

# MATHEMATICS

The Department of Mathematics offers majors and minors in mathematics, applied mathematics and mathematics education. Combined majors are offered in mathematics and computer science, biology and mathematics, chemistry and mathematics, economics and mathematics, and physics and mathematics. The department also offers a Master of Science degree in which there is an emphasis on applied mathematics.

By taking a significant number of graduate math courses as an undergraduate, it is possible to earn both a Bachelor of Science and a Master of Science degree in mathematics within five years of study. Detailed requirements for this option are available from the Department of Mathematics.

The majors mentioned above will serve as components of a liberal education, but each one also prepares the recipient for a career in business, industry, government or education. Further information about career opportunities is available in the department office. Persons planning a career in almost any field will find their opportunities for interesting and challenging positions enhanced by the study of mathematics. A person who develops the ability to formulate and solve quantitative problems will be able to attack many of the complex problems of society.

## MATHEMATICS

Mathematics has developed from attempts to find simple general laws governing the behavior of the phenomena we observe around us, phenomena as diverse as the motion of the planets, the evolution of biological systems and the movement of traffic.

These attempts have been remarkably successful, although many problems remain to be solved. The concepts involved are profound and exciting; their development and use require imagination and careful deductive reasoning.

Mathematics reveals hidden patterns that help us understand the world around us. Now much more than arithmetic and geometry, mathematics is a diverse discipline that deals with data, measurements, and observations from science, with inference, deduction, and proof; and with mathematical models of natural phenomena, of human behavior, and of social systems.

As a practical matter, mathematics is a science of pattern and order. Its domain is not molecules or cells, but numbers, chance, form, algorithms, and change. As a science of abstract objects, mathematics relies on logic rather than on observation as its standard of truth, yet employs observation, simulation, and even experimentation as means of discovering truth.

The special role of mathematics in education is a consequence of its universal applicability. The results of mathematics — theorems and theories — are both significant and useful; the best results are also elegant and deep. Through its theorems, mathematics offers science both a foundation of truth and a standard of certainty.

In addition to theorems and theories, mathematics offers distinctive modes of thought which are both versatile and powerful, including modeling, abstraction, optimization, logical analysis, inference from data, and use of symbols. Experience with mathematical modes of thought builds mathematical power — a capacity of mind of increasing value in this technological age that enables one to read critically, to identify fallacies, to detect bias, to assess risk, and to suggest alternatives.

Mathematics empowers us to understand better the information-laden world in which we live.

— Excerpts from *Everyone Counts: A Report to the Nation on the Future of Mathematics Education*  
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The purpose of the mathematics and applied mathematics majors is to acquaint the student with mathematical concepts; to provide the student with the tools needed to apply the concepts in other fields; and to continue to learn and develop new ideas.

A student primarily interested in the application of mathematical ideas in another field should elect the major in applied mathematics or mathematics and computer science. A student who is interested in some branch of mathematics itself, or who is considering graduate study in mathematics, should choose the mathematics major. A student considering a career as an actuary should consult the department for specific course suggestions. A student who is unsure about future plans should probably choose the mathematics major because of the greater flexibility it offers.

## MATHEMATICS EDUCATION

The Bachelor of Arts in Education major may be completed with either of two concentrations; one prepares the graduate for teaching mathematics on the secondary level, the other concentrates on the elementary level. Those who intend to pursue one of these concentrations must complete certain courses in calculus, linear algebra, discrete mathematics, statistics, number theory, geometry, history of mathematics, and computer science. Successful completion of these courses provides a good part of the training necessary for technical expertise in the classroom.

The elementary concentration emphasizes breadth in mathematics. Breadth of experience is important so that the teacher may expose elementary students to a wide variety of mathematical topics. The specialist in mathematics on the elementary level must be particularly skilled at transforming the material mastered in college to a form suitable for the level in question.

Secondary majors learn the methods of teaching mathematics in MATH 483; elementary majors learn such methods in MATH 381, 382, 383 and 491.

Students who wish to teach mathematics on the secondary level also can gain certification in mathematics by completing any one of the Bachelor of Science majors in mathematics, applied mathematics or mathematics-computer science. In addition to the requirements for the major, they are expected to complete these courses: MATH 302, MATH 360, MATH 419 and MATH 483.

Recommendation for teaching endorsement requires the completion of the major with a minimum grade point average of 2.50 in the courses required for the major. The state of Washington requires a minimum grade of C (2.0) or better for all courses used to meet major certification or endorsement requirements. To gain the Initial Teaching Certificate, students must also complete a program of studies in professional education, including student teaching. Early in their careers at Western, students should seek formal advisement on the appropriate program in education. It is essential that the interested reader consult the *Elementary Education* and *Secondary Education* sections of this catalog for further information.

## ACADEMIC PLACEMENT

Initial placement in most mathematics courses at Western is on the basis of the results of an appropriate placement test, except for students who have successfully completed at least one quarter of calculus in college. Mathematics placement tests are administered throughout the state of Washington each year, and both freshmen and transfer students who are residents in

Washington are advised to take the appropriate examination prior to arrival on campus. Full information on which test to take and how to take it is available from the admissions office or the mathematics department.

Students who have completed at least one year of high school calculus or at least one quarter of college calculus should consult a departmental advisor before registering.

Except by permission of the chair of the Department of Mathematics, a student may not receive credit for any of MATH 101, 106, 107, 112, 114, 115, 118, 156 or 157 if that course is completed after completion of any higher numbered course in this list or after completion of a course in calculus for which college credit has been received.

### ADVICE TO ENTERING STUDENTS

The Bachelor of Science degrees in mathematics, applied mathematics and mathematics-computer science are based on the following core:

- MATH 124, 125, 224, 226 (calculus)
- MATH 204, 304 (linear algebra)
- Either MATH 209 or MATH 302
- MATH 312 (proofs in elementary analysis)
- One of CSCI 139, 140, 141, MATH 207; M/CS majors should complete CSCI 141

The Bachelor of Arts-Secondary Education degree has the same core except for

- MATH 312 and requires both MATH 209 and MATH 302

These courses, except for MATH 312, represent the minimum that a student planning one of these majors should complete during the first two years. In addition, most students pursuing a Bachelor of Science degree in the department should complete MATH 225, the second quarter of multivariable calculus. A well-prepared student will be able to build a stronger program, possibly including some graduate-level courses in the senior year, by completing some 300-level work chosen under advisement in addition to the list above. In particular, MATH 331 (differential equations) will be suitable for many students.

