THE
CITY
COLLEGE

The City University of New York
Convent Avenue at 138th Street
New York, NY 10031

UNDERGRADUATE BULLETIN
1993–1995

CPNY 1993-95

The Major

Every student must complete an approved major (specialization). Each department or program sets specific course requirements for its majors. These requirements are outlined in the departmental listings in the College Bulletin; students should consult with an appropriate advisor before beginning a major. For the B.A. and B.S. degrees, the major consists of twenty-four to forty-eight credits of intermediate and advanced courses. For the B.F.A. degree in the Davis Center for the Arts, the major consists of sixty-four credits. While some courses in the major may be taken at other accredited colleges, at least 60% of the major must be taken at The City College.

Free Electives in CLAS

Free electives are those courses taken in addition to required courses to bring the total to the minimum of 128 credits. Students use free electives to take additional work in the major, concentrate in a second field, or explore particular interests. Students may take almost any course in CLAS as a free elective for which they have the prerequisites. However, no more than five core courses may be taken for credit as free electives.

Students are encouraged to take advantage of the wide range of offerings in the professional schools and special programs at the College. It should be noted, however, that not all courses offered by the Schools of Architecture, Education, Engineering, and Nursing carry credit in the College of Liberal Arts and Science. Students in CLAS may take for credit those courses in the professional schools that teach the basic science of the profession but not those devoted to the practice of the profession. Please consult the Associate Dean for Academic Standards before taking courses in the professional schools.

Other Degree Requirements

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1. The minimum number of credits required for the degree is 128.
2. Students must attain a C average (GPA of 2.00) for all courses taken at City College.
3. Students must also have a C average (GPA of 2.00) in their major.
4. Students must complete 84 credits or the final 32 credits at City College.
5. At least 60% of the credits for the major must be completed at City College.
6. All fees and fines must be paid prior to graduation.

Academic Standards

The Committee on Course and Standing of the College of Liberal Arts and Science acts on student appeals for course withdrawals, drop without penalty (after the deadline); waivers of academic rules; requests for reinstatement; requests to take make-up examinations; and all other matters related to academic standards. The Committee consists of eleven members of the faculty elected by the Faculty Council. The Associate Dean for Academic Standards serves as the non-voting chair of the Committee.

Department of Mathematics
(Division of Science)

Professor Jacob Barshay, Chair

Department Office: NAC 8/133
Telephone: 650-5346

General Information

The City College offers the following undergraduate and combined degrees in Mathematics:

B.A.
B.S.
B.A./M.A. (Combined Degree)

Programs and Objectives

The Mathematics Department offers programs of study that enable students to prepare for graduate study in pure and applied mathematics, and careers in industry and education. Majors may choose to specialize in one of the following areas:

- Pure Mathematics
- Scientific and Industrial Mathematics
- Secondary School Education

Students enrolled in major programs in other departments can obtain a minor in Mathematics by completing the requirements listed below.

The Mathematics Department also offers a comprehensive program of remediation through the Math Skills Office (NAC 8/134, 650-6749) to enable students to advance their level of mathematics to meet the mathematical requirements of the college and of various majors.

Requirements for Majors

Pure Mathematics (B.A. or B.S.)

Students must complete a minimum of 27 credits or eight courses of mathematics and collateral courses beyond the level of Math 204 including the following:

Required Courses
Mathematics:

223: Advanced Calculus I	4
324: Advanced Calculus II	3
325: Advanced Calculus III	3
246: Elements of Linear Algebra	3

One of the following: 4
   347: Elements of Modern Algebra (4 cr.)
   449: Introduction to Modern Algebra (4 cr.)

