

Mathematics

College of Science and Mathematics

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Programs

Undergraduate:

B.A., Mathematics

Mathematics Option

Secondary Teaching Option*

*Secondary Teaching Option is available through the regular degree program, the Four-Year Integrated Mathematics (FYI-Math) Teacher Credential Program, or the Junior-Year Integrated Mathematics (JYI-Math) Teacher Credential Program.

B.S., Mathematics

Mathematics Option

Statistics Option

Applied Mathematical Sciences Option

Minor in Mathematics

Graduate:

M.S., Mathematics

Mathematics Option

Applied Mathematics Option

Mathematics for Educational Careers Option

Credential:

Mathematics Subject Matter Program for the Single Subject Credential

Department Programs

The B.A. in Mathematics is designed for students who plan to teach mathematics in secondary or middle schools or wish to prepare for graduate work in pure mathematics. The B.S. in Mathematics is designed for students who wish to pursue occupational careers involving applied mathematics or wish to prepare for graduate work in applied mathematics. The Minor in Mathematics is designed to provide students with mathematical preparation useful for future employment opportunities.

The Mathematics Department offers an MS program with three distinct options. Option I concentrates on the core subjects in Mathematics. Option II emphasizes Applied Mathematics. Option III is designed for teachers and for other professionals with a baccalaureate degree who are seeking educational careers.

The Major

Mathematicians today are engaged in a wide variety of activities. Research mathematicians create new theories and techniques. Applied mathematicians use that theory and mathematical modeling to solve problems in economics, science, medicine, engineering, and management. Teachers of mathematics develop new ways to teach mathematical concepts to children and adults. University-level mathematics involves more than algorithms and computational techniques. Mathematics majors also learn to construct proofs and how to approach a real life problem from a mathematical point of view.

Credential Information

The Secondary Teaching Option provides preparation for the student planning to teach mathematics at the secondary level. Students in this option may enroll in a post-baccalaureate teacher preparation program to earn a Preliminary Single Subject Credential in Mathematics. Alternatively, students who meet the eligibility requirements can enter either the Four-Year Integrated Mathematics (FYI-Math) Teacher Credential Program or the Junior-Year Integrated Mathematics (JYI-Math) Teacher Credential Program, in which students earn both a bachelor's degree and a Preliminary Single Subject Credential and are qualified to teach full-time upon graduation. These options have been approved by the California Commission on Teacher Credentialing as academic programs for the Single Subject Credential in Mathematics. For details on the Single Subject Credential program, see the Credentials and Department of Secondary Education sections in this catalog.

Careers

Math majors tend to be highly satisfied with the jobs they get after college. The pay is generally good and the work is usually strongly related to mathematics. The best five jobs listed in a recent Jobs Rated Almanac - software engineer, actuary, computer systems analyst, computer programmer, and mathematician - all require a very strong background in mathematics. In fact, almost every one of the top fifty jobs involves a significant amount of mathematical reasoning and knowledge.

Academic Advisement

Upon admission as a mathematics major, the student should contact the Mathematics Department for assignment of an advisor. Courses taken to fulfill elective requirements must have prior approval by the student's advisor. Undergraduate mathematics majors must consult with their advisor each semester in order to be cleared for registration. For a current list of advisors, please visit www.csun.edu/math/advisors.html.

Student Learning Outcomes of the Undergraduate Program

At the end of their program of study, students should be able to

1. demonstrate a command of the content usually associated with an undergraduate degree in mathematics;
2. communicate mathematical ideas clearly and cogently, both orally and in written form;
3. present clear and rigorous proofs;
4. build mathematical models and demonstrate problem solving skills, including proper use of mathematical software;
5. understand the principles underlying various branches of mathematics and recognize their interrelationship;
6. experience mathematical discovery and independently read and understand mathematical articles or texts written at an undergraduate level.

Requirements for the Bachelor Degrees

It is assumed that the student has a facility in mathematics normally gained by recent completion of four years of high school mathematics through trigonometry and "Mathematical Analysis." Because of the

variation in curriculum at the high school level it is necessary to obtain satisfactory scores on the Mathematics Placement Test (MPT) and Entry Level Mathematics Exam (ELM) to enter the first mathematics course in the program, MATH 150A. Without satisfactory scores a student will need to complete additional coursework.

- Lower Division Core For All Programs (23-24)
 - MATH 150A Calculus I (5)
 - MATH 150B Calculus II (5)
 - MATH 250 Calculus III (3)
 - MATH 262 Introduction to Linear Algebra (3)
 - COMP 106/L

Computing in Engineering and Science and Lab (2/1)
or COMP 110/L

- Introduction to Algorithms and Programming and Lab (3/1)
- PHYS 220A Mechanics (3)
 - PHYS 220AL Mechanics Lab (1)

The student must complete the Lower Division Core and one of the following Options, and must have at least a 2.0 grade point average for all upper division units required in the major.

Requirements

In addition to University residence requirements for a bachelor's degree, the student must complete a minimum of 18 units of upper division mathematics in residence at CSUN with the approval of a mathematics advisor. Students in BA programs must fulfill university requirement of at least 40 upper division units overall.

Requirements for the Bachelor of Arts

A. Mathematics Options

1. Lower Division Required Courses (23-24 Units)

Lower Division Core 23-24

2. Upper Division Required Courses (24 Units)

- MATH 320 Foundations of Higher Mathematics (3)
- MATH 340 Introductory Probability (3)
- MATH 350 Advanced Calculus I (3)
- MATH 351 Differential Equations (3)
- MATH 360 Abstract Algebra I (3)
- MATH 382/L Intro. Scientific Computing and Lab (2/1)
- MATH 462 Advanced Linear Algebra (3)
- MATH 493 Seminar in Mathematics (3)

3. Upper Division Electives (9 Units)

Upper Division mathematics electives selected with advisor approval, not to include MATH 310/L, 311, 312, 331, 391 or 490. Students considering graduate work in mathematics are strongly advised to include MATH 450, 455, and 460 in their program of study or to complete a B.S. degree in Mathematics.

General Education: Basic Skills Mathematics and Lifelong Learning are satisfied by required courses in the major. PHYS 220A/L partially satisfies the Natural Sciences section. Students are encouraged to take PHIL 230 to satisfy the Basic Skills Critical Thinking requirement.

B. Secondary Teaching Option

Students interested in a career in teaching in secondary schools may elect the secondary teaching option for the Bachelor of Arts degree:

1. Lower Division Required Courses (26-27 Units)

Lower division core 23-24

- PHIL 230 Introduction to Formal Logic (3)

2. Upper Division Required Courses (23 Units)

- MATH 320 Foundations of Higher Mathematics (3)
- MATH 341 Applied Statistics I (3)
- MATH 350 Advanced Calculus I (3)
- MATH 360 Abstract Algebra I (3)
- MATH 370 Foundations of Geometry (3)

- MATH 382/L Intro. Scientific Computing and Lab (2/1)
- MATH 391 Field Experience in Schools (2)
- MATH 490 Capstone Course (3)

3. Upper Division Electives (9 Units)

Three upper division mathematics electives chosen with advisor. Recommended courses: MATH 441, 460, 463 and 470.

General Education: Basic Skills Mathematics, Basic Skills Critical Thinking and Lifelong Learning are satisfied by required courses in the major. PHYS 220A/L partially satisfies the Natural Sciences section.

