techniques; generation of discrete and continuous random numbers from given distributions; Monte Carlo methods; discrete event simulations, statistical analysis of simulated data; variance reduction; statistical validation; introduction to simulation languages; industry applications. Statistical packages used.

Letter grade only (A-F). (Lecture 3 hrs.) Not open for credit to students with credit in MATH 587 or 487.

### **572. Computational Statistics (3)**

Prerequisite: STAT 381 or consent of instructor.

Random number generation, sampling and subsampling, exploratory data analysis, Markov chain Monte Carlo methods, density estimation and EM algorithm. Topics of current interest.

Letter grade only (A-F). (Lecture 3 hrs.)

### **574. Data Mining (3)**

Prerequisite: STAT 410, or 510, or consent of instructor.

Basics of data mining algorithms with emphasis on industrial applications. Prediction and classification techniques such as decision trees, neural networks, Multivariate Adaptive Regression Splines, and other methods. Several software packages utilized.

Letter grade only (A-F). (Lecture 3 hrs.) Not open for credit to students with credit in MATH 586.

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## Statistics Courses (STAT)

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### 576. Data Informatics (3)

Prerequisite: STAT 410/510 or consent of instructor.

Genetic algorithms, fuzzy logic, discrete choice analysis, online analytical processing, structured query language, statistical database management, and text and web mining. Topics of current interest.

Letter grade only (A-F). (Lecture 3 hrs.)

### 580. Time Series (3)

Prerequisite: STAT 381 or consent of instructor.

Includes moving averages, smoothing, Box-Jenkins (ARIMA) models, testing for nonstationarity, model fitting and checking, prediction and model selection, seasonal adjustment, ARCH, GARCH, cointegration, state-space models. Statistical packages used throughout the course.

Letter grade only (A-F). (Lecture 3 hrs.) Not open for credit to students with credit in MATH 582.

### 590. Statistical Analysis of Medical Data (3)

Prerequisite: STAT 381 or consent of instructor.

Lifetime distributions, hazard and survival functions, censoring and truncation, Kaplan Meier and Nelson-Aalen estimators, Cox proportional hazard models, m-sample tests, goodness-of-fit tests, Bayesian survival analysis, analysis of multivariate survival data, exploring longitudinal data designs and models, clinical trials.

Letter grade only (A-F). (Lecture 3 hrs.)

### 595./495. Topics in Modern Statistics (3)

Prerequisite: Consent of instructor. (Undergraduates register in STAT 495; graduates enroll in STAT 595.)

Topics of current interest from statistics literature.

Letter grade only (A-F). Course may be repeated to a maximum of 6 units with different topics. (Lecture 3 hrs)

### 695. Seminar in Applied Statistics (3)

Prerequisite: Consent of instructor.

Presentation and discussion of advanced work in applied statistics.

May be repeated to a maximum of six units. Letter grade only (A-F).

### 697. Directed Studies in Applied Statistics (1-3)

Prerequisite: Consent of instructor.

Research on a specific area in applied statistics. Topic for study to be approved and directed by a statistics faculty member.

Letter grade only (A-F).

### 698. Thesis or Project (1-6)

Prerequisite: Advancement to candidacy.

Formal report of research or project in mathematics.

Letter grade only (A-F). May be repeated to a maximum of 6 units.