Elective Courses

Students must choose additional courses to complete the 27 credit or eight course minimum requirement from among the following:

Mathematics:
- 275: Elements of Probability Theory (3 cr.)
- 291: Methods of Differential Equations (3 cr.)
- 328: Methods of Numerical Analysis (3 cr.)
- 345: Theory of Numbers (3 cr.)
- 360: Introduction to Modern Geometry (3 cr.)
- 370: Operations Research I (3 cr.)
- 371: Operations Research II (3 cr.)
- 376: Mathematical Statistics (4 cr.)
- 432: Theory of Functions of a Complex Variable (4 cr.)
- 434: Theory of Functions of a Real Variable (4 cr.)
- 435: Partial Differential Equations, Integral Equations, Boundary Value Problems (4 cr.)
- 438: Calculus of Variations (4 cr.)
- 443: Set Theory (4 cr.)
- 444: Mathematical Logic (4 cr.)
- 461: Differential Geometry (4 cr.)
- 463: Topology (4 cr.)
- 477: Probability Theory II (4 cr.)
- 478: Mathematical Statistics II (3 cr.)
- 511: Selected Topics in Pure Mathematics (4 cr.)
- 512: Selected Topics in Classical Analysis (4 cr.)
- 513: Selected Topics in Probability, Statistics, and Operations Research (4 cr.)

Minimum Total Credits for Specialization   27

Additional Requirements
B.A. candidates are required to take:
Mathematics:
  210: The Use of Computers in Mathematics   3

Students are also required to fulfill a minor requirement of two advanced courses with mathematical content from an allied discipline (e.g., Physical Sciences, Computer Science, Philosophy, Economics or Engineering) to be approved by the Vice Chair.

...tific and Industrial Mathematics (B.S.)

...dents must complete a total of 35 credits of
...ed courses in mathematics above the level of Math
...cluding the following:

...red Courses
...hematics:

...6: Elements of Linear Algebra	3
...8: Applied Logic and Discrete Mathematics	4
...5: Elements of Probability Theory	3
...1: Methods of Differential Equations	3
...7: Mathematical Modeling Problems in Industrial Mathematics	3
...6: Mathematical Statistics	4

...mputer Science:

...0: Computers and Assembly Language Programming	3
...e of the following five sequences:	6-7

...equence 1 - Operations Research: (6 cr.)
  Mathematics:
    370: Operations Research I (3 cr.)
    371: Operations Research II (3 cr.)

...equence 2 - Probability and Statistics: (7 cr.)
  Mathematics:
    477: Probability Theory II (4 cr.)
    478: Mathematical Statistics II (3 cr.)

...equence 3 - Actuarial Science: (7 cr.)
  Mathematics:
    287: Actuarial Mathematics I (2 cr.)
    388: Actuarial Mathematics II (1 cr.)
    389: Actuarial Mathematics III (1 cr.)
    328: Methods of Numerical Analysis (3 cr.)

...equence 4 - Mathematics of Computing: (6 cr.)
  Mathematics:
    328: Methods of Numerical Analysis (3 cr.)
  Computer Science:
    One of the following two:
      220: Algorithms (3 cr.)
      442: Systems Simulation (3 cr.)

...equence 5 - Classical Applied Mathematics: (7 cr.)
  Mathematics:
    296: Topics in Advanced Calculus for Students of Physics I (3 cr.)
    One of the following:
      393: Laplace and Fourier Transforms for Scientists and Engineers (4 cr.)
      395: Complex Variables for Scientists and Engineers (4 cr.)

...tive Courses
...tudents must choose additional courses to complete
...5 credit requirement from among the following:

...athematics:
...223: Advanced Calculus I (4 cr.)
...269: Elementary Combinatorial Mathematics (3 cr.)
...296: Topics in Advanced Calculus for Students of Physics I (3 cr.)

324: Advanced Calculus II (3 cr.)
325: Advanced Calculus III (3 cr.)
328: Methods of Numerical Analysis (3 cr.)
370: Operations Research I (3 cr.)
371: Operations Research II (3 cr.)
287: Actuarial Mathematics I (2 cr.)
388: Actuarial Mathematics II (1 cr.)
389: Actuarial Mathematics III (1 cr.)
393: Laplace and Fourier Transforms for Scientists and Engineers (4 cr.)
395: Complex Variables for Scientists and Engineers (4 cr.)
397: Topics in Advanced Calculus for Students of Physics II (3 cr.)
398: Topics in Advanced Calculus for Students of Physics III (3 cr.)
477: Probability Theory II (4 cr.)
478: Mathematical Statistics II (3 cr.)