Transfer students, especially those intending to enter Western with an Associate of Arts degree, should normally complete as much as possible of the core program above, certainly including the entire calculus sequence and linear algebra. Students should be aware that 200-level differential equations courses may not transfer as equivalent to MATH 331, and that certain third quarter calculus courses also may not transfer as equivalent to either MATH 224 or 226.

The Bachelor of Arts major in mathematics provides exposure to a wide range of courses but, relative to the Bachelor of Science major, has fewer requirements for courses in analysis and other upper-division courses. A Bachelor of Science major in mathematics is generally more appropriate than a Bachelor of Arts major in mathematics for students intending to pursue graduate studies in any mathematically intensive discipline.

Instructors in many courses require that students use a graphing calculator. Students should contact the department for recommendations before purchasing a calculator.

### DECLARATION OF MAJOR

Students who intend to complete a major in the department are urged to declare the major formally at an early point in their Western career so that a program of study can be planned in collaboration with a departmental advisor. This does not in any way decrease the opportunity to change plans, but does ensure an efficient program which is not subject to future catalog revisions.

### ACCELERATED BS-MS PROGRAM

By taking a significant number of graduate math courses as an undergraduate, it is possible to earn both a Bachelor of Science and a Master of Science degree in mathematics within five years of study. Detailed requirements for this option are available from the Department of Mathematics.

### ENROLLMENT PREFERENCE FOR MAJORS

The department will give enrollment preference for certain high-demand courses to its majors.

### ACADEMIC EXCELLENCE

The mathematics department offers two means of recognition for outstanding students. One, Graduation with Merit in Mathematics, is an award which recognizes outstanding scholastic achievement in courses required for the major. The second, Graduation with Distinction in Mathematics, is a program which rewards exceptional achievement in mathematics as evidenced by meeting all the requirements for Graduation with Merit and completing certain additional requirements detailed below. While Graduation with Merit is automatically conferred on all students who qualify, students must apply to the Chair of the Department of Mathematics to participate in the program for Graduation with Distinction in Mathematics.

Students interested in these programs should also inquire into the possibility of earning both a Bachelor of Science and a Master of Science degree in mathematics within five years of study. Detailed requirements for this option are available from the Department of Mathematics.

#### *Graduation with Merit*

To graduate with merit in mathematics, a student must complete one of the majors or combined majors offered by mathematics alone or by mathematics in cooperation with another department.

The student's program must include at least 32 quarter hours of mathematics or math-computer science courses taken at Western, including MATH 225, 304 and 312 and at least 23 approved credits at the 400 level or above. The cumulative GPA for mathematics and math-computer science classes taken at Western must be at least 3.6.

#### *Graduation with Distinction*

To graduate with distinction in mathematics, a student must meet all the requirements for graduation with merit in mathematics.

Furthermore, the student must successfully complete:

- A comprehensive examination covering MATH 124, 125, 224, 225, 226, 204, 331
- An approved senior project

The comprehensive examination should be taken no later than the junior year. This examination may be retaken if necessary, but must be passed no later than fall of the senior year and before beginning the senior project.

The senior project is subject to approval of the Undergraduate Committee and is undertaken under the direction of a faculty member. It includes some independent work, the preparation of a report and a colloquium presentation. The senior project constitutes a course at the 400 level and is letter graded with 4 credits applicable towards the major.

Students interested in graduating with distinction in mathematics should declare their interest to the chair of the Department of Mathematics at an early point in their career at Western in order to receive appropriate advice and guidance.

## MATHEMATICS

### INFORMATION

Those interested in the study of mathematics are welcome to write, phone or visit the Chair of the Department of Mathematics, Western Washington University, Bellingham WA 98225, phone 360-650-3785.

### MATHEMATICS FACULTY

**TJALLING J. YPMA** (1987) Chair and Professor. BSc, University of Cape Town; MSc, DPhil, Oxford University.

**EDOH Y. AMIRAN** (1989) Associate Professor. BA, University of Chicago; PhD, Massachusetts Institute of Technology.

**AMY ANDERSON** (2007) Assistant Professor. BS, Central Washington University; MA, University of Oregon; PhD, University of Washington.

**ARPAD BENYI** (2005) Associate Professor. BS, MS, West University of Timisoara, Romania; MA, PhD, University of Kansas-Lawrence.

**DONALD R. CHALICE** (1967) Associate Professor. BA, University of Wisconsin; MA, PhD, Northwestern University.

**VICTOR CHAN** (2001) Associate Professor. BA, Whitman College; MS, State University of New York-Stony Brook; MS, PhD, Iowa State University.

**BRANKO CURGUS** (1988) Professor. BS, MS, PhD, University of Sarajevo.

**RICHARD J. GARDNER** (1991) Professor. BSc, PhD, University College, London; DSc, University of London.

**TILMANN E.C. GLIMM** (2005) Assistant Professor. First Degree, Technische Universität, Berlin; MS, PhD, Emory University.

**DAVID A. HARTENSTINE** (2004) Assistant Professor. BA, University of Pennsylvania; PhD, Temple University, Philadelphia.

**NORA HARTSFIELD** (1984) Professor. BA, Humboldt State University; MA, PhD, University of California-Santa Cruz.

**ROBERT I. JEWETT** (1970) Professor. BS, California Institute of Technology; MS, PhD, University of Oregon.

**JERRY L. JOHNSON** (1984) Professor. BA, Augsburg College; MS, California Institute of Technology; MA, University of California-Los Angeles; PhD, University of Washington.

**MILLIE J. JOHNSON** (1991) Associate Professor. BS, University of Minnesota; MEd, University of Washington.

**STEPHEN R. MCDOWALL** (2001) Associate Professor. BS, MS, University of Canterbury, New Zealand; PhD, University of Washington.

**MICHAEL NAYLOR** (1999) Associate Professor. BS, Michigan State University; MS, PhD, Florida State University.

**ADAM NYMAN** (2008) Assistant Professor. BS, Massachusetts Institute of Technology; PhD, University of Washington.

**THOMAS T. READ** (1967) Professor. BA, Oberlin College; MA, PhD, Yale University.

**AMITES SARKAR** (2007) Assistant Professor. BA, PhD, Cambridge University.

**YUN-QIU SHEN** (1988) Professor. BS, University of Science and Technology of China; MS, PhD, Michigan State University.

**STEPHANIE A. TRENEER** (2008) Assistant Professor. BA, Whitman College; PhD, University of Illinois at Urbana-Champaign.