Four-Year Integrated Mathematics (FYI-Math) Teacher Credential Program

The Four-Year Integrated Mathematics (FYI-Math) Teacher Credential Program is designed for students who are certain about their career choice. For admission, students must be eligible for a course in Basic Skills Analytical Reading and Expository Writing and for MATH 150A and should see a teacher preparation or credential advisor in the Mathematics Department. Upon entering the program in their freshman year, students are assigned to a cohort and for some courses must enroll in a section designated for that cohort.

FYI-Math incorporates the requirements for a bachelor's degree in mathematics (Secondary Teaching Option) with the requirements for General Education, Title 5, and the Preliminary Single Subject Credential in Mathematics. Students will also be responsible for passing the Upper Division Writing Proficiency Exam (UDWPE) and California Basic Educational Skills Test (CBEST). Students enrolled in FYI-Math Teacher follow the schedule and sequence of classes listed below. Completion of the FYI-Math Program satisfies all GE requirements.

Year One: First semester (14 units)

- MATH 150A Calculus I (5)
- GE: BS/AR&EW Select any appropriate course (3)
- GE: SE/A&H Select any appropriate course (3)
- GE: SE/CCS Select any appropriate course (3)

Year One: Second Semester (16 Units)

- MATH 150B Calculus II (5)
- PHIL 230 Introduction to Formal Logic I (3)
- COMS 151/L Fundamentals of Public Speaking and Lab (2/1)
- MATH 391 Field Experience in the Mathematics of the Public Schools (2)
- COMP 106/L* Computing in Engineering and Science and Lab (2/1)

*Note that COMP 110/L Intro to Algorithms and Programming (3/1) may be used to meet this requirement.

Year Two: First Semester (15 Units)

- MATH 250 Calculus III (3)
 - PHYS 220A/L Mechanics and Lab (3/1)
 - POLS 155 American Political Institutions (3)
 - ENGL 255 Introduction to Literature (3)
- Upper or lower division elective from any department (2)

Year Two: Second Semester (16 Units)

- MATH 262 Introduction to Linear Algebra (3)
- MATH 382/L Intro Scientific Computing and Lab (2/1)
- GE:SE/NS&L Select any appropriate course (3/1)
- EPC 420 Educational Psychology of Adolescence (3)
- PSY 312 Psychological Aspects of Parenthood (3)

Additional Requirements

Students should take the CBEST and apply for admission to the Credential Program in the College of Education.

Year Three: First Semester (15 Units)

- MATH 320 Foundations of Higher Mathematics (3)

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MATH	341	Applied Statistics I (3)
SED	511	Fundamentals of Secondary Education in Multiethnic Secondary Schools (3)
SED	514	Computers in the Instructional Program (3)
AAS/ARMN/CHS/ELPS/PAS	417	Equity and Diversity in Schools (3)

Year Three: Second semester (16 units)

MATH	360	Abstract Algebra I (3)
MATH	370	Foundations of Geometry (3)
MATH	Upper Division Elective/Select any appropriate course (3)	
SED	525MA/L	Methods of Teaching Mathematics in the Secondary School and Lab (2/1)
SPED	420	Improving the Learning of Students with Special Needs through Differentiated Instruction and Collaboration (3)
HSCI	496ADO	Health Concerns of the Adolescent (1)

Year Four: First Semester (16 Units)

MATH	350	Advanced Calculus I (3)
ASTR	301	The Dynamical Universe (3)
SED	554	Supervised Field Experience and Seminar (4)
SED	521	Literacy, Language, and Learning in Multiethnic Secondary Schools (3)
HIST	371	Problems in American History:1865 to Present (3)

Year Four: Second Semester (12 Units)

MATH	490	Capstone Course (3)
MATH	Upper Division Elective/Select any appropriate course (3)	
SED	555	Supervised Practicum and Seminar (6)

Junior-Year Integrated Mathematics (JYI-Math) Teacher Credential Program

The Junior-Year Integrated Mathematics (JYI-Math) Teacher Credential Program begins in the junior year for students who apply and have been accepted to the program. JYI-Math integrates undergraduate subject matter knowledge with teacher education content and leads to both a BA in Mathematics and a Preliminary Single Subject Credential in Mathematics. For admission, students must be juniors who have completed (with sufficient grades) the lower division general education requirements and the lower division core of the math major. Applications to both the Mathematics Department and the Credential Program are necessary.

Upon entering the JYI-Math Program during their junior year, full-time students may join a cohort and take courses as outlined by a teacher-preparation advisor in the Mathematics Department (two and three year plans are available). Part-time students may work at their own pace in a non-cohorted version of the program. JYI-Math incorporates the upper division requirements for a bachelor's degree in mathematics (secondary teaching option) with the requirements for the Preliminary Single Subject Credential in Mathematics. Students will be responsible for passing the Upper Division Writing Proficiency Exam (UDWPE). Students considering JYI-Math should seek advisement as soon as possible for guidance in meeting admission and program requirements.

Students accepted to the JYI-Math Program must complete all courses listed below . A GPA of at least 2.6 is required for all courses in the math major (Secondary Teaching Option) and no major course grade may be lower than C. A GPA of 3.0 or higher is required for all professional education coursework and no professional education course grade may be lower than C.

1. Lower Division Required Courses (must be completed PRIOR to admission to program) (26-27 Units)

Lower division core of the math major 23-24		
PHIL	230	Introduction to Formal Logic (3)

2. Upper Division Required Courses MATH (26 Units)

MATH	320	Foundations of Higher Mathematics (3)
MATH	341	Applied Statistics I (3)
MATH	350	Advanced Calculus I (3)
MATH	360	Abstract Algebra I (3)
MATH	370	Foundations of Geometry (3)
MATH	382/L	Intro. Scientific Computing and Lab (2/1)
MATH	391	Field Experience in Schools (2)
MATH	490	Capstone Course (3)
ASTR	301	The Dynamical Universe (3)

3. Upper Division Electives MATH (6 Units)

Two upper division mathematics electives chosen with advisor. Recommended courses: MATH 441, 460, 462, 463 and 470.

4. Required Courses CREDENTIAL (32 Units)

SED	511	Fundamentals of Teaching in Multiethnic Secondary Schools (3)
EPC	420	Educational Psychology of Adolescence (3)
SED	514	Technology in Instruction (3)
SED	525MA/L	Methods of Teaching Mathematics in the Secondary School and Lab (2/1)
HSCI	496ADO	Health Concerns of the Adolescent (1)
SPED	420	Improving the Learning of Students with Special Needs through Differentiated Instruction and Collaboration (3)
AAS/ARMN/CHS/ELPS/PAS	417	Equity and Diversity in Schools (3)
SED	521	Literacy, Language, and Learning in Multiethnic Secondary Schools (3)
SED	554	Advanced Field Experience and Seminar (4)
SED	555	Supervised Practicum and Seminar for the Single Subject Credential (6)

5. Upper Division General Education Requirement (6 Units)

General Education: Basic Skills Mathematics, Basic Skills Critical Thinking and Lifelong Learning are satisfied by required courses in the major. PHYS 220A/L partially satisfies the Natural Sciences section. ASTR 301 partially satisfies the upper division section.