[Any other advanced mathematics course approved by the Vice Chair.]

Computer Science:
  220: Algorithms (3 cr.)
  442: Systems Simulation (3 cr.)

Total Credits for Specialization   **35**

Secondary School Education (B.A.)

Students can choose between two options: one with a
pure mathematics emphasis and the other with an
educational emphasis. In both cases students must
complete a minimum of 27 credits or eight courses of
mathematics beyond the level of Math 204 including the
following:

Mathematical Emphasis

Required Courses
  Mathematics:

223: Advanced Calculus I	4
324: Advanced Calculus II	3
325: Advanced Calculus III	3
246: Elements of Linear Algebra	3
One of the following:	4
347: Elements of Modern Algebra (4 cr.)	
449: Introduction to Modern Algebra (4 cr.)	

Elective Courses
  Students selecting the mathematical emphasis option
must choose additional courses to complete the 27 credits
or eight course minimum requirement from among the
following:
  Mathematics:
    275: Elements of Probability Theory (3 cr.)
    328: Methods of Numerical Analysis (3 cr.)
    342: History of Mathematics (3 cr.)
    345: Theory of Numbers (3 cr.)
    360: Introduction to Modern Geometry (3 cr.)
    376: Mathematical Statistics (4 cr.)

Minimum Total Credits for Specialization   **27**

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Educational Emphasis

Required Courses
Mathematics:

223: Advanced Calculus I	4
246: Elements of Linear Algebra	3
275: Elements of Probability Theory	3
One of the following two:	4
347: Elements of Modern Algebra (4 cr.)	
449: Introduction to Modern Algebra (4 cr.)	
360: Introduction to Modern Geometry	3

Elective Courses

Additional courses to complete the 27 credits or eight courses minimum requirement to be chosen with the guidance of the Vice Chair.

Minimum Total Credits for Specialization   27

Additional Requirement For All Majors

Grades: Mathematics majors must maintain at least a C average in Mathematics courses. No advanced undergraduate course may be taken unless a C is obtained in all prerequisite courses (or permission is received from the Vice Chair).

Seminars and Courses: With the permission of the Vice Chair, students may participate in honors seminars or elect advanced work in the Master's level courses: Mathematics 511, 512, 513, 1732, 1734, 1735, 1739, 1749, 1763, 1768, 1776, 1777, 1791.

Foreign Language: Mathematics majors who plan to go to graduate school are advised to select a foreign language from among French, Russian and German.

Four-Year B.A./M.A. Program

Students enrolled in the Honors Program may, with the permission from the Honors Office and the graduate advisor in the Department of Mathematics, participate in a special course of study culminating in the simultaneous awarding of a Bachelor's and Master's degrees in Mathematics in four years. Details for this special course of study are available from the Honors Program Office or the Vice Chair of Mathematics.

Requirements for the Minor

Students enrolled in major programs in other departments can also obtain a minor in Mathematics by completing the following requirements:

Required courses
I. A calculus sequence through Math 203 or 208.

II. One linear algebra course chosen
  from among the following:
  246: Elements of Linear Algebra (3 cr.)
  294: Linear and Boolean Algebra for Electrical
     Engineers (3 cr.)
  392: Linear Algebra and Vector Analysis
     for Engineers (3 cr.)

397: Topics in Advanced Calculus for Students of
    Physics II (3 cr.)

III. A total of 12 credits at The City College in
    Advanced Courses in Mathematics
    (excluding Math 287, 294, 388, and 389)

Electives for Non-Majors

Students wishing to take courses beyond 203 or 208 advised to consult with the Vice Chair on the selection appropriate courses.