**JIANYING ZHANG** (2006) Assistant Professor. BS, MS, Tsinghua University, China; PhD, University of California-Santa Barbara.

### BACHELOR OF ARTS

#### *Major — Mathematics*

70 credits in mathematics plus 17-20 credits in supporting courses

- MATH 124-125 or 134-135 or 138
- MATH 204, 224, 226, 331, 341 or 441, 419 or 420
- NOTE:** The pair MATH 203 and 303 may be substituted for MATH 204 and 331
- One of CSCI 139, 140, 141, MATH 207
- NOTE:** If the supporting sequence from CSCI below is chosen, this requirement is fulfilled.
- Three courses from:
  - MATH 209, 302, 304, 312, 360

- Two courses from:
  - MATH 410; M/CS 335, 375, 435, 475
- Sixteen additional approved credits in mathematics or math-computer science, which includes completion of two of the following pairs:
  - MATH 303 or 331, together with one of: MATH 415, 430, 431, 432
  - Only one of the pairs from the above group can be used
  - MATH 341 and 342
  - MATH 401 and 402
  - MATH 441 and 442
  - M/CS 335 and 435
  - M/CS 375 and 475
- NOTE:** Courses counted toward the major in the preceding boxes do not count toward the 16 credits but can serve as part (or all) of the pair.
- One of the following sequences
  - PHYS 121, 122, 123
  - CHEM 121, 122, 123 (or 125, 126, 225)
  - CSCI 141, 145, 211, 241, 401
  - ECON 206, 207, 306 and one of 375, 470, 475

#### *Combined Major — Economics/Mathematics* 94-95 credits

This major is for students who wish considerable depth in both disciplines, and it is particularly recommended as preparation for graduate study in economics.

- ECON 206, 207, 303, 306, 307, 406 or 407, 475
- 16 additional credits in upper-division courses in economics, under prior departmental advisement: 8 of these 16 credits must be at the 400 level
- Take one Communication Focus (CF) course and complete the upper-division Writing Proficiency (WP-3 points) requirement. The CF course must be taken within CBE while the WP requirement can be met with courses from any of the combined major departments. These requirements can be completed as part of the above required and elective credits.
- MATH 124-125 or 134-135 or 138
- MATH 204, 224, 225, 226, 304, 331; 341-342 or 441-442
- NOTE:** The pair MATH 203 and 303 may be substituted for MATH 204 and 331
- M/CS 435
- One of CSCI 139, 140, 141, MATH 207

### BACHELOR OF ARTS IN EDUCATION

#### *Teaching Certification and Endorsement*

The BAE degrees below require completion of the professional secondary teacher preparation program in the Woodring College of Education. Recommendation for teaching endorsement normally requires completion of one of the above majors with a grade point of 2.50 or better in the required major courses. The state of Washington requires a minimum grade of C (2.0) or better for courses used to meet the endorsement requirements.

#### *Major — Mathematics — Elementary* 50 credits

This major must be accompanied by the professional preparation program in elementary education. See the *Elementary Education* section of this catalog for program admission, completion, and teacher certification requirements.

- MATH 124-125 or 134-135 or 138
- MATH 204, 207, 209, 302, 341, 360, 381, 382, 383, 419, 491

**Major — Mathematics — Secondary**

70 credits

This major must be accompanied by the professional preparation program in secondary education and leads to an endorsement in secondary mathematics. See the *Secondary Education* section of this catalog for program admission, completion, and teacher certification requirements.

- MATH 124-125 or 134-135 or 138
- MATH 204, 207, 209, 224, 226, 302, 331, 341, 360, 419, 483
- NOTE:** The pair MATH 203 and 303 may be substituted for MATH 204 and 331
- At least four courses selected from the following: MATH 304, 312, 401, 402, 410, 441, M/CS 375

**Minor — Mathematics — Secondary**

40 credits

This minor leads to endorsement in secondary mathematics when accompanied by the professional program in secondary education and a qualifying endorsement in another content area. See the *Secondary Education* section of this catalog for program admission, completion, and teacher certification requirements.

- MATH 124-125 or 134-135 or 138
- MATH 204, 207, 209, 302, 341, 360, 419, 483

**Combined Major — Chemistry/Mathematics — Secondary**

102-121 credits plus supporting courses in physics

This major must be accompanied by the professional education program in secondary education. This major meets the requirements for Washington state teaching endorsements in both chemistry and mathematics. See the *Secondary Education* section of this catalog for program admission, completion, and teacher certification requirements.

- CHEM 121, 122, 123, 333 (or 125, 126, 225)
- Option A or B:
  - A: CHEM 251 and 375
  - B: CHEM 351, 352, 353, 354; either 375 or 471-473
- CHEM 461, 462
- MATH 124-125 or 134-135 or 138
- MATH 204, 209, 224, 331, 360, 419, 483
- NOTE:** The pair MATH 203 and 303 may be substituted for MATH 204 and 331
- At least two of the following: MATH 207, 341, 410
- PHYS 121, 122, 123
- SCED 370, 481, 491

**Combined Major — Physics/Mathematics — Secondary**

106-107 credits

This major must be accompanied by the professional education program in secondary education. This major meets the requirements for Washington state teaching endorsements in both physics and mathematics. See the *Secondary Education* section of this catalog for program admission, completion, and teacher certification requirements.

- PHYS 121, 122, 123, 219, 223, 224, 225, 233, 322, 326, 391
- ASTR 315
- 10 additional credits of upper-division physics or astronomy courses, including 2-3 credits of PHYS 491, 492, ASTR 493
- MATH 124-125 or 134-135 or 138
- MATH 204, 209, 224, 331, 360, 419, 483
- NOTE:** The pair MATH 203 and 303 may be substituted for MATH 204 and 331.
- At least two of the following: MATH 207, 341, 410

- SCED 370, 481, 491

A cumulative GPA of at least 2.50, plus a minimum grade of C (2.0) or better in the individual courses, must be maintained in the courses required by the major.

**BACHELOR OF SCIENCE**

**Major — Mathematics**

70 credits in mathematics plus 17-20 credits in supporting courses

- MATH 124-125 or 134-135 or 138
- MATH 204, 224, 225, 226, 304, 312; 209 or 302
- No fewer than 31 approved credits in mathematics or math-computer science, including at least two of the following pairs:
  - MATH 303 or 331, together with one of: MATH 415, 430, 431, 432
  - Only one of the pairs from the above group can be used
  - MATH 341 and 342
  - MATH 401 and 402
  - MATH 421 and 422
  - MATH 441 and 442
  - M/CS 335 and 435
  - M/CS 375 and 475

At least 19 credits from 400-level courses in mathematics or math-computer science except MATH 483, and including at most one of MATH 419 or MATH 420.

