2005-2007 Undergraduate Catalog

UNDERGRADUATE STUDY AT UW-MADISON

REQUIREMENTS FOR UNDERGRADUATE DEGREES

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The University of Wisconsin-Madison sets minimum standards that must be met by all students pursuing an undergraduate degree. **Many departments and programs have requirements that exceed these basic requirements.** It is important that students become familiar with the specific requirements of the colleges and individual departments

and programs. The information in the following paragraphs provides general information about study at UW-Madison. Requirements may vary among the schools and colleges.

TOTAL DEGREE CREDITS

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To receive a bachelor's degree from UW-Madison, most students must earn a**minimum of 120 degree credits.** The total degree credits for some programs may exceed 120 degree credits. Students should consult with their college or department advisor for information on specific credit requirements. See Undergraduate Majors in this catalog.

EXAMS FOR DEGREE CREDIT

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Advanced Placement (AP), International Baccalaureate (IB), the College Level Examination Program (CLEP), the UW-Madison Advanced Placement Calculus Exam, and foreign language retroactive credit all offer the possibility of earning degree credit by exam. For more information on these exams, see the Admissions section.

RESIDENCE CREDIT

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Degree candidates are required to earn a **minimum of 30 credits in residence** at UW-Madison. "In residence" means *on the UW-Madison campus with an undergraduate degree classification.* Normally these credits are completed after earning the first 90 credits toward an undergraduate degree.

PROBATION

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Undergraduate students must maintain the minimum grade point average specified by the school or college. Not doing so can result in being placed on academic probation. Some programs require students to maintain a stated GPA higher than the minimum to remain in good standing.

GENERAL EDUCATION REQUIREMENTS

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The purpose of the General Education Requirements is to ensure that every graduate of the University of Wisconsin-Madison acquires the essential core of an undergraduate education that establishes the foundations for living a productive life, being a citizen of the world, appreciating aesthetic values, and engaging in lifelong learning in a continually changing world. For this reason, these core requirements provide for breadth across the humanities and arts, social studies, biological sciences, and physical sciences; competence in communication, critical thinking and analytical skills appropriate for a university-educated person; and investigation of the issues raised by living in a culturally diverse society.

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ACADEMIC CALENDAR

First Semester	2005-2006	2006-2007	2007-2008
Advising and orientation week	August 25 (R)	August 28 (M)	August 27 (M)
Labor Day	September 5 (M)	September 4 (M)	September 3 (M)
Instruction begins	September 2 (F)	September 5 (T)	September 4 (T)
Rosh Hashanah*	October 4 (T)	September 23 (S)	September 13 (R)
Yom Kippur*	October 13 (R)	Ocober 2 (M)	September 22 (S)
Thanksgiving recess	November 24-27 (R-N)	November 23-26 (R-N)	November 22-25 (R-N)
Last class day	December 15 (R)	December 15 (F)	December 14 (F)
Exams begin	December 16 (F)	December 16 (S)	December 16 (N)
Exams end	December 23 (F)	December 23 (S)	December 22 (S)
Commencement	December 18 (N)	December 17 (N)	December 16 (N)
Last day grades in	December 27 (T)	December 27 (W)	December 26 (W)

Second Semester	2005-2006	2006-2007	2007-2008
Advising and orientation week	January 9 (M)	January 16 (T)	January 14 (M)
Martin Luther King, Jr., Day	January 16 (M)	January 15 (M)	January 21 (M)
Instruction begins	January 17 (T)	January 22 (M)	January 22 (T)

Spring recess	March 11-19 (S-N)	March 31-April 8 (S-N)	March 15-23 (S-N)
Classes resume	March 20 (M)	April 9 (M)	March 24 (M)
Passover*	April 13 (R)	April 3 (T)	April 20 (N)
Good Friday*	April 14 (F)	April 6 (F)	March 21 (F)
Last class day	May 5 (F)	May 11 (F)	May 9 (F)
Exams begin	May 7 (N)	May 13 (N)	May 11 (N)
Exams end	May 13 (S)	May 19 (S)	May 17 (S)
Commencement weekend	May 12-14 (F-N)	May 18-20 (F-N)	May 16-18 (F-N)
Last day grades in	May 17 (W)	May 23 (W)	May 21 (W)

Summer Sessions	2005-2006	2006-2007	2007-2008
Memorial Day	May 29 (M)	May 28 (M)	May 26 (M)
3-week session	May 30 (T)	May 29 (T)	May 27 (T)
8-week session	June 19 (M)	June 18 (M)	June 16 (M)
8-week session ends	August 11(F)	August 10 (F)	August 8 (F)

Notes

*In accordance with Faculty Document 488a, faculty are asked not to schedule mandatory exercises on these dates.

Days: T Tuesday; R Thursday; S Saturday; N Sunday.

The Academic Calendar is subject to change.