Mathematics Subject Matter Program for the Single Subject Credential**1. Core**

MATH	150A	Calculus I (5)
MATH	150B	Calculus II (5)
MATH	250	Calculus III (3)
MATH	262	Introduction to Linear Algebra (3)
MATH	320	Foundations of Higher Mathematics (3)
MATH	341	Applied Statistics I (3)
MATH	350	Advanced Calculus I (3)
MATH	360	Abstract Algebra I (3)
MATH	370	Foundations of Geometry (3)
MATH	382/L	Intro. Scientific Computing and Lab (2/1)
MATH	490	Capstone Course (3)

Total 35 Units**2. Breadth and Perspective**

MATH	391	Field Experience in Mathematics (2)
COMP	106/L	Computing in Engineering and Science and Lab (2/1)
<i>or</i> COMP 110/L Introduction to Algorithms and Programming (3/1)		
PHIL	230	Introduction to Formal Logic I (3)
PHYS	220A	Mechanics (3)
PHYS	220AL	Mechanics Laboratory (1)

Three upper division mathematics electives (at least 9 units) chosen with advisor approval.

Recommended courses: MATH 441, 460, 463, and 470

Total: 21-22

Grand Total: 58-59 Units

Requirements for the Bachelor of Science

A. Option I. Mathematics

1. Lower Division Required Courses (23-24 Units)

Lower Division core 23-24

2. Upper Division Required Courses (24 Units)

MATH	320	Foundations of Higher Mathematics (3)
MATH	340	Introductory Probability (3)
MATH	350	Advanced Calculus I (3)
MATH	351	Differential Equations (3)
MATH	360	Abstract Algebra I (3)
MATH	382/L	Intro. Scientific Computing and Lab (2/1)
MATH	462	Advanced Linear Algebra (3)
MATH	493	Seminar in Mathematics (3)

3. Upper Division Electives (15 Units)

Students must take 5 elective courses chosen with an advisor from the following list, including at least one from MATH 450 and MATH 460: MATH 440A, MATH 440B, MATH 450, MATH 455, MATH 460, MATH 480, MATH 481ABCD, MATH 483, MATH 366, MATH 463, and all 500 level Math courses except those numbered 510-514.

General Education: Basic Skills Mathematics and Lifelong Learning are satisfied by required courses in the major. PHYS 220A/L partially satisfies the Natural Sciences section. Students are encouraged to take PHIL 230 to satisfy the Basic Skills Critical Thinking requirement.

B. Option II. Statistics

1. Lower Division Required Courses (23-24 Units)

Lower Division core 23-24

2. Upper Division Required Courses (30 Units)

MATH	320	Foundations of Higher Mathematics (3)
MATH	340	Introductory Probability (3)
MATH	350	Advanced Calculus I (3)
MATH	351	Differential Equations (3)
MATH	382/L	Intro. Scientific Computing and Lab (2/1)
MATH	440A	Mathematical Statistics I (3)
MATH	440B	Mathematical Statistics II (3)
MATH	462	Advanced Linear Algebra (3)
MATH	483	Mathematical Modeling (3)
MATH	494	Practical Experience in Mathematics (3)

3. Upper Division Electives (9 Units)

Choose 9 units from among (i) all upper division math courses (excluding MATH 310, 310L, 311, 312, 331, 391 and 490) and (ii) approved courses in other departments. At least 3 units must be in mathematics. Recommended courses are listed below:

MATH 366, 442, 450, 480, 481ABCD, 482, 540, 542ABCD
PSY 322, 420, SOM 409, 467

All classes taken outside the Mathematics Department must have the approval of an advisor prior to enrollment and students must either meet prerequisites or obtain permission of instructor.

NOTE: Early completion of MATH 340 and 440A is recommended, and courses outside the Mathematics Department are encouraged.

General Education: Basic Skills Mathematics and Lifelong Learning are satisfied by required courses in the major. PHYS 220A/L partially satisfies the Natural Sciences section.

C. Option III. Applied Mathematical Sciences

1. Lower Division Required Courses (23-24 Units)

Lower Division core 23-24

2. Upper Division Required Courses (15 Units)

MATH	320	Foundations of Higher Mathematics (3)
MATH	340	Introductory Probability (3)
MATH	350	Advanced Calculus I (3)
MATH	382/L	Intro. Scientific Computing and Lab (2/1)
MATH	494	Practical Experience in Mathematics (3)

3. Upper Division Electives (24 Units)

Choose (with an advisor) 24 units from among (i) all upper division math courses (excluding MATH 310, 310L, 311, 312, 331, 391 and 490) and (ii) approved courses in other departments. At least 12 units must be in mathematics. Students are encouraged to take courses outside the Mathematics Department. We especially encourage upper division courses in the Sciences, Engineering, and Economics. All courses must have the approval of an advisor prior to enrollment. Students in this option must meet with an advisor in their junior year and file a program form outlining the planned course work with the Mathematics Department.

General Education: Basic Skills Mathematics and Lifelong Learning are satisfied by required courses in the major. PHYS 220A/L partially satisfies the Natural Sciences section.

Double Major

A student pursuing either a B.A. or a B.S. degree may combine a second major with mathematics. In this circumstance, upon approval of an advisor, 6 units of Upper Division electives may be satisfied by courses in the second major. The remaining electives must be taken in the department of mathematics. Under certain rare conditions the physics requirement in the Lower Division Core may be replaced by appropriate course work in the second major. Prior approval must be obtained from an advisor and the chair of the department of mathematics for this latter occurrence.

Requirements for the Minor

1. Lower Division Required Courses (16 Units)

MATH	150A	Calculus I (5)
MATH	150B	Calculus II (5)
MATH	250	Calculus III (3)
MATH	262	Introduction to Linear Algebra (3)

Note: PHIL 230, Symbolic Logic I, is recommended and satisfies the Critical Thinking section of General Education.

2. Upper Division Electives (12 Units)

Selected upper division mathematics courses totaling at least 12 units which must be approved in advance by a mathematics minor advisor. Depending on the student's area of interest, any one of the following sequences could be used as part or all of the required 12 units (or other choices if approved by the mathematics minor advisor).

Computer Mathematics: MATH 326, 340, 481A, 482

Secondary Teaching: MATH 320, 341 or 360, 370

Statistics: MATH 340, 440A, 440B

Requirements for the Master of Science Degree Options I and II

A. For Admission to Graduate Status:

Admission as a classified graduate student requires: 1) academic preparation essentially equivalent to a B.A. or B.S. degree in mathematics at CSU Northridge with a GPA of at least 3.0 in all undergraduate work, and 2) a grade of B or better in each of the common five upper division core courses in the Mathematics major. Students with less than a B average may be eligible for conditionally classified status. Applicants

with undergraduate degrees in fields outside the Mathematical Sciences may also be considered for conditionally classified status, provided that they have successfully taken a significant number of both lower and upper division mathematics courses. Their eligibility and admission status will be determined by the Graduate Committee on an individual basis. Conditionally classified students are required to attain classified status by passing the Mathematics Screening Exam and satisfying all University requirements within two semesters of being admitted as a conditionally classified graduate student.

B. The Mathematics Screening Examination

This exam will be given three times every year, in the week just before the start of each semester and in the week just after the end of the spring semester. It will cover topics from the core undergraduate upper division mathematics curriculum – with emphasis on Analysis and Linear Algebra.