*Supporting Courses:*

- One of CSCI 139, 140, 141, MATH 207
- NOTE:** If the supporting sequence from CSCI below is chosen, this requirement is fulfilled.
- One of the following sequences:
  - PHYS 121, 122, 123
  - CHEM 121, 122, 123 (or 125, 126, 225)
  - CSCI 141, 145, 211, 241, 401
  - ECON 206, 207, 306 and one of 375, 470, 475

Language competency in French, German or Russian is strongly recommended for those students who may go to graduate school.

**NOTE:** The pair MATH 203 and 303 may be substituted for MATH 204 and 331.

Students who are interested in the actuarial sciences should complete: MATH 441 and 442, M/CS 335 and 435, M/CS 375 and 475 as part of their major programs.

**Major — Applied Mathematics**

70 credits in mathematics plus 17-20 credits in supporting courses

- MATH 124-125 or 134-135 or 138
- MATH 204; 209 or 302; 224, 226, 304, 312, 331; 341-342 or 441-442
- NOTE:** The pair MATH 203 and 303 may be substituted for MATH 204 and 331
- One of CSCI 139, 140, 141, MATH 207
- NOTE:** If the supporting sequence from CSCI below is chosen, this requirement is fulfilled.
- M/CS 375 and 475
- One of the following concentrations:
  - Engineering Concentration: MATH 225; together with one of MATH 430 or 432; and 438
  - Operations Research Concentration: M/CS 335 and 435; MATH 410
- No fewer than 3 additional credits at the 400 level from MATH, M/CS, or CSCI 405 or 480
- One of the following sequences:
  - PHYS 121, 122, 123

## MATHEMATICS

- CHEM 121, 122, 123 (or 125, 126, 225)
- CSCI 141, 145, 211, 241, 401
- ECON 206, 207, 306 and one of 375, 470, 475

### Minor — Mathematics

34-35 credits

- MATH 124-125 or 134-135 or 138
- MATH 204, 224
- One of CSCI 139, 140, 141, MATH 207
- 12 credits of approved electives from MATH 209, 225, 226 and upper-division courses except MATH 381, 382, 383, 483, 491

### Combined Major — Mathematics/Computer Science

91 credits

- MATH 124-125 or 134-135 or 138
- MATH 204, 224, 226, 302, 312, 331; 430 or 432; 341 or 441; 304 or 401

**NOTE:** The pair MATH 203-303 may be substituted for MATH 204 and 331

- Three courses from M/CS 335, 375, 435, 475
- CSCI 141, 145, 211, 241, 245, 305, 401, 405
- 3 additional upper-division credits in mathematics or computer science as advised

### Combined Major — Biology/Mathematics

104-105 credits; biology Phase II status required for admission into 300- and 400-level biology courses for biology majors.

- BIOL 204, 205, 206, 321, 323, 325, 432
- MATH 124-125 or 134-135 or 138
- MATH 204, 224, 331, 341, 342, 432

**NOTE:** The pair MATH 203 and 303 may be substituted for MATH 204 and 331

- One of CSCI 139, 140, 141, MATH 207
- Plus 8 credits of approved upper-division electives from biology, math or math/computer science
- CHEM 121, 122, 123 (or 125, 126, 225); 251
- PHYS 121, 122

Faculty advisor: Merrill Peterson, Biology; Tilmann Glimm, Mathematics.

## GRADUATE STUDY

For a concentration leading to the Master of Science degree, see the *Graduate School* section of this catalog.

By taking a significant number of graduate math courses as an undergraduate, it is possible to earn both a Bachelor of Science and a Master of Science degree in mathematics within five years of study. Detailed requirements for this option are available from the Department of Mathematics.

## COURSES IN MATHEMATICS (MATH)

Courses numbered X37; X97; 300, 400; 417, 445 are described on page 35 of this catalog. (Courses in Mathematics-Computer Science are listed after the listings in Mathematics).

### 99 INTRODUCTORY ALGEBRA (0, 5 FOR FINANCIAL AID PURPOSES ONLY)

**NOTE:** This course fulfills 5 credits towards financial aid and veterans benefits requirements only. No credit will be allowed toward the graduation requirements of 180 credits. Prereq: None. Gain skill working with algebraic language and concepts using graphs, tables and algebraic expressions and equations in order to prepare for math 112. Develop problem solving abilities and understanding. Polynomials, exponents, roots, radicals, and linear equations and inequalities and their graphs. Pass/Fail grading. A TI-83 is recommended.

### 101 FUNCTIONS AND ALGEBRAIC METHODS FOR K-8 TEACHERS (5)

Prereq: suitable score on the Intermediate Math Placement Test or completion

of a college intermediate algebra course with a grade of C- or better and permission of instructor. Designed for prospective K-8 teachers. Emphasizes pattern recognition and generalization, building mathematical models and problem solving. Supporting topics include polynomials, linear and quadratic equations, inequalities, graphs, rational expressions and functions. Graphing calculators required. Cannot be counted toward majors or minors in mathematics or computer science.

### 106 QUANTITATIVE REASONING (4)

Develops abilities to understand quantitative information and make reasoned decisions using it. Focus is on reasoning and symbolic and quantitative models as they are commonly encountered in personal life, careers, and public issues.

### 107 MATHEMATICAL REASONING AND ITS APPLICATIONS (4)

Prereq: suitable score on the Intermediate Math Placement Test or at least C- in MATH 99, 106, 112, or a college intermediate algebra course. Reading quantitative information, reasoning, personal finance, data display and summary, assessing risk; quantitative decisions in life, careers, and public issues. Students interested in studying a single area of mathematics in detail should consider substituting a course from MATH 114, 118, 124, 156, 157 or 240. To take MATH 114, a student must take a math placement test or MATH 112.

### 112 FUNCTIONS AND ALGEBRAIC METHODS (5)

Prereq: suitable score on the Intermediate Math Placement Test or completion of a college intermediate algebra course with C- or better. Pattern recognition and generalization, building mathematical models and problem solving are emphasized. Supporting topics include polynomials, linear and quadratic equations, inequalities, graphs, rational expressions, radicals and functions. Graphing calculator required. Cannot be counted toward majors or minors in mathematics or computer science.