File last updated: June 10, 2005

2005-2007 Undergraduate Catalog

COLLEGE OF LETTERS AND SCIENCE

MATHEMATICS

213 Van Vleck Hall, 480 Lincoln Drive, Madison, WI 53706; 608/263-3053; recept@math.wisc.edu; www.math.wisc.edu

Professors Adem, Ahern, Angenent, Assadi, Bach, Beck, Benkart, Bolotin, Boston, Brualdi, Cai, Dickey, Griffeath, Isaacs, Jin, Johnson, Kuelbs, Kunen, Kurtz, Lempp, Milewski, Millar, Miller, Nagel, Oh, Ono, Orlik, Passman, Rabinowitz, Ram, Robbin, Ron, Rosay, Ruan, Seeger, Slemrod, Smith, Terwilliger, Tzavaras, Uhlenbrock, Wainger, Walleffe, Wilson; Associate Professors Borisov, Chen, Feldman, Gong, Ionel, Kiselev, Klemm, Propp, Seppalainen, Yang; Assistant Professors Ben-Yaacov, Caldararu, Denisov, Ellenberg, Ionescu, Mitchell

Undergraduate advisor, honors advisor: Gloria Mari Beffa, 309 Van Vleck, 263-1634; maribeff@math.wisc.edu

Faculty diversity liaison: David Griffeath, griffeat@math.wisc.edu

Mathematics is classified with both the humanities and the sciences. Its position among the humanities is based on the study of mathematics as one of the liberal arts for more than two thousand years. Still an expanding subject, mathematics offers more new and challenging frontiers than at any time in its long history—with many new fields, requiring new techniques and ideas for exploration.

The place of mathematics among the sciences is well founded. The natural sciences have invariably turned to mathematics for techniques needed to explore the consequences of scientific theories. In the last few decades social scientists have increasingly found higher mathematics of value in their training and research.

Although job opportunities have varied with the changes in the national economy, in recent years graduating math majors have obtained employment in a variety of jobs in

business, industry, and governmental agencies and also have obtained teaching positions at the secondary school level (such teaching positions normally require teaching certification). Others have continued their educations at the graduate level in mathematics and other fields. Departments in a variety of fields which use mathematics, including some in the social and biological sciences as well as in engineering and the physical sciences, are interested in attracting math majors into their graduate programs. Math PhDs obtain academic positions at the college and university level and nonacademic positions entailing consulting and research. The math major requirements are flexible enough to allow preparation for various goals.

Students interested in mathematics should also consider related programs offered by the computer sciences department, the statistics department, the School of Business, the School of Education, and the Applied Mathematics, Engineering and Physics major.

REQUIREMENTS FOR THE MAJOR

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A detailed description of the mathematics major program is in the *Guidebook for Undergraduate Math Majors* available in 207 Van Vleck Hall.

Acceptance. To be accepted as a major in mathematics a student must complete Math 221, 222, and 234 (or equivalent sequence) with a grade point average of 2.5 or better in this sequence. However, a somewhat higher grade point average is advisable. Soon after completing Math 234, math majors should have their math advisors complete the Major Declaration Form and, perhaps later, but by the beginning of the senior year, the Math Major Approval Form. The former indicates acceptance into the major and the latter specifies which major requirements the student will satisfy. Majors are assigned math advisors through the mathematics undergraduate program secretary in 207 Van Vleck Hall.

The student chooses one of two options. Since both options allow considerable flexibility, students should plan their programs with the advice of their math advisors. Indeed, those following Option II must have their programs formally approved by their mathematics advisors. Option II emphasizes the applications of mathematics, and those following Option I are also encouraged to take courses in other departments which involve the application of mathematics.

All students must complete the L&S requirement of at least **15 credits of upper-level work in the major** completed in residence. All math courses above 306 (except for Math 425) count toward this requirement.

OPTION I

Seven mathematics courses numbered above 306, excluding 425 and 490.

These seven courses must include (1) 320 or 340 or 341 or 375 (341 is strongly recommended, 320 is not recommended although accepted in some circumstances), and (2) three courses numbered above 500 including at least two of the following: 521, 541, 551. Students are strongly recommended to take either 341 or 421 before advancing

into courses numbered above 500.

It is recommended that **students preparing for graduate work in mathematics** satisfy (a), (b), and (c) below.

(a) 341, 521, 522, 541, 542

(b) 551 or 561

(c) Two other courses, to complete a varied program

Students who plan to enter a mathematics Ph.D. program should acquire a **reading knowledge of at least one foreign language** as early as possible. For mathematics study, the most useful languages are French, German, and Russian.

OPTION II

(For students interested in a particular area of application)

(a) Four courses in some area of application of mathematics, including at least three courses at the intermediate or advanced level, selected with the approval of the student's mathematics advisor; and

(b) Six mathematics courses numbered above 306, excluding 425 and 490, selected with the approval of the student's mathematics advisor, including 320 or 340 or 341 and two courses numbered above 500.

No courses may be used to fulfill both (a) and (b). Approval of a program under Option II will be required before a significant part of the program is completed and changes in the approved program will require prior consent of the mathematics advisor. The program is formally approved on the Math Major Approval Form, a copy of which is sent to the Office of the Registrar.

Sample programs for Option II are in the *Guidebook for Undergraduate Math Majors.* The areas of application in these sample programs include: computer sciences, chemistry, physics, statistics, actuarial mathematics, finance, meteorology, economics, ecology, genetics, forestry, business, and engineering.

HONORS IN THE MAJOR

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Honors majors must successfully complete with grades of B or better the following mathematics courses: 521H, 522H, 541H, 542H, or their equivalents, and at least two more courses above 500 (usually 551 will be one of the courses) chosen in consultation with the honors advisor. They must also complete a "cap-stone" project consisting of Math 681-682 (Senior Honors Thesis), or a sequence of two mathematics courses numbered above 700, chosen with the approval of the honors advisor. Further, the student should request candidacy for the honors program from the honors advisor by the start of the junior year. At least one of the two sequences 521-522, 541-542 must

be completed by the end of the student's junior year.

Before choosing the honors thesis (681-682) option, the student must consult with the honors advisor and a faculty thesis advisor to prepare for and complete a suitable thesis project; the student who elects to complete the alternative sequence of graduate-level courses should give a substantial report on his/her progress in the sequence. The student must complete the above program with a cumulative GPA in the major of at least 3.3. Information on research opportunities for undergraduates can be found at www.math.wisc.edu/undergrad.