C. Residency Requirement

In order to maintain good standing, graduate students must complete at least one approved course during each semester. Students who fail to do so will be placed on probation. Students who fail to fulfill this requirement twice will be disqualified.

D. Comprehensive Exam or Master's Thesis

Students must successfully complete one of the following:

- Comprehensive Examination: This two-part examination will be based on the students' required courses. Students in Option I must take Algebra and either Analysis I or Analysis II. Students in Option II must take Analysis I and one other excluding Algebra.

Comprehensive exams are given in the following areas:

- Algebra (material from 462, 460, and 560)
- Analysis I (material from 501 and 552)
- Analysis II (material from 550 and 655)
- Numerical Analysis (material from 581, 582)
- Applied Functional Analysis (material from 680 A/B)
- Probability/Statistics (material from 540, 542)

- A Master's Thesis: In order to write a master's thesis students must maintain a grade point average of 3.4 in their required courses. Each student must also defend his/her thesis in an oral examination by his or her thesis committee.

The University requires that students take at least one unit of MATH 697 (if they take a Comprehensive Exam) or one unit of MATH 698 (if they write a thesis). Units for MATH 697 or MATH 698 do not count toward the 31 units required for the degree.

Courses of Study

A. Option I. Mathematics

This Option is primarily designed to prepare students for community college teaching, entry level positions in industry, or future graduate work in mathematics. The core of this program consists of an in depth study of the mainstream of modern mathematics: algebra, analysis and topology.

1. Required Courses (16 Units)

Basic course work:

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|------|-----|---------------------------|
| MATH | 501 | Topology (3) |
| MATH | 550 | Calculus on Manifolds (3) |
| MATH | 552 | Real Analysis (3) |
| MATH | 560 | Abstract Algebra III (3) |
| MATH | 655 | Complex Analysis (3) |

Participating Seminar:

- | | | |
|------|-----|-----------------------------|
| MATH | 589 | Seminar in Mathematics. (1) |
|------|-----|-----------------------------|

2. Electives (15 Units)

Select approved courses. At least 6 of these 15 units must be at 500 or 600-level. Up to 6 units may be taken in fields outside mathematics with prior approval of the Graduate committee.

B. Option II. Applied Mathematics

This option is designed to prepare students for entry-level positions in industry, business, government, or for future graduate work in applied mathematics. Its core consists of the basic preparation in Analysis and courses in Differential Equations, Modeling, Numerical Analysis, or Probability/Statistics. The option allows the student to design an individual course of study that best satisfies their needs.

1. Required Courses (16 Units)

Basic preparation:

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| MATH | 501 | Topology (3) |
| MATH | 552 | Real Analysis (3) |

Participating Seminar:

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|------|-----|--|
| MATH | 589 | Seminar in Mathematics (1) |
| | | <i>and either</i> MATH 542A-D Topics in Probability/Statistics (3) |
| | | <i>or</i> MATH 581 Numerical Methods for Linear Systems (3) |

and two courses from the following list:

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|------|---------|--|
| MATH | 540 | Regression Analysis (3) |
| MATH | 542 A-D | Topics in Probability/Statistics (3) |
| MATH | 581 | Numerical Methods for Linear Systems (3) |
| MATH | 582 A-D | Topics in Numerical Analysis (3) |
| MATH | 592 A-D | Topics in Applied Mathematics (3) |
| MATH | 625 | Advanced Mathematical Modeling (3) |
| MATH | 655 | Complex Analysis (3) |
| MATH | 680 A/B | Applied Functional Analysis I/II (3) |

2. Electives (15 Units)

Select approved courses. At least 6 of these 15 units must be at 500 or 600-level. Up to 9 units may be taken in fields outside mathematics with prior approval of the Graduate committee.

Switching Between Options I and II

Students may request in writing to switch between Option I and II. Such requests will be considered by the Graduate Committee.

Requirements for the Master of Science Degree Option III

A. For Admission to Graduate Status

Students are expected to have cleared competency for single subject mathematics, by program or examination. Students with a baccalaureate degree who have not cleared subject matter competency in mathematics may be eligible for the program with the conditionally classified status. Conditionally classified students need to meet the conditions required by the University and clear competency for single subject matter in mathematics within two semesters.

B. Culminating Experience

At the end of each B section of the courses listed below students will write a paper that will provide the opportunity for an individual study in depth of one topic of the course that has relevance for mathematics at the secondary school level. A portfolio containing all articles and individual contributions to the courses will show candidate's mastery of concepts, mathematical breadth, and ability to communicate mathematics clearly and engagingly. Students should provide a summary of what they have learned in this curriculum and reflect upon the applicability of it to their career. The portfolio will be submitted to a committee chosen by the candidate and approved by the Graduate Committee. The University requires that students take at least one unit of MATH 698 (Thesis or Graduate Project). Units taken in MATH 698 will not count toward the total 30 units required for the degree.

C. Option III. Mathematics For Educational Careers

This program is especially designed for secondary teachers and for other professionals with a baccalaureate degree who are seeking educational careers. It will deepen students' knowledge beyond what can be learned in a baccalaureate degree program for secondary teachers of mathematics.

All courses include active learning and presentations on selected topics. In addition, each B section of the courses will culminate with the student working on a project and writing an article. The overall goal is to enable teachers to take leadership roles in their schools. In addition, they will be knowledgeable instructors of AP Statistics and AP Calculus.

1. Required Courses (30 Units)

MATH	510A/B	Algebra and Number Theory (3-3)
MATH	511A/B	Linear Algebra and Geometry (3-3)
MATH	512A/B	Concepts of Analysis (3-3)
MATH	513A/B	Discrete Mathematics (3-3)
MATH	514A/B	Probability and Statistics (3-3)

These courses cannot be replaced in the program by any other graduate course.

Entry Level Mathematics Exam (ELM)

The ELM examination assesses entry-level mathematics skills that the CSU expects entering students to have acquired in three years of rigorous college preparatory mathematics coursework (Algebra I, Geometry, and Algebra II). All entering CSU undergraduates must take the ELM examination, with the exception of those who present proof of one of the following:

1. Successful completion of the Early Assessment Program (EAP)
2. A score of 550 or above on the mathematics section of the College Board SAT I Reasoning Test or on the College Board SAT II Mathematics Test Level IC or IIC.
3. A score of 23 or above on the American College Testing (ACT) Mathematics Test.
4. A score of 3 or above on the College Board Advanced Placement Calculus AB or Calculus BC or Statistics Examination.
5. Completion and transfer of a course that satisfies the General Education–Breadth or Intersegmental General Education Transfer Curriculum (IGETC) quantitative reasoning requirement, provided such course was completed with a grade of C or better.

Successful completion of the ELM examination or a grade of credit in the appropriate developmental mathematics courses is one of the requirements for enrollment in most university-level mathematics courses at CSUN, as well as CHEM 103, 100 and PHSC 170. ELM exemption based on SAT, ACT or Advanced Placement Test scores, as listed above, will also meet this requirement. However, students who wish to qualify for enrollment in university-level mathematics courses at CSUN on the basis of a transfer course can only do so if the transfer course is an approved mathematics course above the level of intermediate algebra.