### 114 PRECALCULUS I (5)

Prereq: suitable score on the Intermediate Math Placement Test or at least C- in MATH 112. Data analysis, functions as mathematical models, functions and their graphs. Graphing calculators are required. Cannot be counted toward majors or minors in mathematics or computer science. Students needing math for GUR purposes only should consider MATH 107 instead of MATH 114.

### 115 PRECALCULUS II (5)

Prereq: At least C- in MATH 114. Data analysis, modeling, trigonometry, inverse functions. Graphing calculator required. Cannot be counted toward majors or minors in mathematics or computer science.

### 118 ACCELERATED PRECALCULUS (5)

Prereq: suitable score on the Intermediate or the Advanced Math Placement Test. Not open to students who have taken a lower numbered mathematics course at Western. Functions as mathematical models, functions and their graphs, inverse functions, trigonometry. Graphing calculator required. Cannot be counted toward majors or minors in mathematics or computer science.

### 119A TOPICS IN MATHEMATICS (VARIABLE)

Prereq: permission of instructor. A supplement to one or more math courses offered at the 100 level. Repeatable subject to permission of department.

### 119B TOPICS IN MATHEMATICS (VARIABLE)

Prereq: permission of instructor. A supplement to one or more math courses offered at the 100 level. Repeatable subject to permission of department. S/U grading.

### 124 CALCULUS AND ANALYTIC GEOMETRY I (5)

Prereq: suitable score on the Advanced Math Placement Test or at least C- in MATH 115 or 118. Average and instantaneous rates of change, interpretation, computation, and application of derivatives to optimization, rates, graphing, and antiderivative problems. Graphing calculator required.

### 125 CALCULUS AND ANALYTIC GEOMETRY II (5)

Prereq: MATH 124 or 134. Riemann sums and the definite integral, interpretation and application to area, volume, growth and decay, techniques of integration. Introduction to differential equations.

### 134 HONORS CALCULUS I (5)

Prereq: suitable score on the Advanced Math Placement Test or at least an A in MATH 115 or 118, and permission of instructor. Intended for particularly strong students. Average and instantaneous rates of change, interpretation, computation, and application of derivatives to optimization, rates, graphing, and antiderivative problems. Frequent writing assignments. Graphing calculator required.

**135 HONORS CALCULUS II (5)**

Prereq: MATH 124 or 134, and permission of instructor. Intended for particularly strong students. Riemann sums and the definite integral, interpretation and application to area, volume, growth and decay, techniques of integration. Introduction to differential equations. Frequent writing assignments.

**138 ACCELERATED CALCULUS (5)**

Prereq: one year of AP-level high school calculus and permission. Designed for entering freshmen who are thoroughly familiar with the computational aspects of single variable calculus. Students study selected topics from MATH 124 and 125 from a more conceptual point of view. Students who complete this course also receive five credits of advanced placement (unless previously received). Not open to students who have taken MATH 124 or 125. Offered fall quarter only. AP mathematics credit and MATH 138 are equivalent to MATH 124 and 125.

**156 ALGEBRA WITH APPLICATIONS TO BUSINESS AND ECONOMICS (4)**

Prereq: suitable score on the intermediate mathematics placement test or at least C- in MATH 112. Equations and inequalities, graphs and functions, exponential and logarithmic functions, mathematics of finance, systems of linear equations and matrices, systems of linear inequalities.

**157 CALCULUS WITH APPLICATIONS TO BUSINESS AND ECONOMICS (4)**

Prereq: suitable score on the advanced mathematics placement test or at least C- in MATH 156, MATH 114 or 118. Limits, rates of change, differentiation, graphing and optimization, integration, business applications, partial differentiation. MATH 124 may be substituted for MATH 157. Cannot be taken for credit by a student who has already completed another college-level calculus course.

**203 LINEAR ALGEBRA AND DIFFERENTIAL EQUATIONS I (4)**

Prereq: MATH 125 or 135 or equivalent. First course in the 203-303 sequence. A unified treatment of the material on elementary linear algebra and elementary differential equations covered in MATH 204 and 331. Together with MATH 303, is equivalent to MATH 204 and MATH 331.

**204 ELEMENTARY LINEAR ALGEBRA (4)**

Prereq: MATH 125 or 135; MATH 224 recommended. Systems of linear equations; matrices; the vector space  $R^n$ ; linear independence, bases, subspaces and dimension in  $R^n$ ; introduction to determinants and the eigenvalue problem; applications.

**205 LINEAR ALGEBRA WORKSHOP (1)**

Prereq: MATH 204 or concurrent. Elementary linear algebra projects on a computer. S/U grading.

**207 MATHEMATICAL COMPUTING (3)**

Prereq: Basic computer literacy (CSCI 101 or equivalent); MATH 125 or 135, and 204. Use of mathematical soft-ware such as Matlab and Mathematica. Elementary programming, numerical and symbolic computation, visualization and technical reporting in mathematical context.

**209 DISCRETE MATHEMATICS (4)**

Prereq: MATH 124 or 134 or 138. The logic of proofs, combinatorics, graph theory, and topics from recurrences and generating functions, set theory.

**217A TOPICS IN MATHEMATICS (1-4)**

Prereq: permission of instructor. A supplement to one or more math courses offered at the 200 level. Repeatable subject to permission of department.

**217B TOPICS IN MATHEMATICS (1-4)**

Prereq: permission of instructor. A supplement to one or more math courses offered at the 200 level. Repeatable subject to permission of department. S/U grading.

**220 VISUALIZATION IN MULTIVARIABLE CALCULUS (1)**

Prereq: MATH 224 or concurrent. Weekly lab projects emphasizing the creation and interpretation of computer-generated graphs and contour diagrams for functions of several variables. Problems are drawn from material being studied in MATH 224. S/U grading.

**224 MULTIVARIABLE CALCULUS AND GEOMETRY I (5)**

Prereq: MATH 125 or 135 or 138. Coordinate systems, curves and vectors in the plane and in space, partial derivatives, applications including optimization and motion, multiple integrals.

**225 MULTIVARIABLE CALCULUS AND GEOMETRY II (4)**

Prereq: MATH 224. Multiple integrals, line and surface integrals, gradient fields, Green's and Stokes' theorems.

**226 LIMITS AND INFINITE SERIES (4)**

Prereq: MATH 125 or 135 or 138. Formal treatment of limits of functions and sequences and of continuity, including a thorough training in constructing rigorous proofs of the epsilon-delta type. Convergence tests for infinite series. Radius of convergence, differentiation, and integration of Taylor series.