Students should check with the department honors advisor at least once a year, to report progress and to seek guidance about planning an Honors in the Major curriculum that reflects their special interests.

William Lowell Putnam Competition. This is an annual international mathematics competition for undergraduates, based on originality and cleverness rather than sophisticated mathematical knowledge. Students interested in preparation for this examination may join the Putnam Club. The club is run by Prof. Passman and Prof. Borisov. The organizer of the club selects a team to represent UW-Madison.

TEACHER PREPARATION

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Students interested in teaching mathematics at the primary or secondary level should consult the School of Education section in this catalog.

GENERAL LEVELS OF COMPETENCE IN MATHEMATICS

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Three years of mathematics preparation in high school (algebra, geometry, and a third year unit in algebra, trigonometry, analytic geometry, or calculus) satisfies the minimum requirement in mathematics for admission to UW-Madison. The Department of Mathematics strongly recommends that students take four years of mathematics preparation at the high school level. Students with only three years of mathematics preparation will be at a competitive disadvantage to other students for admission.

Students who wish to choose a major that requires calculus (e.g., the physical and biological sciences, business, economics, engineering, some majors in agricultural and life sciences) will be at a disadvantage in college without a rigorous college-preparatory *mathematics* sequence in high school. Such a sequence should emphasize both understanding and problem-solving in algebra, geometry, and trigonometry, and should include substantial work in algebraic manipulation and equation-solving **without the use of calculators**, algebraic and geometric proofs, mathematical modeling, trigonometric manipulation and equations, hand-graphing of functions, and 3-dimensional geometry.

Admission to one's first mathematics course at UW-Madison is based on the mathematics placement exam. For a sample of the types of questions that appear on the

placement exam, see www.math wisc/undergrad. It is strongly suggested that students look at this collection of mathematics problems for an indication of the skills, knowledge, and understanding expected from a rigorous high school mathematics curriculum.

Four levels of pre-university competence are specified below. (Levels of competence, except superior, are measured by the placement examinations described below.) Prospective students of mathematics, science, and engineering should achieve advanced mathematical competence (Levels 3a and 3b) before coming to the university so that they may enroll in Math 221 at the start of the freshman year. Students with only minimum and intermediate mathematical competence are strongly advised to remove this deficiency by independent study through the UW-Extension or by enrolling for the summer session preceding the freshman year.

Students must be able to apply all of the listed competencies in problem solving situations, and to select and combine techniques appropriate to the problem.

1. Minimum mathematical competence. From algebra and arithmetic: an understanding of the axioms that underlie arithmetic, the decimal system and its use in calculation, and the definition and elementary properties of rational numbers; basic algebraic skills, including special products, factoring, positive integral exponents, and the manipulation of algebraic fractions; setting up and solving linear equations and inequalities; from geometry: axioms, theorems, and proofs of theorems concerning straight lines, triangles, and circles; graphing of linear equations and interpretation of systems of two linear equations; measurement formulas for the perimeter, circumference, area, and volume of common two- and three-dimensional figures.

2. Intermediate mathematical competence. The competencies of Level 1, together with: equations, laws of rational exponents, and radicals; additional topics in factoring; zero product rule; setting up and solving quadratic equations; complex numbers; algebra of polynomials and rational expressions; setting up and solving simultaneous linear equations and inequalities; graphing, including linear and quadratic polynomials; definition and application of absolute value and of scientific notation; definition and elementary properties of logarithms.

3a. Advanced mathematical competence—algebra. The competencies of Levels 1 and 2, together with: functions: definition, domain, range, algebraic combinations, composition, inverse, symmetries, translations, graphs; theory of polynomial equations, including the remainder and factor theorems; solution of simultaneous linear equations; equivalent and partially equivalent equations and systems of equations; equations solvable by linear and quadratic techniques; exponential and logarithmic functions, equations, and inequalities; nonlinear inequalities; analytic geometry of conic sections; representation of plane curves and regions by equations or inequalities; sequences, sums, and series, including arithmetic and geometric sequences and series; mathematical induction.

3b. Advanced mathematical competence—trigonometry. The competencies of Levels 1 and 2, together with: functions: definition, domain, range, algebraic combinations,

composition, inverse, and graphs; trigonometric functions of a real number including their basic properties and graphs; trigonometric equations and identities; geometric significance of the trigonometric functions and elementary applications; polar form of complex numbers and DeMoivre's Theorem.

4. Superior mathematical competence. Some high schools find it possible to offer additional topics to able, well-prepared students who have already achieved advanced mathematical competence. For example, courses in probability and statistics, analytic geometry, number theory, calculus, or discrete mathematics are suitable for these high school students.

Advanced placement credit. A student who has completed a substantial calculus course in high school may earn university degree credit for Math 221 or for 221 and 222 by one of the following: (1) the College Board calculus advanced placement exam; (2) the math department calculus credit by examination exam; or (3) advanced placement tests given in conjunction with calculus courses at certain Wisconsin high schools.

PLACEMENT

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Each entering student (freshman or transfer student not having transfer credit for a specific UW mathematics course) who will take Mathematics 95, 101, 112, 113, 114, 141, 171, 210, 211, 221, or 275 is required to take the placement examinations in mathematics before enrolling in any of these courses. Placement in a course is not guaranteed on the basis of the high school record; placement in the course appropriate to the student's needs and competence will be made by the Department of Mathematics on the basis of placement scores.