Advisement

Vice-Chair, Undergraduate Student Advisor
Professor Ralph Artino

Graduate Advisor
Professor Karel Hrbacek

Math Skills Advisors
Mr. Walter Daum
Dr. Nathaniel Silver

Evening Session Advisor
Professor Joseph Bak

Math Lab Supervisor
Ms. Lorraine Cooley

The Math Skills Office (NAC 8/134) administers al remedial (70s level) courses and provides academic advisement for students in these courses.

Exemption Credit

Students can earn exemption credit in any Mathematics course by taking an exemption examination arranged by the Vice Chair's office. Exemption from the course is awarded for a grade of 60 or above; credit is granted for a grade of 80 or above. Students who have registered for a course or who have previously failed an exemption examination in a course may not take an exemption examination for that course. The Mathematics Department awards credit in Mathematics 101, 105 or 107 to students who score 4 or above on the College Board AB Advanced Placement examination or score 3 or above on the BC examination.

Departmental Activities

The Mathematics Club is open to all mathematics majors. The club plans and organizes lectures, discussions and social functions.

The Mathematics Colloquium meets regularly for talks by invited guests as well as Department faculty.

Various seminars on Algebra, Topology and Mathematical Physics meet regularly and discuss selected topics in these areas.

Awards and Assistantships

The Mathematics Department awards several medals and prizes to outstanding students.

The Belden Medal

To the student or students who complete the Advanced Calculus sequence with distinction.

The Israel E. Drabkin Memorial Award

To a promising mathematics student with broad cultural interests.

The Bennington P. Gill Memorial Award

To the most promising graduating senior committed to graduate study in Mathematics.

The Emil Post Memorial Award

To the graduating senior or seniors judged most promising in Mathematics.

The Harry Schwartz Fellowship

To a Mathematics Major who has shown promise in Mathematics.

In addition to the medals and prizes listed above, the Mathematics Department annually awards prizes to the students turning in the best final examinations in a certain group of courses over the preceding two semesters.

The Department offers a number of Undergraduate Tutoring Assistantships with stipends from $500 to $1000 to students with high academic standing. Assistants tutor in remedial and freshman level courses under the guidance of faculty members.

Tutoring

The Mathematics Laboratory (Harris 010) offers free tutoring in courses from the remedial level through elementary calculus. The lab is staffed with qualified tutors under the supervision of the faculty and lab supervisor. The lab is equipped with up-to-date computer hardware and computer aided programs to help students advance mathematically.

Course Descriptions

Remedial Courses

71: Arithmetic and Elementary Algebra
Arithmetic of positive integers; fractions and decimals; percent; ratio and proportion; roots; measurement and geometry; verbal problems; signed numbers; concepts of algebra. Prereq: placement by the Department. May be taken simultaneously with Math 72 with permission of Mathematics Department.
2 hr./wk.; no cr.

72: Elementary Algebra
Review of arithmetic; exponents; algebraic expressions; linear equations and graphs; systems of equations; polynomials and factoring; monomial fractions; verbal problems. Prereq: Math 71 or placement by the Department.
4 hr./wk.; no cr.

73: Modern Mathematical Ideas
Use of calculators, metric system; permutations and combinations, introductory probability and statistics; introduction to computers and BASIC. Prereq: Math 72 or placement by the Department.
4 hr./wk.; 2 cr.

There are two pre-calculus sequences: Math 74, 75, 76 (standard sequence) and Math 77, 78 (accelerated sequence). Either sequence meets the prerequisites for calculus.

74: Intermediate Algebra and Geometry
Roots and radicals, rational expressions, quadratic equations, geometry topics, verbal problems. Prereq: Math 72 or placement by the Department.
4 hr./wk.; 1 cr.

75: Functions and Graphs
Functional notation; graphing; composite and inverse functions; exponential and logarithmic functions; analytic geometry; polynomial and rational functions; complex numbers; inequalities. Prereq: Math 74 or placement by the Department.
4 hr./wk.; 2 cr.

76: Trigonometry
Geometric foundations, right triangle trigonometry; trigonometric functions; laws of sines and cosines; inverse trigonometric functions; identities, equalities, trigonometric formulas. Coreq: Math 75 or placement by the Department.
2 hr./wk.; 1 cr.