**240 INTRODUCTION TO STATISTICS (4)**

Prereq: suitable score on the intermediate mathematics placement test or at least C- in MATH 112. Descriptive statistics, basic ideas of probability, normal distribution, sampling, confidence intervals, hypothesis testing, contingency tables, and one-way analysis of variance. Use of a statistical software package. Cannot be counted toward any major in the Department of Mathematics.

**245 STATISTICS FOR ENGINEERING TECHNOLOGY (3)**

Prereq: MATH 115 or 118. Descriptive statistics, basic probability, discrete distributions, normal distribution, statistical methods useful in engineering.

**302 INTRODUCTION TO PROOFS VIA NUMBER THEORY (4)**

Prereq: MATH 125 or 135 or 138. The properties of integers, prime numbers, Euclidean algorithm, congruences. The student is expected to develop competence in proving basic results in number theory.

**303 LINEAR ALGEBRA AND DIFFERENTIAL EQUATIONS II (4)**

Prereq: MATH 203. Second course in the MATH 203-303 sequence. A unified treatment of the material on elementary linear algebra and elementary differential equations covered in MATH 204 and 331. Together with MATH 203, is equivalent to MATH 204 and MATH 331.

**304 LINEAR ALGEBRA (4)**

Prereq: MATH 204, 224. Orthogonality and orthogonal bases; linear transformations and the least squares problem; further study of eigenvalues and eigenvectors and their applications; abstract vector spaces and linear transformations.

**312 PROOFS IN ELEMENTARY ANALYSIS (4)**

Prereq: MATH 226 and either MATH 209 or 302; restricted to majors during Phase I of registration. Open and closed sets in the line and plane, sequences, least upper bound axiom, continuous functions and their properties. The student is expected to develop competence in proving basic theorems involving these concepts.

**321 MATHEMATICS FOR TECHNOLOGY (4)**

Prereq: MATH 125 or 135. A survey of topics from differential equations and the Laplace Transform. Designed especially for students majoring in engineering technology. Students may count only one of MATH 321 or MATH 331 toward any major or minor in the Department of Mathematics.

**331 ORDINARY DIFFERENTIAL EQUATIONS (4)**

Prereq: MATH 204; MATH 224 recommended or concurrent. First order equations, first order systems (primarily linear), applications and modeling, qualitative reasoning. First course in the 331-432 sequence.

**341 PROBABILITY AND STATISTICAL INFERENCE (4)**

Prereq: MATH 125 or 135 or 138. Probability, including combinatorial methods, discrete distributions and continuous distributions using integrals. Descriptive statistics and the use of a computer statistical package. Statistical inference, including confidence intervals and hypothesis testing.

**342 STATISTICAL METHODS (4)**

Prereq: MATH 341. Statistical techniques including chi square tests, simple and multiple linear regression, and one-way analysis of variance. Extensive use of a computer statistical package.

**360 EUCLIDEAN AND NON-EUCLIDEAN GEOMETRY (4)**

Prereq: MATH 125 or 135 or 138, 204 and either MATH 209 or 302. Metric development of Euclidean geometry and consideration of non-Euclidean geometries.

**381 TEACHING K-8 MATHEMATICS I (4)**

Prereq: suitable score on the Intermediate Math Placement Test or a grade of C or better in MATH 112 or a college intermediate algebra course, and any one of the following: ELED 370, 372, SPED 420, or ECE 391. Investigations of

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mathematical topics that focus on logical reasoning, number concepts, and number operations. Emphasis on problem solving, the use of manipulatives and computing technologies, remediation and resource materials, and optimal pedagogical techniques that help students learn quality mathematics. Not acceptable for any department major except BA/Ed-Elementary, and does not satisfy GUR mathematics requirement except for those who complete the BA/Ed-Elementary.

### 382 TEACHING K-8 MATHEMATICS II (4)

Prereq: a grade of C or better in MATH 381. Investigations of mathematics topics that focus on proportional thinking, measurement, and informal geometry. Emphasis on problem solving, the use of manipulatives and computing technologies, remediation and resource materials, and optimal pedagogical techniques that help students learn quality mathematics. Not acceptable for any department major except BA/Ed, Elementary, and does not satisfy GUR mathematics requirement except for those who complete the BA/Ed-Elementary.

### 383 TEACHING K-8 MATHEMATICS III (4)

Prereq: a grade of C or better in MATH 382. Investigation of mathematics topics that focus on probability and statistics. Emphasis on problem solving, the use of manipulatives and computing technologies, remediation and resource materials, and optimal pedagogical techniques that help students learn quality mathematics. Not acceptable for any departmental major except BA/Ed, Elementary, and does not satisfy GUR mathematics requirement except for those who complete the BA/Ed, Elementary.

### 401, 402 INTRODUCTION TO ABSTRACT ALGEBRA (4 EA)

Prereq: MATH 204 and either MATH 209 or 302; MATH 401 prerequisite to 402. Groups, rings, fields, field extensions, Galois Theory.

### 410 MATHEMATICAL MODELING (4)

Prereq: MATH 204 and 331 or 203 and 303; and 224. The construction and solution of mathematical models, using optimization, stability analysis, eigenvalue methods, probability and simulation.

### 412 MATHEMATICAL MODELING COMPETITION (1)

Prereq: permission of instructor. Preparation for participation in the national mathematics modeling competition. Repeatable, no maximum.

### 415 MATHEMATICAL BIOLOGY (4)

Prereq: MATH 224; either 204 and 331, or 203 and 303. An introduction to mathematical models in biology. Population models, Michaelis-Menten kinetics, models for neuron functioning, pattern formation. Mathematical topics: difference equations, dynamical systems, conservation equations, stochastic models.

### 419 HISTORICAL PERSPECTIVES OF MATHEMATICS (3)

Prereq: 12 credits of upper-division mathematics. History and development of mathematical thought from ancient to modern times. Philosophical, sociological and biographical perspectives.

### 420 TOPICS IN THE HISTORY AND PHILOSOPHY OF MATHEMATICS (3)

Prereq: MATH 312. Concentrated study of a topic or a closely connected group of topics associated with the history and philosophy of mathematics. Students are required to write a substantial expository paper.

### 421 METHODS OF MATHEMATICAL ANALYSIS I (4)

Prereq: MATH 312. Introduction to metric spaces, properties of functions on metric spaces, compactness and continuity. The student is expected to develop competence in proving basic theorems involving these concepts.

### 422 METHODS OF MATHEMATICAL ANALYSIS II (4)

Prereq: MATH 421. Analysis on the real line, including uniform convergence of series, using metric space notions. The student is expected to develop competence in proving theorems involving these concepts.