Expected levels and courses. A student with three years of high school mathematics may possibly achieve Intermediate Competence and be placed in Math 112, 113, 114, or 171. A student with four years of high school mathematics may possibly achieve Advanced Competence and be placed in Math 210, 211, 221, or 275. Students with three or four years of high school mathematics who do not achieve these competencies will be placed in lower level courses. These achievements are not guaranteed since it depends on the quality of the courses taken in high school.

Lower-level mathematics. Students may be placed in Math 95 if the ACT (or SAT) math scores and the mathematics placements scores are low. Math 95 does not carry degree credit. L&S students whose mathematics placement test scores place them in Math 95 must complete that course or a higher-level mathematics course by the time the 30th degree credit is earned.

Enrollment information. The enrollment system checks for the appropriate math placement scores and the course prerequisites for the following Math courses: 95, 101, 112, 113, 114, 141, 171, 210, 211, and 221. The system will also check for the prerequisites and appropriate student classification for Math 130, 131 and 132. In addition, students will need math department authorization to enroll in Math 275, 276,

298, 375, or 376.

Department policy regarding a D grade. A student should repeat on a refresher basis a math course in which a grade of D is earned and which serves either as a prerequisite to another course or which satisfies a given requirement. A grade of D commonly signifies some achievement but usually denotes a weak foundation upon which to build subsequent course work.

SATISFACTION OF GENERAL EDUCATION REQUIREMENTS

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The course Math 141 or any 3-credit mathematics course numbered 112 or above is sufficient to satisfy the Quantitative Reasoning-Part A General Education requirement. Students may be exempted from Part A by high school course work or placement tests. Any 3-credit mathematics course numbered 200 or above is sufficient to satisfy the Quantitative Reasoning-Part B General Education requirement.

Students who first matriculated at a college or university before May 20, 1996, should consult their DARS report and major advisor for information regarding L&S requirements for Basic Composition and English Proficiency in the Major.

COURSES

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Courses are normally offered according to the following schedule; however, changes may be necessary because of staffing difficulties or low enrollment.

Every semester: 112, 113, 114, 130, 131, 132, 141, 210, 211, 213, 221, 222, 234, 298, 303, 319, 320, 321, 322, 340, 341, 421, 431, 441, 461, 475, 521, 541, 551, 632, 681, 682, 691, 692, 699;

Every first semester: 95, 171, 275, 309, 375, 415, 443, 473, 525, 567, 571, 623;

Every second semester: 101, 217, 231, 276, 310, 331, 371, 376, 435, 519, 522, 542, 561, 629;

Second semester, even years: 635, 552.

LOWER-LEVEL MATH

Note that Math 95 does not carry degree credit but counts 3 credits for determining fees and a student's semester study load. L&S students whose mathematics placement test scores place them in Math 95 must complete that course or a higher-level mathematics course by the time the 30th degree credit is earned.

95 Fundamental Mathematical Skills. I. 3 cr. Covers the fundamental mathematics necessary both as survival skills in daily life and as tool for success in college. Includes arithmetic procedures and their applications. Intended for students fulfilling the remediation requirements in mathematics. P: Remedial status as determined by the University; does not count for degree credit. Open to Fr.

ELEMENTARY

Note on Math 130, 131, and 132: Courses 130, 131, 132 are designed for future teachers and are open only to students in the School of Education and in the School of Human Ecology. These courses may not be used for satisfaction of degree requirements within the College of Letters and Science.

101 Intermediate Algebra. II; 3 cr (E). Real numbers, linear equations and inequalities, integral and fractional exponents, polynomials and their arithmetic, polynomial equations and equations with fractional exponents, quadratic formula and completing the square, systems of two linear equations, graphing (linear and other basic equations, and inequalities), problem solving using algebra and graphs. P: Minimum math comp (1 unit ea HS alg & geom) & satisfactory placemt scores. Open to Fr. Stdts may not receive cr for both Math 99 & 101, nor for both Math 100 & 101.

112 Algebra. I, II, SS; 3 cr (q-E). Polynomial equations, remainder and factor theorems, functions, graphs of functions, simultaneous linear equations, logarithm and exponential functions, sequences and series, mathematical induction, binomial theorem. P: Intmed math comp (usually 3 units of HS math) & suitable placement scores, or Math 100 or 101. Open to Fr. Stdts may not receive cr for both Math 112 & 114.

113 Trigonometry. I, II, SS; 2 cr (E). Graphs, properties and geometric significance of trigonometric functions of a real variable, trigonometric equations and identities, applications, trigonometric form of complex numbers, DeMoivre's theorem. P: Adv Math comp-algebra & suitable placement scores, or completion of Math 112. Stdts may not receive cr for both Math 113 & 114. Open to Fr.

114 Algebra and Trigonometry. I, II; 5 cr (q-E). Covers Math 112 and Math 113. Not recommended for students with less than an AB in Math 100 or 101. P: Intmed math comp (usu 3 units HS math) & suitable plct scores, or Math 100 or 101. Open to Fr. Stdts may not receive cr for both Math 112 & 114 nor for both 113 & 114.

130 Arithmetical Problem Solving. I, II; 3 cr (q). This course emphasizes problem solving and mathematical writing. Topics will be chosen from: rational numbers; decimals; logic and set theory; place value; scientific notation; number theory; functions and relations; exponentiation; algebra. P: Open to Fr. Intermed math comptnce (usually 3 units HS math)&placemnt score,or Math 100 or 101. Does not count toward degree req in L&S. Open only to stdts in Educ & SoHE.

131 Geometrical Inference and Reasoning. I, II; 3 cr. Discovery, conjecture, and proof through geometric explorations in the following areas: lines; polygons; formal constructions; tesselations; polyhedra; symmetry; rigid motions; lengh; area and volume. P: Math 130 or cons inst. Open to Fr. Does not count toward degree req in L&S. Open only to stdts in Educ & Frcs.