Liberal Studies majors who are credential candidates should be aware that the ELM requirement must be met in order to enroll in either MATH 210 or 310. A transfer course equivalent to MATH 210 will not enable students to enroll in MATH 310 at CSUN unless they have also met the ELM requirement for enrollment.

Mathematics Placement Test (MPT)

The Mathematics Placement Test (MPT) is a CSUN test which is used to determine eligibility for enrollment in MATH 103, 104, 105, 150A and 255A and must have been taken within the year preceding enrollment in these courses. The MPT does not replace the ELM

requirement, but is used in addition to the ELM to determine eligibility for enrollment.

Part I of the MPT consists of questions on intermediate algebra. Part II of the MPT consists of questions on trigonometry and advanced topics from intermediate algebra (precalculus). A qualifying score on Part I is required for entry into MATH 103, 104, and 105. Qualifying scores on both Parts I and II are required for entry into MATH 150A and 255A.

Visit the Testing Center website at www.csun.edu/testing for registration information, required qualifying scores and test dates.

Prerequisite Mathematics Courses

The University entrance requirements (2 years of high school algebra and one year of geometry) are the basic prerequisites to all courses. Additional prerequisites may be listed in the course descriptions which follow. Prerequisite courses must be passed with a grade of C or better.

Course List

MATH 090. Introduction to Problem Solving (2)

Introduction to problem-solving, with an emphasis on basic mathematics skills. Diagnostic tests enable students to identify specific topics for study. Involves collaborative learning, individualized advisement and instruction, and use of media and computers. Normally offered as a Summer Bridge course. Credit will not apply toward the baccalaureate degree but will apply as two units of University credit.

MATH 092. Developmental Mathematics I (3)

First in a 2-semester sequence of developmental mathematics courses. Students scoring below 34 on the ELM need to complete MATH 092 and 093 successfully to be remediated. Credit will not apply toward the baccalaureate degree but will apply as 3 units of University Credit. Students who earn Credit in MATH 092 are eligible to enroll in MATH 093. Topics covered include fractions, decimal notation, percent, real numbers and algebraic expressions, equations and inequalities. (Credit/No Credit only)

MATH 093. Developmental Mathematics II (5)

Prerequisite: Score of 34 or above, but below 50 on the Entry Level Mathematics (ELM) exam or credit in MATH 092. Credit will not apply toward the baccalaureate degree but will apply as 5 units of University Credit. Successful completion of MATH 093 qualifies students for entrance into MATH 102, 131, 140 and 210. Review of elementary algebra topics: equations and inequalities, polynomials, factoring, rational expressions, graphing, radical expressions, quadratic equations and functions. (Credit/No Credit only)

MATH 102. College Algebra (3)

Prerequisites: Passing score on or exemption from the Entry Level Mathematics Examination (ELM), or credit in MATH 093. Functions, linear equations, quadratic equations, theory of equations, progressions, inequalities, and absolute value, logarithms, permutations, combinations, probability, determinants. Not open to students who have credit in MATH 103, 105, or 106. (Available for General Education, Basic Skills Mathematics)

MATH 103. Mathematical Methods for Business (3)

Prerequisites: Passing score on or exemption from the Entry Level Mathematics Examination (ELM) or credit in Math 093; AND a passing score on the Mathematics Placement Test, Part I or credit or concurrent enrollment in Math 103L. Concepts and applications of algebra and calculus to business. Topics include functions, systems of equations, matrices, the derivative and business-related topics in calculus. (Available for General Education, Basic Skills Mathematics)

MATH 103L. Mathematics for Business Laboratory (1)

Prerequisite: Passing score on the ELM Exam. This self-paced module-based laboratory is designed to give students additional exposure to the applications of College Algebra to business and economics beyond what can be done in lecture. The additional hands-on problem-solving skills learned in this class enhance the lecture experience and strengthen the skills necessary for success in MATH 103 and subsequent courses in business majors. The lab environment allows students to both work at their own pace and receive small-group instruction with the laboratory instructor on all modules. Students with an MPT Part I score below 24 may enroll in MATH 103 if and only if they enroll in this course. Two hours lab per week. (Credit/No Credit only.)

MATH 104. Trigonometry and Analytic Geometry (3)

Prerequisites: Passing score on or exemption from the Entry Level Mathematics Examination and a passing score on the Mathematics Placement Test, or MATH 102 with a grade of C or better. Rectangular and polar coordinates; trigonometric functions, identities and equations; inverse trigonometric functions; conic sections; complex numbers. Not open to students who have credit in MATH 103, 105, or 106.

MATH 105. Pre-Calculus (5)

Prerequisites: Passing score on or exemption from the Entry Level Mathematics Examination (ELM) or credit in MATH 093, and a passing score on the Mathematics Placement Test (MPT) or MATH 102 with a grade of C or better. Number systems and their algebraic properties; systems of equations and inequalities; basic analytic geometry of lines and conic sections; elementary functions including polynomial, rational, exponential, and logarithmic, with emphasis on trigonometric functions; polar equations. Graphing calculators are used and the interplay between graphical and algebraic solutions is stressed. Not open for credit to students who have successfully completed MATH 150A. (Available for General Education, Basic Skills Mathematics)

MATH 131. Mathematical Ideas (3)

Prerequisites: Passing score on or exemption from the Entry Level Mathematics Examination, or credit in MATH 093. General Education course intended to acquaint the student with basic mathematical ideas. (Available for General Education, Basic Skills Mathematics)

MATH 140. Introductory Statistics (4)

Prerequisites: Passing score on or exemption from the Entry Level Mathematics Examination, or credit in MATH 093. Methods for displaying, describing, and producing data. Normal distribution. Correlation and regression. Sampling distributions and probability. Statistical inference for means and proportions. (Available for General Education, Basic Skills Mathematics)

MATH 150A. Calculus I (5)

Prerequisites: Passing score on or exemption from the Entry Level Mathematics Examination or credit in MATH 093, and either a passing score on the Mathematics Placement Test or completion of MATH 105, or both MATH 102 and 104, at CSUN with grades of C or better. Students who transfer the equivalent of MATH 105, or both MATH 102 and 104, with a C or better are required to achieve a passing score on the Math Placement Test. Limits, derivatives, applications of differentiation. Definite and indefinite integrals, the Fundamental Theorem of Calculus. (Available for General Education, Basic Skills Mathematics)

MATH 150AL. Calculus Computer Lab A (1)

Prerequisite: MATH 150A. Reinforcement of calculus concepts and applications of calculus through the use of computers. Introduction to mathematical software to prepare students for use in later courses. Three lab hours per week.

MATH 150B. Calculus II (5)

Prerequisite: MATH 150A with a grade of C or better. Techniques of integration, numerical integration, improper integrals, applications of the integral. Taylor polynomials, sequences and series, power series.

MATH 150BL. Calculus Computer Lab B (1)

Prerequisite: MATH 150B. Reinforcement of calculus concepts and applications of calculus through the use of computers. Introduction to mathematical software to prepare students for use in later courses. Three lab hours per week.

MATH 210. Basic Number Concepts (3)

Prerequisites: Passing score on or exemption from the Entry Level Mathematics Examination (ELM), or credit in MATH 093. Language of sets, systems of numeration, nature of numbers and fundamentals of operations, relations and functions, domain of integers, field of rational and real numbers. Designed primarily for students intending to teach in elementary or junior high school. Not available for credit toward the major or minor in Mathematics.