### 424 TOPICS IN ANALYSIS (4)

Prereq: MATH 422. Topics such as pointwise convergence of Fourier series, Gibbs phenomenon, Poisson summability, Dirichlet problem for the disc, Weierstrass approximation theorem. Repeatable with various topics.

### 430 FOURIER SERIES AND APPLICATIONS TO PARTIAL DIFFERENTIAL EQUATIONS (4)

Prereq: MATH 204 and 331 or 203 and 303; and 226. An introduction to

Fourier series and the Fourier transform; applications to boundary value problems including the wave and heat equations.

### 431 ANALYSIS OF PARTIAL DIFFERENTIAL EQUATIONS (4)

Prereq: MATH 204, 225, 226, 312, 331, or equivalent(s). Solutions for general first order and linear second order partial differential equations. Topics from characteristics; propagation of singularities; hyperbolic, and elliptic equations; Cauchy problem; Dirichlet problem; Green's function; Poisson formula; maximum principle.

### 432 SYSTEMS OF DIFFERENTIAL EQUATIONS (4)

Prereq: either MATH 204 and 331, or MATH 203 and 303. Forced second order equations, systems of nonlinear differential equations, applications.

### 438 INTRODUCTION TO COMPLEX VARIABLES (4)

Prereq: MATH 225, 226. Differentiation and integration of complex-valued functions; Cauchy integral theorem; calculations of residues.

### 441 PROBABILITY (4)

Prereq: MATH 204, 224 and 312. Discrete and continuous random variables, moment generating functions, multivariate distributions, survey of widely used distributions such as normal, chi-square, gamma, t and F distributions. Emphasis on the theoretical aspects of probability.

### 442 MATHEMATICAL STATISTICS (4)

Prereq: MATH 441 or equivalent. Limiting distributions, the Central Limit Theorem, statistical inferences such as confidence intervals, hypothesis testing and chi-square tests, maximum likelihood methods, sufficiency.

### 443 LINEAR STATISTICAL MODELS (4)

Prereq: MATH 441/541, and either MATH 342 or 442/542, or equivalent(s). Matrix algebra for linear models, multivariate normal distribution, quadratic forms, Gauss-Markov Theorem, estimation in full-rank and less-than-full-rank models, hypothesis testing in full-rank models.

### 483 METHODS OF TEACHING SECONDARY MATHEMATICS (4)

Prereq: at least two upper-division mathematics courses. Topics include pre-algebra, algebra, geometry, problem solving and resource materials.

### 490 SENIOR PROJECT (4)

Prereq: permission of the chair. Intensive study of an advanced topic in mathematics.

### 491 INTERNSHIP SEMINAR — TEACHING K-8 MATHEMATICS (2)

Prereq: a grade of C or better in MATH 383. Focus on issues and practices related to teaching K-8 mathematics, coordinated with the year-long K-8 classroom internship. Includes the use of ideas, theory, and lesson plans from the MATH 381-383 sequence in actual classroom settings, plus opportunity to assess and work with K-8 students on an individual, small group, and whole class basis. Not acceptable for any departmental major except BA/Ed, Elementary.

### 495 ACADEMIC OR INDUSTRIAL LEARNING AND RESEARCH EXPERIENCE IN MATH (1-4)

Prereq: 20 credits in Math above 100 level, and permission of department. Participation in a learning program, research project or internship in business, industry, a government agency or academic institution. Oral and written report required. Repeatable to a maximum of 8 credits. S/U grading.

## Graduate Courses

*Courses numbered 500; 517; 545; 597 are described on page 35 of this catalog. Admission to Graduate School or special permission required. See the Graduate School section of this catalog.*

### 502 ABSTRACT ALGEBRA (4)

Prereq: MATH 401 or equivalent. Rings, fields, field extensions, Galois Theory.

### 503 TOPICS IN ABSTRACT ALGEBRA (3)

Prereq: MATH 502 or equivalent. Topics based on the theory of groups and its applications. Repeatable with various topics.

### 504 ABSTRACT LINEAR ALGEBRA (4)

Prereq: MATH 304 or equivalent. Abstract vector spaces, linear transformations, spectral theory.

### 510 MATHEMATICAL MODELING (4)

Prereq: MATH 204 and 331 or 203 and 303; and 224. The construction

and solution of mathematical models, using optimization, stability analysis, eigenvalue methods, probability and simulation.

**511 ADVANCED MODELING (4)**

Prereq: MATH 331, permission of instructor. Exact and numerical techniques for the development and analysis of models of dynamic processes, including the construction and validation of models.

**515 MATHEMATICAL BIOLOGY (4)**

Prereq: MATH 224; either 204 and 331, or 203 and 303. An introduction to mathematical models in biology. Population models, Michaelis-Menten kinetics, models for neuron functioning, pattern formation. Mathematical topics: difference equations, dynamical systems, conservation equations, stochastic models.

**521 METHODS OF MATHEMATICAL ANALYSIS I (4)**

Introduction to metric spaces, properties of functions on metric spaces, compactness and continuity.

**522 METHODS OF MATHEMATICAL ANALYSIS II (4)**

Prereq: MATH 521. Analysis on the real line, including uniform convergence of series, using metric space notions.

**523 ADVANCED CALCULUS OF SEVERAL VARIABLES (4)**

Prereq: MATH 304 or equivalent, MATH 521. Parameterization, integration and changes of variables in Euclidean spaces.

**524 TOPICS IN ANALYSIS (4)**

Prereq: MATH 522. Topics such as pointwise convergence of Fourier series, Gibbs phenomenon, Poisson summability, Dirichlet problem for the disc, Weierstrass approximation theorem. Repeatable with various topics.

**525 TOPOLOGY (3)**

Prereq: MATH 521. Topological spaces, connectedness, compactness, product and quotient spaces, homotopy.

**527 REAL ANALYSIS (4)**

Prereq: MATH 522. Theory of Lebesgue measure and integration.

**528 FUNCTIONAL ANALYSIS (4)**

Prereq: MATH 522. Spaces of functions, linear functionals and their representation, applications.

**530 FOURIER SERIES AND APPLICATIONS TO PARTIAL DIFFERENTIAL EQUATIONS (4)**

Prereq: MATH 204 and 331 or 203 and 303; and 226. An introduction to Fourier series and the Fourier transform; applications to boundary value problems including the wave and heat equations.