132 Mathematical Models. I, II; 2 cr (r). Developing and using mathematical models to solve problems. (1) Using equations and algebraic and analytic tools; (2) probabilistic reasoning and descriptive statistics. P: Math 130 & 131, or cons inst. Open to Fr. Does

not count toward degree in L&S. Open only to stdts in Educ & Frcs.

141 Quantitative Reasoning and Problem Solving. I, II; 3 cr (q-E). Quantitative reasoning for students who need to satisfy part A of the Quantitative Reasoning requirement and prepare for Qr-B courses, but do not want to continue in the calculus sequence. P: Min math competency & satisfactory placement scores. Open to Fr.

171 Calculus with Algebra and Trigonometry I. I; 5 cr (q-E). Topics in algebra, trigonometry and precalculus are integrated with elementary differential calculus. Part of a 2-semester sequence with Math 217; these two courses together are equivalent to Math 114 and 221. P: Intermed math comp (usually 3 units HS math) & suitable placement scores, or Math 101. Open to Fr.

198 Directed Study. SS; 1-3 cr (E).

INTERMEDIATE AND ADVANCED

Calculus Sequences. The Math 221-222 sequence is the first two semesters of the standard three-semester calculus sequence, completed with 234, which is normally required for all higher level math courses and should be taken by those preparing for major study in mathematics, the physical sciences, computer sciences, or engineering. It is also recommended for students in the social and life sciences who may want a more substantial introduction to calculus than is offered in the Math 211-213 sequence. Note that some biological sciences and economics programs require Math 221-222. The Math 211-213 sequence does not prepare the student for higher-level mathematics courses and does not provide adequate math background for some courses in related fields. Transferring from the 211-213 sequence into the 221-222-234 sequence is usually quite awkward. Math 211 is not adequate preparation for Math 222 and students may not earn credit for both Math 211 and 221; students may not earn full degree credit for both Math 213 and 222 or for both 213 and 234.

The sequence Math 171-217 is offered to provide a single sequence integrating the pre-calculus material of Math 114 with the content of Math 221. The honors calculus sequence, Math 275-276, is offered to provide a more rigorous presentation of standard calculus topics covered in Math 221-222.

Pre-Business Mathematics Requirements. For many majors in the School of Business, Math 210 and 211 or 210 and 221 satisfy this requirement. However some business majors require the Math 221-222 sequence or Math 210, 211, 213 or Math 210, 221, 213. Interested students should obtain more detailed information from the School of Business.

Courses that count toward the 15 credits of upper-level work in the major: Mathematics courses numbered above 306 (except for Math 425) taken in residence count toward this requirement.

Honors Courses. In advanced mathematics courses, honors sections or sections in which honors credit is available normally will be offered in the following rotation: Sem I: 341!, 521!, 541!; Sem II: 341!, 522!, 542!. Math 681 and 682 are taken for honors

credit. In addition, students may enroll for honors credit in most 4XX, 5XX and 6XX level courses, as denoted in the *Timetable* with "%," but he/she will need to reach an agreement with the instructor as to which extra work the student will be asked to complete. A graduate course will automatically carry honors credit.

Admission to honors courses. In order to be admitted to an honors section or to enroll for honors credit a student must have a 3.5 average in previous mathematics courses numbered 221 and above. A student is not required to be in the honors program nor to be an honors major in order to enroll in an honors section except for Math 681 and 682. Students will need math department authorization to enter the sequence Math 275, 276, 375, 376.

210 Topics in Finite Mathematics. I, II, SS; 3 cr (r-N-I). Topics in finite mathematics including elementary matrix algebra, linear programming, introduction to probability, and mathematics of finance. Students planning to take both Math 210 and Math 211 are advised to take Math 210 first. Primarily for students in social and biological science and prebusiness. Students preparing for advanced study in mathematics should take Math 221-222-223 rather than Math 210-211-213. P: Adv math competency—algebra and suitable placement scores or Math 112 or 114. Open to Fr.

211 Calculus. I, II, SS; 5 cr (r-N-I). Essential concepts of differential and integral calculus; trigonometric, exponential and logarithmic functions; functions of several variables. Primarily for students in social and biological science and prebusiness. Students preparing for advanced study in mathematics should take Math 221-222-223 rather than Math 210-211-213. P: (I)Adv math comp-alg&suitable plct scores, or Math 112 & (II)Adv math comp-trig&suitable plct scores, or Math 113; or Math 114. Open to Fr. May not rec cr for both Math 211 & 221.

213 Calculus and Introduction to Differential Equations. I, II; 3 cr (r-N-I). Techniques of integration, multiple integrals, infinite sequences and series, first order differential equations, two-dimensional systems of differential equations, difference equations, with models from and applications in business and the social and biological sciences. P: Math 211 or 221. Stdts may not receive full degree cr for both Math 222 and 213 or both Math 223 and 213 or both Math 234 and 213.

217 Calculus with Algebra and Trigonometry II. II; 5 cr (r-N-I). Continuation of Math 171. Topics in algebra, trigonometry and precalculus are integrated with elementary differential calculus. Completion of Math 217 implies completion of 221. P: Math 171. Open to Fr.

221 Calculus and Analytic Geometry. I, II, SS; 5 cr (r-N-I). Introduction to differential and integral calculus and plane analytic geometry; applications; transcendental functions. P: (I)Adv math comp-alg&suitable plct scores, or Math 112 & (II) Adv math comp-trig&suitable plct scores, or Math 113; or Math 114. Open to Fr. May not rec cr for both Math 211 & 221.