MATH 250. Calculus III (3)

Prerequisite: Completion of MATH 150B with a grade of C or better. Continuation of MATH 150B. Solid analytic geometry, partial differentiation, and multiple integrals with applications.

MATH 255A. Calculus for the Life Sciences I (3)

Prerequisites: Passing score on or exemption from the Entry Level Mathematics Examination (ELM) or credit in MATH 093, and either a passing score on the Mathematics Placement Test (MPT) or completion of MATH 105, or both MATH 102 and 104, or articulated courses from another college equivalent to MATH 105, or both MATH 102 and 104, with grades of C or better. Knowledge of trigonometry is assumed. First semester of a short course in the calculus. Topics in calculus of functions of one variable including techniques of differentiation, applications to graphing, extreme problems, and an introduction to integration. Not open for credit to students who have successfully completed MATH 150A. (Available for General Education, Basic Skills Mathematics)

MATH 255B. Calculus for the Life Sciences II (3)

Prerequisite: Completion of MATH 255A with a grade of C or better. Continuation of MATH 255A. Techniques of integration, series, applications, functions of several variables and partial differentiation. Not open for credit to students who have successfully completed MATH 150AB.

MATH 262. Introduction to Linear Algebra (3)

Prerequisite: MATH 150B. Systems of linear equations, matrices, determinants, eigenvalues, vector spaces, linear transformations, introduction to inner products on R^n , spectral theorem for symmetric matrices.

MATH 280. Applied Differential Equations (3)

Prerequisite: MATH 150B. Recommended Corequisite or Preparatory: MATH 250. Ordinary differential equations, series solutions, systems of equations, Laplace transforms, with emphasis on applications and introduction to numerical techniques. Course is not open to students who have credit for MATH 351.

Upper Division**MATH 310. Basic Concepts of Geometry, Probability and Statistics (3)**

Prerequisites: Passing score on or exemption from the Entry Level Mathematics Examination (ELM) or credit in MATH 093, and completion of MATH 210 with a grade of C or better. Articulated course from another college equivalent to MATH 210 may only satisfy the course prerequisite for MATH 310. Students passing such a course with a C or better will still need to fulfill the ELM requirement. Second course for students

intending to teach in elementary or junior high school. Geometry as a system; congruence and similarity through construction with straightedge and compass; transformational geometry; the nature of measurement, precision, and accuracy; basic principles of probability and statistics. Not available for credit toward the major or minor in Mathematics.

MATH 310L. Geometry, Probability and Statistics Lab (1)

Recommended Corequisite or Preparatory: MATH 310. Problem solving using models and simulation in mathematics appropriate for the elementary school classroom. Two hours of activities per week. (Credit/No Credit Only)

MATH 311. Basic Geometric Concepts (3)

Prerequisites: Passing score on the Entry Level Mathematics Examination (ELM) and completion of MATH 210 and 310 with a grade of C or better or instructor consent. Continuation of the investigation of elementary geometry begun in MATH 310. Topics selected from: topology, motion geometry, metric geometry, geometry as a mathematical system, absolute geometry, Euclidean geometry, non-Euclidean geometry. Not available for credit toward the math major or minor.

MATH 312. Basic Algebraic Concepts (3)

Prerequisites: Passing score on the Entry Level Mathematics Examination (ELM) and completion of MATH 210 and 310 with a grade of C or better, or instructor consent. Topics selected from: abstract algebra and applied algebra using elementary mathematical models. Not available for credit toward the math major or minor.

MATH 320. Foundations of Higher Mathematics (3)

Prerequisite: MATH 150B. The goal of this course is to help students transition from a primarily computational mode of doing mathematics to a more conceptual mode of doing mathematics. The emphasis will be on proofs, which are taught in the context of elementary number theory, combinatorics, and analysis; the language of sets, relations, order, equivalence classes, functions, cardinality is introduced. Students are expected to write large numbers of proofs and communicate mathematical ideas clearly.

MATH 326. Discrete Mathematics (3)

Prerequisites: MATH 150B; PHIL 230 or ECE 320. Propositional calculus, predicate calculus, set algebra, relations, functions, mappings, fields, number systems.

MATH 331. Mathematical Explorations (3)

Prerequisites: Passing Score on the Entry Level Mathematics Examination (ELM); completion of the lower division writing requirement and upper division standing. A course designed to give students an appreciation of the diversity of mathematics and the spirit in which it is employed in various applications. The character and origin of key topics from different branches of mathematics are explored. The contributions of various cultures to the field are studied along with the use of mathematical models for physical problems. The development is conceptual rather than axiomatic and includes several supervised reading and writing assignments. One significant writing assignment is required. Strongly recommended for prospective teachers in all fields. (Available for General Education, Basic Skills Mathematics)

MATH 340. Introductory Probability (3)

Prerequisite: MATH 150B. Sample spaces, probability rules, independence, conditional probability, Bayes' Theorem, discrete and continuous random variables and distributions (e.g. binomial, Poisson, geometric, normal, exponential, uniform), expectation, moment generating functions, joint distributions, central limit theorem.

MATH 341. Applied Statistics I (3)

Prerequisite: MATH 150B. Introduction to the practice of statistics, emphasizing the role of probability. Includes basic probability, discrete and continuous probability distributions, expectation and variance, sample surveys and experiments, displaying and summarizing data, sampling distributions, central limit theorem, inference for proportions, chi-square test, least squares regression. Mathematics majors who are not in the secondary teaching option may not receive credit for both Math 340 and Math 341.

MATH 350. Advanced Calculus I (3)

Prerequisite: MATH 320. Topics include the real number system, continuous functions, differentiation, and Riemann integration of functions of 1 real variable.

MATH 351. Differential Equations (3)

Prerequisites: MATH 250; 262. Linear equations, series solutions, singular points, existence and uniqueness of solutions, systems of equations. Course is not open to students who have credit for Math 280.

MATH 360. Abstract Algebra I (3)

Prerequisites: MATH 262; 320. Survey course in abstract algebra. Introduction to groups, rings, fields, vector spaces.

MATH 366. Combinatorics (3)

Corequisite: MATH 320 or MATH 326. This is a one-semester introduction to combinatorics. Topics will include enumerative combinatorics (inclusion-exclusion, generating functions, Polya's Theorem, etc.) and combinatorial structures (graphs, designs, etc.).

MATH 370. Foundations of Geometry (3)

Prerequisite or Corequisite: MATH 320. One of the goals of this course is to help students write rigorous proofs of results of plane Euclidean geometry. It is also expected that students visualize and develop geometric intuition through the use of dynamic geometry software. The content includes history, axiomatic structure, and theorems of plane Euclidean geometry, geometric transformations of the plane: rigid motions, similarities, and inversion, coordinate geometry and an introduction to non-Euclidean geometries.

MATH 382/L. Introduction to Scientific Computing and Lab (2/1)

Corequisite: MATH 262. This course gives students an introduction to basic numerical techniques and to programming using some of the common software packages used in mathematics. Students apply these techniques in projects from different branches of mathematics. [Note: This course does not replace a rigorous course in Numerical Analysis.] Two hours lecture, two hours lab.