**531 ANALYSIS OF PARTIAL DIFFERENTIAL EQUATIONS (4)**

Prereq: MATH 204, 225, 226, 312, 331, or equivalent. Solutions for general first order and linear second order partial differential equations emphasizing geometric properties and integral representations. Topics include characteristics; propagation of singularities; hyperbolic, elliptic, and parabolic equations; Cauchy problem; Dirichlet problem; Green's function; Poisson formula; maximum principle.

**533 ADVANCED ORDINARY DIFFERENTIAL EQUATIONS (3)**

Prereq: MATH 432 or equivalent, MATH 521. Existence and uniqueness of solutions, stability theory for nonlinear equations, bifurcation.

**535 NONLINEAR OPTIMIZATION (4)**

Prereq: MATH 204, 224, and one of CSCI 140 or 141 or MATH 207. Nonlinear programming with emphasis on basic theory (including Lagrange multipliers and the Kuhn-Tucker conditions), algorithms for numerical solution of problems, and applications. Introductory dynamic programming, with emphasis on applications and algorithms.

**538 COMPLEX VARIABLES (4)**

Prereq: MATH 226 or equivalent. Differentiation and integration of complex-valued functions, Cauchy integral theorem, residues.

**539 TOPICS IN COMPLEX ANALYSIS (3)**

Prereq: MATH 521, 538. Topics such as normal families, mapping properties of analytic functions, conformal mappings, fluid flow, Dirichlet and Neumann problems, Julia sets. Repeatable with various topics.

**541 PROBABILITY (4)**

Prereq: MATH 204, 224 and 312. Discrete and continuous random variables, moment generating functions, multi-variate distributions, survey of widely used distributions such as normal, chi-square, gamma, t and F distributions. Emphasis on the theoretical aspects of probability.

**542 MATHEMATICAL STATISTICS (4)**

Prereq: MATH 441 or equivalent. Limiting distributions, the Central Limit Theorem, statistical inferences such as confidence intervals, hypothesis testing and chi-square tests, maximum likelihood methods, sufficiency.

**543 LINEAR STATISTICAL MODELS (4)**

Prereq: MATH 441/541, and either MATH 342 or 442/542 or equivalent(s). Matrix algebra for linear models, multivariate normal distribution, quadratic forms, Gauss-Markov Theorem, estimation in full-rank and less-than-full-rank models, hypothesis testing in full-rank models.

**545 TOPICS IN PROBABILITY (3)**

Prereq: MATH 541. Topics from Markov and sequential decision processes, renewal theory, inventory theory, stochastic control, random arrival and service processes, waiting time, number in queue, bulk arrivals, networks, balking. Repeatable with various topics.

**560 TOPICS IN GEOMETRY (3)**

A study of one or more topics in geometry such as convex sets, polytopes, tilings, integral geometry or combinatorial geometry. Repeatable with various topics.

**562 DIFFERENTIAL GEOMETRY (4)**

Prereq: MATH 522. Geometry of curves, surfaces and manifolds.

**564 GRAPH THEORY (3)**

Basic properties of graphs, trees, Eulerian and Hamiltonian circuits, genera of graphs, algorithms, applications.

**566 TOPICS IN COMBINATORICS (3)**

Counting techniques, generating functions, coding, coloring and relations with probability theory. Repeatable with various topics.

**570 TOPICS IN OPTIMIZATION (4)**

Prereq: MATH 304 and 521. Topics taken from nonlinear programming, calculus of variations or the theory of optimal control. Repeatable with various topics.

**573 NUMERICAL LINEAR ALGEBRA (4)**

Prereq: MATH 304, ability to program. Norms; fundamental matrix types, transformations and factorizations; linear equations, linear least squares; rounding error, condition and stability; the algebraic eigenvalue problem (QR method).

**575 NUMERICAL ANALYSIS (4)**

Prereq: MATH 224, M/CS 375. Polynomial interpolation including splines, orthogonal systems of functions and least squares approximation; numerical differentiation and integration; solution of systems of nonlinear equations and unconstrained optimization.

**577 TOPICS IN NUMERICAL ANALYSIS (4)**

Prereq: M/CS 375 or MATH 573. Topics from numerical optimization, approximation, linear algebra, quadrature, and the solution of algebraic and differential equations. Repeatable with various topics.

**595 TEACHING ALGEBRA AND PRECALCULUS (2)**

Curriculum and instructional support for teaching the algebra and precalculus sequence. S/U grading.

**599 MATHEMATICS SEMINAR (1-3)**

Repeatable to a maximum of 4 credits.

**680 INTERNSHIP IN INDUSTRIAL MATHEMATICS (2-8)**

Prereq: MATH 510, 547, and 575 or equivalents. An internship in industry, government, or other organizations during which participants will work with people in the host organization on problems of a quantitative nature. Number of credits depends on time spent at the host organization.

**690 THESIS (VARIABLE CREDIT)**

Repeatable to a maximum of 4 credits. S/U grading.

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### **691 REQUIRED PROJECT (1 OR 2)**

Prereq: advancement to candidacy. Repeatable to a maximum of 2 credits. S/U grading.

### **COURSES IN MATHEMATICS-COMPUTER SCIENCE (M/CS)**

*Courses numbered X37; X97; 300, 400; 417, 445 are described on page 35 of this catalog. The courses listed below require background in both mathematics and computer science. The problems attacked in these courses cannot be solved without fruitful wedding of knowledge from both areas. In many of the upper-level computer science and math-computer science courses, majors have priority for admission.*

#### **335 LINEAR OPTIMIZATION (4)**

Prereq: MATH 204 and one of CSCI 140 or 141 or MATH 207. The optimization of linear functions subject to linear constraints. Linear programming, duality theory, sensitivity analysis, applications.

#### **375 NUMERICAL COMPUTATION (4)**

Prereq: MATH 204 and one of CSCI 140 or 141 or MATH 207. Computer arithmetic, solution of nonlinear equations and optimization in a single variable; matrix factorization; matrix iterative techniques.

#### **435 NONLINEAR OPTIMIZATION (4)**

Prereq: MATH 204, 224 and one of CSCI 140 or 141 or MATH 207. Nonlinear optimization with emphasis on basic theory (including Lagrange multipliers and the Kuhn-Tucker conditions), algorithms for numerical solution of problems, and applications. Introductory dynamic programming, with emphasis on applications and algorithms.

#### **475 NUMERICAL ANALYSIS (4)**

Prereq: MATH 224, M/CS 375. Polynomial interpolation including splines, orthogonal systems of functions and least squares approximation; numerical differentiation and integration; solution of systems of nonlinear equations and unconstrained optimization.