222 Calculus and Analytic Geometry. I, II, SS; 5 cr (r-N-I). Techniques of integration,

first order ordinary differential equations, conic sections, polar coordinates, vectors, two and three dimensional analytic geometry, infinite series. P: Math 221. Stdts may not receive full degree cr for both Math 222 & 213. Open to Fr.

231 Introduction to Probability for Biologists. Irr.; 2 cr (N-I). Introduction to probability, random var-iables, density functions, probability distribution of functions, mean and variance with applications in genetics and other areas of biology. P: Math 221 or 211. Open to Fr.

232 Introduction to Dynamical Systems for Biologists. Irr.; 3 cr (N-I). Elementary differential equations and difference equations studied from a qualitative point of view with examples and applications in the biological sciences. P: Math 221 or 211. Open to Fr.

234 Calculus—Functions of Several Variables. I, II, SS; 3 cr (N-I). Introduction to calculus of functions of several variables; calculus on parameterized curves, derivatives of functions of several variables, multiple integrals, vector calculus. P: Math 222. Stdts may not receive cr for both Math 223 & Math 234.

240 Introduction to Discrete Mathematics. (Cross-listed with Comp Sci) I, II; 3 cr (N-I). Basic concepts of logic, sets, partial order and other relations, and functions. Fundamental principles of counting. Basic algebraic structures: modulo arithmetic, group, ring, and field structures, Boolean algebra. Introduction to graph theory: trees, depth first search, matching, max-flow min-cut, and other optimization algorithms. Applications. P: Math 221.

275 Topics in Calculus I. I; 2-5 cr (r-N-I). Topics in first semester calculus. P: Open to Fr & cons inst.

276 Topics in Calculus II. II; 2-5 cr (r-N-I). Topics in second semester calculus. P: Math 275 or cons inst.

298 Directed Study in Mathematics. I, II; 1-3 cr (I). P: Cons inst. Open to Fr.

303 Theory of Interest and Life Insurance. (Cross-listed with Act Sci) II; 3 cr (N-I). Application of calculus to compound interest and insurance functions; interest compounded discretely and continuously; force of interest function; annuities payable discretely and continuously; bonds and yield rates; life tables, life annuities, single and annual premiums for insurance and annuities; reserves. P: Math 234 or con reg, or cons inst.

309 Introduction to Mathematical Statistics. (Cross-listed with Stat) I; 4 cr (N-A). Probability and combinatorial methods, discrete and continuous, univar-iate and multivariate distributions, expected values, moments, normal distribution and derived distributions, estimation. P: For majors in math and stats, Math 223 or 234.

310 Introduction to Mathematical Statistics. (Crosslisted with Stat) II; 4 cr (N-A). Unbiased estimation, maximum likelihood estimation, confidence intervals, tests of hypotheses, Neyman-Pearson fundamental lemma, likelihood ratio test, applications to

general linear model and analysis of variance, categorical data analysis, nonparametric methods. P: For majors in Math and Stat, Math 309 or Stat 309.

319 Techniques in Ordinary Differential Equations. I, II, SS; 3 cr (N-A). Review of linear differential equations; series solution of linear differential equations; boundary value problems; Laplace transforms; possibly numerical methods and two dimensional autonomous systems. P: Math 222.

320 Linear Algebra and Differential Equations. I, II; 3 cr (N-A). Introduction to linear algebra, including matrices, linear transformations, eigenvalues and eigenvectors. Linear systems of differential equations. Numerical aspects of linear problems. P: Math 222. Credit may not be received for both Math 320 & 340.

321 Applied Mathematical Analysis. I, II; 3 cr (N-A). Vector analysis: algebra and geometry of vectors, vector differential and integral calculus, theorems of Green, Gauss, and Stokes; complex analysis: analytic functions, complex integrals and residues, Taylor and Laurent series. P: Math 223 or 234.

322 Applied Mathematical Analysis. I, II; 3 cr (N-A). Sturm-Liouville theory; Fourier series, including mean convergence; boundary value problems for linear second order partial differential equations, including separation of variables and eigenfunction expansions. P: Math 319, 321.

331 An Introduction to Probability and Markov Chain Models. I, II; 3 cr (N-A). An overview of basic probability including discrete and continuous random variables, moment generating functions, limit theorems, conditional probability and expectations, random walks, and Markov chains. P: Math 234 or Math 222 & 240.

340 Elementary Matrix and Linear Algebra. I, II, SS; 3 cr (N-A). Matrix algebra, linear systems of equations, vector spaces, sub-spaces, linear dependence, rank of matrices, determinants, linear transformations, eigenvalues and eigenvectors, diagonalization, inner products and orthogonal vectors, symmetric matrices. P: Math 234 or Math 222 & 240. Credit may not be received for both Math 320 & 340.

341 Linear Algebra. I, II; 3 cr (N-A). This course emphasizes the understanding of concepts in linear algebra and teaches to write and understand proofs in mathematics in general and in linear algebra in particular. P: Math 234 or cons inst. Stdts cannot receive cr for both Math 340 & 341 or for both Math 375 & 341. Open to Fr.

371 Basic Concepts of Math. II; 3 cr (N-A). Informal treatment of propositional and first-order logic. Proof techniques. Naive set theory. Relations and function. Peano axioms. Construction of the real numbers from the natural numbers. Countable and uncountable sets. Axiom of Choice and Zorn's Lemma. P: Math 340 or con reg.