77: Pre-Calculus I
Review of elementary algebra; geometry; functions and graphs; verbal problems; polynomial and rational functions; exponential and logarithmic functions. The sequence Math 77-78 covers the same material as Math 74-75-76 at a faster pace. Prereq: grade A in Math 72 or placement by the Department. This course may not be repeated: a grade of D means placement in Math 75, a failing grade means placement in Math 74. Credit will not be given for both Math 74 and 77.
4 hr./wk.; 1 cr.

78: Pre-Calculus II
Right triangle trigonometry; trigonometric functions; laws of sines and cosines; inverse trigonometric functions; identities, equalities, trigonometric formulas; inequalities; sequences; binomial theorem, remainder and factor theorems; roots of polynomials, composite and inverse functions. Prereq: grade of C in Math 77 or placement by the Department. This course may not be repeated; a grade of D or failure means placement in Math 75 and 76. Credit will not be given for both Math 75 and 78 or for both Math 76 and 78.
4 hr./wk.; 3 cr.

Introductory Courses

There are three calculus sequences: Math 107 and 208; Math 101, 202, and 203; and Math 105 and 209. Math 107 and 208 cover the same material as 101, 202, and 203, but at an accelerated pace. Entry to the above sequences is determined by the placement examination or completion of the course prerequisites.

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Math 105 and 209 may be taken by students who do not intend to study more advanced mathematics (e.g. Biology, Economics, Predental, Premedical, and Architecture majors). Students who seek a B.S. degree should check the requirements of their major to determine which calculus sequence is appropriate.

Math 203 or 208 is a prerequisite for all advanced courses (except Math 294). After Math 105, students may take 202 with the permission of the Vice Chair. Without prior approval by the Vice Chair no credit is allowed for an introductory course if a more advanced course has previously been completed .

101: Analytic Geometry and Calculus I
Limits, derivatives, rules of differentiation, trigonometric functions and their derivatives, differentials, graph sketching, maximum and minimum problem, related rates, antiderivatives, areas. Prereq: grade of C or higher in Math 78, or grade of C or higher in Math 75 and fulfillment of a trigonometry requirement, or placement by the Department. The trigonometry requirement may be satisfied by Math 76 or by placement exam. (Math 76 may be taken simultaneously with Math 101, but it is recommended that Math 76 be taken before Math 101.) Credit will not be given for both Math 101 and 105. (Part of sequence 101, 202, 203).
4 hr./wk.; 3 cr.

105: Elements of Calculus
Limits, derivatives, rules of differentiation, differentials, graph sketching, maximum and minimum problems, related rates, exponential and logarithmic functions, differential equations, antiderivatives, area, volume, applications to economics. Prereq: grade of C or higher in Math 78, or grade of C or higher in Math 75 and fulfillment of a trigonometry requirement, or placement by the Department. The trigonometry requirement may be satisfied by Math 76 or by placement exam. (Math 76 may be taken simultaneously with Math 105, but it is recommended that Math 76 be taken before Math 105.) Credit will not be given for both Math 101 and Math 105.
4 hr./wk.; 4 cr.

107: Analytic Geometry and Calculus A
Limits, derivatives; rules of differentiation; differentials, graph sketching, maximum and minimum problems; related rates; antiderivatives, vectors, areas, volumes of solids of revolution; exponential, logarithmic, and trigonometric functions. Prereq: grade of A in Math 78 and departmental approval, or placement by the Department. With departmental permission, partial credit may be given for Math 107 after completion of Math 105.(Part of sequence 107, 208.)
5 hr./wk.; 5 cr.

173: Introduction to Probability and Statistics
Descriptive statistics and frequency histograms; measures of location and dispersion; elementary probability; permutations and combinations; multiplication rule and conditional probability; Bayes' Theorem; independent events; random variables, expected values; applications to binomial, hypergeometric, uniform and normal distributions; the Central Limit Theorem; testing statistical hypotheses; correlation; linear regression and least squares. Prereq: Math 74 or 77 or placement by the Department. Credit given for only one of the following courses: Math 173, Eco 295, Psy 215, Soc 231.
4 hr./wk.; 4 cr.