MATH 390A-D. Mini-Courses in Mathematics for Pre and in Service Teachers (1)

Prerequisites: Passing score on Entry Level Mathematics Examination (ELM); MATH 210 with a grade of C or better or instructor consent. Course is intended for Liberal Studies Credential Candidates and in-service elementary and middle school teachers. Important concepts of mathematics that have particular application to the elementary school curriculum. A—History of Mathematics; B—Computational Methods; C—Computer-Assisted Instruction; D—Strategies in Problem Solving. (Credit/No Credit Only)

MATH 391. Field Experience in the Mathematics of the Public Schools (2)

Prerequisites: (Multiple Subject Candidates) MATH 210 and 310 or corequisite with 310; passing score on the Entry Level Mathematics Examination (ELM). (Single Subject Candidates) MATH 150A; 150B; junior standing. Field experience course designed to give the prospective teacher an appreciation of a quality mathematics program in the public schools. Requirements include 45 hours of participation in an

assigned school and regular group meetings to discuss the classroom experience. (Credit/No Credit Only)

MATH 440A. Mathematical Statistics I (3)

Prerequisites: MATH 262; 340. Point estimation, bias and mean squared error, optimality theory for estimates, maximum likelihood estimation, confidence intervals, test of hypotheses, power, optimality theory for tests.

MATH 440B. Mathematical Statistics II (3)

Prerequisite: MATH 440A. Chi-square goodness of fit tests, simple and multiple linear regression, 1 and 2-way analysis of variance, statistical analysis using the computer.

MATH 441. Applied Statistics II (3)

Prerequisite: MATH 341. Continuation of Math 341 with emphasis on statistical inference. Includes design of surveys and experiments, the t-distribution, inference for means, correlation and regression with transformations, inference for slope.

MATH 442A-Z. Topics in Mathematical Statistics (3)

Prerequisite: MATH 340 or 440A. Topics selected from statistics and/or probability, such as nonparametric statistics, multivariate statistics, experimental design, decision theory, and advanced probability theory.

MATH 450. Advanced Calculus II (3)

Prerequisite: MATH 350. Topics include sequences and series of functions, Heine-Borel theorem, Jacobians, inverse and implicit function theorems.

MATH 455. Complex Variables (3)

Prerequisite: MATH 350. Complex numbers, analytic functions, complex integration, Cauchy's Theorem, power series, calculus of residues, conformal mappings.

MATH 460. Abstract Algebra II (3)

Prerequisite: MATH 360. Second course in abstract algebra. Group theory, rings and modules, field extensions.

MATH 462. Advanced Linear Algebra (3)

Prerequisites: MATH 262; 320. Finite dimensional vector spaces, linear transformations, matrix polynomials, canonical forms.

MATH 463. Number Theory (3)

Prerequisite: MATH 320. Recommended Corequisite or Preparatory: MATH 360. Euclidean algorithm and the unique factorization theorem, congruences, primitive roots and indices, quadratic residues and the law of quadratic reciprocity, distribution of primes.

MATH 470. Topics of Geometry (3)

Prerequisite: MATH 370 or 350. Non-Euclidean geometries and/or advanced results in Euclidean geometry.

MATH 480. Partial Differential Equations (3)

Prerequisite: MATH 351 or 280. Orthogonal functions, Laplace's equation, Poisson's equation, Bessel's equation, self-adjoint operators, Sturm-Liouville theory, Fourier series, separation of variables applied to the heat equation and wave equation, nonhomogeneous problems, Green's functions for time-independent problems, infinite domain problems.

MATH 481A. Numerical Analysis (3)

Prerequisites: MATH 262; COMP 106/L or 110/L. Techniques of applied mathematics, solution of equations, interpolation, numerical integration, numerical solution of differential equations.

MATH 481B. Numerical Analysis (3)

Prerequisite: MATH 481A. Numerical solution of linear systems of equations. Included are direct and iterative methods for solving linear systems, iterative techniques in matrix algebra, applications to approxi-

mation theory, techniques for finding eigenvalues. Formal instructions are combined with practical assignments in scientific computing.

MATH 481C. Numerical Methods for Partial Differential Equations (3)

Prerequisite: MATH 481B. *Corequisite:* MATH 480. Numerical Methods for PDEs are covered, in particular, finite difference methods and finite element methods. Application of these methods to linear partial differential equations.

MATH 481D. Topics in Numerical Mathematics (3)

Prerequisite: MATH 481A. This course explores topics in numerical mathematics that have not been explored elsewhere in the sequence. These topics include, but are not limited to, topics from statistics and linear and non-linear optimization. The course may be taken twice for credit with the consent of an advisor.

MATH 482. Combinatorial Algorithms (3)

Prerequisites: MATH 150B; 262; some computer programming experience. Computer oriented study of seminumerical and non-numerical algorithms. Sorting, tree searching, generation of combinatorial structures, algorithm proof techniques, best algorithms, programming complexity.

MATH 483. Mathematical Modeling (3)

Prerequisites: MATH 340; 351. Applications of mathematical techniques to solve selected problems in ecology, biology, economics, finance, social sciences, life sciences, physical sciences, and engineering. Models discussed include deterministic, stochastic, optimization, static, and dynamic ones. Emphasis is placed on the initial phase of building mathematical models and the final phase of interpreting the solutions in terms of real-life applications.

MATH 490. Capstone Course (3)

Prerequisite: Senior standing. A course where prospective teachers see high school level mathematics from a more advanced perspective, where there is considerably more emphasis on issues of pedagogy than in other content courses, and where students will see connections between the mathematics they have learned and some of the activities that they will themselves be engaged in as teachers. Math 490 is required for the Secondary Teaching Option, but a student may choose, in consultation with his or her advisor, to take the course a second time as an elective.

MATH 493. Undergraduate Seminar in Mathematics (3)

Prerequisite: Junior Standing in the Major. Students will study current topics in mathematical and/or statistical literature and will prepare written summaries and give oral presentations to the class. Students will be active participants in all seminars by asking questions and providing written critiques and summaries of the presentations of other students.

MATH 494. Practical Experience in Mathematics (3)

Prerequisite: Junior Standing in the Major. Students will gain practical experience in the profession by either participating in an internship doing mathematical/statistical work at an outside organization, or by doing directed research within the Department. All students are expected to work a minimum of 8 hours per week on this assignment and meet with the course instructor on a regular basis. All students are required to produce a written report on their work at the end of the semester. Students will give oral reports to the Department and their peers.

MATH 496A-Z. Experimental Topics in Modern Mathematics (3)

Prerequisites: Senior standing and instructor consent.

MATH 499A-C. Independent Study (1-3)

See Independent Study under courses of study.

Graduate

MATH 501. Topology (3)

Prerequisite: MATH 350. Metric Spaces, Topological Spaces, compactness, completeness and connectedness. Introduction to function spaces, with emphasis on the uniform topology.

MATH 510A/B. Algebra and Number Theory (3-3)

Prerequisite: Admission to the program. A two-course sequence on integers and prime numbers, rational and complex algebraic numbers, symmetry and group theory, rings of polynomials and algebraic integers, basic algebraic geometry and algebraic extensions, elementary Galois Theory, and the theory of equations. Math 510A is the prerequisite for Math 510B. These courses cannot be taken for credit towards degree in Options I and II.