375 Topics in Multi-Variable Calculus and Linear Algebra. I; 5 cr (A). Vector spaces and linear transformations, differential calculus of scalar and vector fields, determinants, eigenvalues and eigenvectors, multiple integrals, line integrals, and surface integrals. P: Math 276 or cons inst. Stdts may not receive cr for both Math 375 & any of Math 234, 320 & 340.

376 Topics in Multi-Variable Calculus and Differential Equations. II; 5 cr (N-A). Topics in Multi-variable calculus and introduction to differential equiations. P: Math 375 or cons inst. Open to Fr.

415 Applied Dynamical Systems, Chaos and Modeling. I; 3 cr (N-A). An introduction to nonlinear dynamical systems including stability, bifurcations and chaos. The course will give underlying mathematical ideas, but emphasize applications from many scientific fields. P: Math 319 or 320 or cons inst.

421 The Theory of Single Variable Calculus. I, II; 3 cr (N-A). This course covers material in first and second semester calculus but it is intended to teach math majors to write and understand proofs in mathematics in general and in calculus in particular. P: Math 234 or cons inst. Stdts cannot receive cr for Math 421 if they have taken Math 275-276. Open to Fr.

425 Introduction to Combinatorial Optimization. (Crosslisted with Comp Sci, ISyE) Irr.; 3 cr (P-I). Exact and heuristic methods for key combinatorial optimization problems such as: shortest path, maximum flow problems, and the traveling salesman problem. Techniques include problem-specific methods and general approaches such as branch-and-bound, genetic algorithms, simulated annealing, and neural networks. P: Math 221 or Comp Sci 302 or cons inst.

431 Introduction to the Theory of Probability. (Crosslisted with Stat) I, II, SS; 3 cr (N-A). Probability in discrete sample spaces; combinatorial analysis; conditional probabilities, stochastic independence, Laplace limit theorem, Poisson distribution, laws of large numbers, random variables, central limit theorem, applications. P: Math 223 or 234.

435 Introduction to Cryptography. (Crosslisted with Comp Sci, ECE) II; 3 cr (A). Cryptography is the art and science of transmitting digital information in a secure manner. This course will provide an introduction to its technical aspects. P: Math 320 or 340 or cons inst. Open to Fr.

441 Introduction to Modern Algebra. I, II; 3 cr (A). The integers, emphasizing general group and ring properties. Permutation groups, symmetry groups, polynomial rings, leading to notions of abstract groups and rings. Congruences, computations, including finite fields and applications. Emphasis on concepts and concrete examples and computations, not complicated proofs. P: Math 340. Stdts who have passed Math 541 are not permitted to take Math 441 for credit.

443 Applied Linear Algebra. I; 3 cr (N-A). Review of matrix algebra. Simultaneous linear equations, linear dependence and rank, vector space, eigenvalues and eigenvectors, diagonalization, quadratic forms, inner product spaces, norms, canonical forms. For students whose main field of interest is not pure mathematics. Discussion of numerical aspects and applications in the sciences. P: Math 320 or 340 or cons inst.

461 College Geometry I. I, II; 3 cr (N-A). An introduction to Euclidean or non-Euclidean geometry at the college level. P: Math 223 or 234.

473 History of Mathematics. (Crosslisted with Hist Sci) I; 3 cr (X-A). An historical survey of the main lines of mathematical development. P: Cons inst.

475 Introduction to Combinatorics. (Crosslisted with Stat, Comp Sci) I, II; 3 cr (N-A). Problems of enumeration, distribution, and arrangement. Inclusion-exclusion principle. Generating functions and linear recurrence relations. Combinatorial identities. Graph coloring problems. Finite designs. Systems of distinct representatives and matching problems in graphs. Potential applications in the social, biological, and physical sciences. Puzzles. Problem solving. P: Math 320 or 340 or cons inst.

491 Topics in Undergraduate Mathematics. Irr.; 3 cr (A). Topics will vary. P: Math 223 or 234 & cons inst.

513 Numerical Linear Algebra. (Crosslisted with Comp Sci) I; 3 cr (N-A). Direct and iterative solution of linear and nonlinear systems and of eigen-problems. LU and symmetric LU factorization. Complexity, stability, and conditioning. Nonlinear systems. Iterative methods for linear systems. Qr-factorization and least squares. Eigenproblems: local and global methods. P: Math 340 or equiv, Comp Sci 302 or equiv.

514 Numerical Analysis. (Crosslisted with Comp Sci) II; 3 cr (N-A). Polynomial forms, divided differences. Polynomial interpolation. Polynomial approximation: uniform approximation and Chebyshev polynomials, least-squares approximation and orthogonal polynomials. Numerical differentiation and integration. Splines, B-splines and spline approximation. Numerical methods for solving initial and boundary value problems for ordinary differential equations. P: Math 340 or equiv, Comp Sci 302 or equiv.

515 Introduction to Splines and Wavelets. (Cross-listed with Comp Sci) I or II; 3 cr (P-A). Introduction to Fourier series and Fourier transform; time-frequency localization; wavelets and frames. Applications: denoising and compression of signals and images. Interpolation and approximation by splines: interpolation, least-squares approximation, smoothing, knot insertion and subdivision; splines in Cagd. P: Comp Sci 302 or equiv, Math 340 or equiv.

519 Ordinary Differential Equations. Alt yrs.; II; 3 cr (A). Provides a rigorous introduction to ordinary differential equations and dynamical systems. Intended for math majors and advanced (or graduate) students in other disciplines. P: Math 319 or 320 or 340, & Math 421 or 521; or cons inst.

521 Advanced Calculus. I, II, SS; 3 cr (N-A). Fundamental notions of limits, continuity, differentiation, and integration, for functions of one or more variables, convergence and uniform convergence of infinite series, and improper integrals. P: Math 340 or con reg.