185: Basic Ideas in Mathematics
Sets, operations with sets, relations, functions, construction of number systems, numerical systems with different bases, topics in number theory, geometry. Prereq: Math 73, 74, or 77 or placement by the Department. Recommended for prospective elementary school teachers.
4 hr./wk.; 3 cr.

202: Analytic Geometry and Calculus II
Areas between curves; volumes of solids of revolution; integration of trigonometric, exponential and logarithmic functions; methods of integration; conic sections; polar coordinates; parametric representation of curves. Prereq: grade of C or higher in Math 101 and Math 76 or placement by the Department.(Part of sequence 101,202,203.) After completion of Math 107, only 1 credit will be given for Math 202. After completion of Math 209, only 2 credits will be given for Math 202.
4 hr./wk.; 3 cr.

203: Analytic Geometry and Calculus III
Vectors, infinite series, Taylor's theorem, solid analytic geometry, partial derivatives, multiple integrals with applications. Prereq: Math 202. (Part of sequence 101, 202, 203.)
4 hr./wk.; 4 cr.

204: Bridge to Advanced Mathematics
This course explores the logical and foundational structures of mathematics, with an emphasis on understanding and writing proofs. Topics include set theory, logic, mathematical induction, relations and orders, functions, and Cantor's theory of countability.
3 hr./wk.; 3 cr.

208: Analytic Geometry and Calculus B
Methods of integration, moments, and centroids, improper integrals, infinite series, Taylor's theorem, conic sections, parametric representation of curves, polar coordinates, solid analytic geometry, partial derivatives, multiple integrals with applications. Prereq: Math 107. (Part of sequence 107, 208.)
5 hr./wk.; 5 cr.

209: Elements of Calculus and Statistics
Exponential and logarithmic functions, equations of growth and decay, integration techniques, improper integrals, differential equations, counting techniques, probability on finite sample spaces, binomial distributions; continuous distributions, normal distribution, statistical measures, statistical inference, biological applications. Prereq: Math 105 and Math 76 or placement by the Department. After completion of Math 107, only 3 credits will be given for Math 209. (Part of sequence 105, 209 for Biology majors.)
4 hr./wk.; 4 cr.

210: The Use of Computers in Mathematics
Rapid survey of FORTRAN programming; backtracking; Monte Carlo and simulation techniques; combinatorial and graph theoretic algorithms; applications to mathematical programs. Through work on projects, students will gain experience in the use of computers to solve elementary problems in areas of mathematics such as number theory, probability, games, queuing theory, and geometry. Prereq: Math 203 or 208 or departmental permission. This course is required for all Math majors planning to graduate with a B.A. degree and recommended for all who plan to do advanced work in mathematics. Prior knowledge of computer programming is not required. Credit will not be allowed for both Science 200 and Math 210.
3 hr./wk.; 3 cr.

Advanced Courses

223: Advanced Calculus I
A more advanced treatment of the real number system, properties of continuous functions, derivatives and differentials, rigorous work with limits, uniform continuity, uniform convergence, infinite sequences, functions defined by series. Prereq: Math 204 or departmental permission.
4 hr./wk.; 4 cr.

46: Elements of Linear Algebra
Vector spaces, basis and dimension, matrices, linear transformations, determinants, solution of systems of linear equations, eigenvalues, and eigenvectors. Prereq: Math 203 or 208; coreq: Math 203 or 208 and departmental permission. After completion of Math 294, only 2 credits will be given for Math 246.
3 hr./wk.; 3 cr.

268: Applied Logic and Discrete Mathematics
Set theory, binary relations, functions, mathematical induction, elements of mathematical logic, counting techniques, graph theory, analysis of algorithms. Prereq: Math 203 or 208.
4 hr./wk.; 4 cr.