MATH 511A/B. Linear Algebra and Geometry (3-3)

Prerequisite: Admission to the program. A two-course sequence on modern applications of mathematics that involve matrices, basic properties of vectors of \mathbb{R}^2 and \mathbb{R}^3 , dot product, orthonormal basis, and cross product. linear transformations of Euclidean 2- and 3-Space and the classification of its rigid motions, symmetric bilinear forms, conics and quadrics, basic topology of \mathbb{R}^n , spherical geometry, Poincaré's models of the hyperbolic plane and their isometries. Math 511A is the prerequisite for Math 511B. These courses cannot be taken for credit towards degree in Options I and II.

Math 512A/B. Concepts of Analysis (3-3)

Prerequisite: Admission to the program. A two-course sequence on the real number system, countable and uncountable sets, cardinal numbers, Cantor diagonal argument, well-ordered sets, ordinal numbers, numerical sequences and numerical series of real numbers, continuity, differentiability, and integration of functions of one variable, sequences and series of functions, uniform convergence, and ordinary differential equations. Math 512A is the prerequisite for Math 512B. These courses cannot be taken for credit towards degree in Options I and II.

Math 513A/B. Discrete Mathematics (3-3)

Prerequisite: Admission to the program. A two-course sequence on permutations, combinations, multinomial coefficients and Pascal Triangles, Pigeon Hole Principle, Inclusion-Exclusion Principle, Ramsey Numbers, Characteristic Functions and Algorithms, Generating Functions, Finite Probabilities, Recurrence Relations, Connected Graphs, Graph Colorings, Planar Graphs, Trees, Adjacency Matrices, Eulerian Paths, Hamiltonian Paths, Tournaments, Matching and Covering, Networks, Information Transmission, Coding and Decoding, Error Correcting Codes. Math 513A is the prerequisite for Math 513 B. These courses cannot be taken for credit towards degree in Options I and II.

Math 514A/B. Probability and Statistics (3-3)

Prerequisite: Admission to the program. A two-course sequence on probability rules, discrete and continuous random variables and their distributions, central limit theorem, on elementary topics in statistics from the advanced point of view: exploratory analysis, graphical display, random phenomena, probability distributions, simulation, correlation and regression, survey sampling and experimental design, sampling distributions, confidence intervals and significance tests for proportions and means, chi-square tests. Math 514A is the prerequisite for Math 514B. These courses cannot be taken for credit towards degree in Options I and II.

MATH 540. Regression Analysis (3)

Prerequisite: MATH 440A. General linear model in matrix form, simple and multiple regression analysis, transformations, variable selec-

tion, multicollinearity, analysis of variance, robust regression, logistic regression, principal components and factor analysis. Statistical software utilized.

MATH 542A-D. Probability and Statistics (3-3-3-3)

Prerequisite: Math 340 or 440A. This course will cover topics in probability and statistics not covered elsewhere in the program. Part A is usually devoted to Multivariate Statistics, Part B to Stochastic Processes, and Part C to Probability Theory. Part D is left to a topic chosen by the individual instructor.

MATH 550. Calculus On Manifolds (3)

Prerequisite: Math 450. Integration of functions of several variables. Differential forms and differential manifolds, Line integrals, integration on manifolds, Stokes' Theorem and Poincaré's Lemma.

MATH 552. Real Analysis (3)

Prerequisite: MATH 501. Introduction to measure theory and Lebesgue integration and their application to probability theory. Monotone and Dominated Convergence Theorems, Fubini's Theorem, Fourier Analysis and Banach Spaces.

MATH 560. Abstract Algebra III (3)

Prerequisite: Math 460. Graduate course in abstract algebra. Group theory, Galois Theory, other topics.

MATH 570. Differential Geometry (3)

Prerequisite: Math 450. The local theory of regular curves in \mathbb{R}^3 and Frenet formulas. Regular surfaces in \mathbb{R}^3 , the first and second fundamental forms, Gaussian and mean curvatures, and the Egregium Gauss theorem. Geodesics and the Gauss-Bonnet theorem.

MATH 581. Numerical Methods for Linear Systems (3)

Prerequisite: MATH 462. Methods for solving large linear problems and eigenvalue problems are presented at an advanced level. Direct methods such as LU factorization, Cholesky factorization, the Least Squares method, and Iterative methods such as the Jacobi, Gauss-Seidel, SOR and conjugate Gradient methods are discussed in detail. Eigenvalue problems are solved via power iteration, the QR method and the Jacobi method.

MATH 582 A-D. Topics in Numerical Analysis (3-3-3-3)

Prerequisite: Math 581 or consent of instructor. The course will cover topics in numerical analysis which are important in many applications and which are not covered elsewhere in the program. Part A usually covers Numerical Methods in Optimization, Part B covers Numerical Methods for Ordinary Differential Equations, and Part C covers Numerical Solution of Partial Differential Equations. Part D covers a subject chosen by the instructor.

MATH 589. Seminar in Mathematics (1)

Prerequisite: Senior or graduate standing in the Mathematics Department. Students will read about advanced topics in the recent literature in Mathematics and report on them in a lecture. This course is graded on a Credit/No Credit basis, and may be taken up to two times with the consent of the advisor.

MATH 592A-D. Topics in Applied Mathematics (3-3-3-3)

Prerequisites: Math 552 or consent of instructor. This course is devoted to a variety of important topics in Applied Mathematics that are not covered elsewhere in the program. In particular, Part A will cover the Mathematical Theory of Partial Differential Equations, Part B Mathematical Optimization and Operations Research, and Part C Mathematical Biology. The topic of Part D is left to the individual instructor.

MATH 595A-Z. Experimental Topics (1-3)

Prerequisite: Consent of instructor. Specialized topics from a concentrated field of current interest presented at an advanced level.

MATH 625. Advanced Mathematical Modeling (3)

Selected problems in ecology, biology, economics, finance, social sciences, life sciences, physical sciences, and engineering is used to develop advanced techniques of mathematical modeling.

MATH 651 ABC. Advanced Topics in Analysis, Geometry and Topology (3-3-3)

Prerequisite: Consent of instructor. Advanced topics not covered in the previous classes on the subject. Part A covers topics in Analysis, Part B topics in Geometry, and Part C covers topics in Topology. May be taken repeatedly, with the consent of the advisor.

MATH 655. Complex Analysis (3)

Prerequisites: MATH 501; 455. Topics covered: the general Cauchy theorem, power series and analytic continuation, series and product expansions, conformal mapping, the Dirichlet problem.

MATH 661 ABC. Advanced Topics in Algebra, Number Theory and Discrete Mathematics (3-3-3)

Prerequisite: Consent of instructor. Advanced topics not covered in the previous classes on the subject. Part A covers topics in Algebra, Part B topics in Number Theory, and Part C covers other topics in Discrete Mathematics. May be taken repeatedly, with the consent of the advisor.

MATH 680A/B. Applied Functional Analysis (3-3)

Prerequisites: MATH 501; 552. This two semester sequence gives an introduction to Banach spaces and Hilbert spaces and their applications. Fixed Point Theorems, and their applications to differential and integral equations, variational principles. Adjoint and self-adjoint operators and spectral theory of linear operators. 680A is a prerequisite for 680B.

MATH 697A-C. Directed Comprehensive Studies (1-3)**MATH 698A-C. Thesis or Graduate Project (1-3)****MATH 699A-F. Independent Study (1-6)**

See Independent Study under courses of study.