522 Advanced Calculus. II; 3 cr (N-A). Differentials and Jacobians, transformation of coordinates and of multiple integrals, line and surface integrals. P: Math 521.

525 Linear Programming Methods. (Crosslisted with Comp Sci, ISyE, Stat) I, II; 3 cr (N-A). Real linear algebra over polyhedral cones; theorems of the alternative for matrices. Formulation of linear programs. Duality theory and solvability. The simplex method and

related methods for efficient computer solution. Perturbation and sensitivity analysis. Applications and extensions, such as game theory, linear economic models, and quadratic programming. P: Math 443 or 320 or 340 or cons inst.

541 Modern Algebra. I, II; 3 cr (N-A). Groups, normal subgroups, Cayley's theorem, rings, ideals, homomorphisms, polynomial rings, abstract vector spaces. P: Math 320 or 340 or cons inst.

542 Modern Algebra. II; 3 cr (N-A). Field extensions, roots of polynomials, splitting fields, simple extensions, linear transformations, matrices, characteristic roots, canonical forms, determinants. P: Math 541.

551 Elementary Topology. I, II; 3 cr (N-A). Topological spaces, connectedness, compactness, separation axioms, metric spaces. P: Math 223 or 234.

552 Elementary Geometric and Algebraic Topology. Irr.; 3 cr (N-A). Introduction to algebraic topology. Emphasis on geometric aspects, including two-dimensional manifolds, the fundamental group, covering spaces, basic simplicial homology theory, the Euler-Poincare formula, and homotopy classes of mappings. P: Math 551 and 542.

561 Differential Geometry. II; 3 cr (N-A). Theory of curves and surfaces by differential methods. P: Math 320 or 340; and Math 521.

567 Elementary Number Theory. I; 3 cr (N-A). Fun-damental theorem of arithmetic, quadratic residues and quadratic reciprocity, number-theoretic functions, certain diophantine equations, Farey fractions, continued fractions. P: Math 340 or con reg.

571 Mathematical Logic. (Crosslisted with Philos) I; 3 cr (X-A). Basics of logic and mathematical proofs; propositional logic; first order logic; undecidability. P: Math 223 or 234 or equiv.

615 Introduction to Applied Mathematics and Numerical Analysis. Irr.; 3 cr (N-A). P: Cons inst.

623 Complex Analysis. I; 3 cr (N-A). Elementary functions of a complex variable; conformal mapping; complex integrals; the calculus of residues. P: Math 321 or 521.

627 Introduction to Fourier Analysis. I; 3 cr (A). Fourier series and integrals, and their applications. P: Math 521.

629 Introduction to Measure and Integration. II; 3 cr (N-A). Lebesgue integral and measure, abstract measure and integration, differentiation, spaces of integrable functions. P: Math 522.

632 Introduction to Stochastic Processes. (Crosslisted with Stat, ISyE, OIM) I, II; 3 cr (N-A). Markov chains: classification, recurrence, transcience, limit theory. Renewal theory, Markov processes, birth-death processes. Applications to queueing, branching, and other models in science, engineering and business. Topics drawn from semi-Markov processes, martingales, Brownian motion. P: Math 431, or Stat 309 & 310, or Stat 311 & 312, or Stat 313 or 314.

633 Queuing Theory and Stochastic Modeling. (Crosslisted with ISyE, OIM) Irr.; 3 cr (N-A). Reliability theory; coherent systems and reliability bounds. Markovian queues and Jackson networks. Steady-state behavior of general service time queues. Priority queues. Approximation methods and algorithms for complex queues. Simulation. Dynamic programming; applications to inventory and queueing. P: Math, Ind Engr 632 or cons inst.

635 An Introduction to Brownian Motion and Stochastic Calculus. Irr.; 3 cr (A). This course presents an introduction to Brownian motion and its application to stochastic calculus. Sample path properties of Brownian motion, Ito stochastic integrals, Ito's formula, stochastic differential equations and properties of their solutions, and various applications will be included. P: Math 521 & 632.

641 Introduction to Error-Correcting Codes. (Cross-listed with ECE) Irr.; 3 cr (N-A). A first course in coding theory. Codes (linear, Hamming, Golay, dual); decoding-encoding; Shannon's theorem; sphere-packing; singleton and Gilbert-Varshamov bounds; weight enumerators; MacWilliams identities; finite fields; other codes (Reed-Muller, cyclic, BCH, Reed-Solomon) and error-correction algorithms. P: Math 320 or 340, and Math 541 or cons inst.

642 Linear Algebra. Alt yrs.; 3 cr (A). A rigorous course in linear algebra. Topics: finite and infinite dimensional vector spaces over division rings; determinants; diagonalization; canonical forms; inner products (Euclidean, Hermitian); bilinear and quadratic forms over various fields; orthogonal and symplectic geometries over finite fields; linear groups. P: Math 340 & 541 or cons inst.

681 Senior Honors Thesis. I, II, SS; 3 cr (N-A). P: Sr st & enrollment in the honors program.

682 Senior Honors Thesis. I, II, SS; 3 cr (N-A). P: Cons inst.

691 Undergraduate Thesis. I; 2-4 cr (A). P: Cons inst.

692 Undergraduate Thesis. II; 2-4 cr (A). P: Cons inst.

699 Directed Study. I, II, SS; 1-6 cr (A). P: Jr or Sr st. Graded on a lettered basis; requires cons inst.

File last updated: June 10, 2005
Feedback, questions or accessibility issues: catalogs@uc.wisc.edu