269: Elementary Combinatorial Mathematics
Classification of finite functions, partitions, sets, relations, principle of induction, permutations and combinations, binomial and multinomial coefficients, stochastic processes, basic definitions of abstract algebra. Prereq: Math 203 or 208 or permission of the instructor. Credit will not be given for both Math 269 and CSc 350.
3 hr./wk. 3 cr.

275: Elements of Probability Theory
Permutations and combinations, conditional probability, independent events, random variables, probability distributions and densities, expectation, moments, moment generating functions, functions of random variables, Central Limit Theorem, sampling, confidence intervals. Prereq: Math 203 or 208.
3 hr./wk.; 3 cr.

287: Actuarial Mathematics I
Special aspects of calculus, linear algebra, and algebra of complex numbers which are found on the first actuarial examination. Prereq: Math 203 or 208; coreq: Math 246. In order to receive specialization credit, a student must be in the actuarial mathematics option and must either receive at least the grade of B or pass the actuarial examination.
2 hr./wk.; 2 cr.

291: Methods of Differential Equations
First order equations; higher order linear equations with constant coefficients, undetermined coefficients, variation of parameters, applications; Euler's equation, series solutions, special functions; linear systems; elementary partial differential equations and separation of variables; Fourier series. Prereq: Math 203 or 208.
3 hr./wk.; 3 cr.

294: Linear and Boolean Algebra for Electrical Engineers
Matrices, determinants, solutions of systems of equations, vector spaces, linear transformations, eigenvalues; Boolean algebra and functions, the Quine-McCluskey method for finding prime implicants, minimization, Karnaugh Maps, basic logical gates, NAND and NOR circuits. Prereq: Math 101.
3 hr./wk.; 3 cr.

296: Topics in Advanced Calculus for Students of Physics I
Topics in ordinary differential equations; functions of several variables, vector analysis; integration, Green's, Stokes' and divergence theorems. Prereq: Math 203 or 208.
3 hr./wk.: 3 cr.

324: Advanced Calculus II
Theory of integration for functions of one variable, functions defined by integrals, improper integrals; complete metric space, contraction mappings and fixed point theorems, applications to differential equations; Fourier analysis. Prereq: Math 223 and 246. (Part of sequence 223, 324, 325.)
3 hr./wk.; 3 cr.

325: Advanced Calculus III
Differentiation and integration in n-space, implicit and inverse function theorems, change of variables in multiple integrals, vector fields, line and surface integrals, theorems of Green, Stokes, and Gauss. Prereq: Math 324 and 246. (Part of sequence 223, 324, 325.)
3 hr./wk.; 3 cr.

328: Methods of Numerical Analysis
Solution of equations by iteration techniques; Lagrange and Newton interpolation, Neville's method, divided differences, cubic splines; numerical integration, Romberg integration; systems of linear equations and pivoting techniques; Runge-Kutta methods for initial value problems. Prereq: Math 246, 294, or 392, and knowledge of FORTRAN or PASCAL. Coreq: Math 291.
3 hr./wk.; 3 cr.

342: History of Mathematics
Greek mathematics, non-Euclidean geometries, Hilbert's Grundlagen, algebraic structure, the modern method, axiomatics for the reals, symbolic logic, and foundations. Prereq: Math 204.
3 hr./wk.; 3 cr.

345: Theory of Numbers
Divisibility, primes, fundamental theorem of arithmetic, congruences, number theory from an algebraic viewpoint, quadratic reciprocity, number theoretic functions, diophantine equations. Prereq: Math 204 or departmental permission.
3 hr./wk.; 3 cr.

347: Elements of Modern Algebra
Sets, mappings, rings, isomorphisms, integral domains, properties of integers, fields, rational numbers, complex numbers, polynomials, groups. Prereq: Math 204. With departmental permission, partial credit may be given for Math 449 after completion of Math 347. Recommended for prospective teachers and others who want a basic course in abstract algebra.
4 hr./wk.; 4 cr.

360: Introduction to Modern Geometry
Logical deficiencies in Euclidean geometry, Euclid's parallel postulate, introduction to non-Euclidean geometry, the logical consistency of the non-Euclidean geometries, Hilbert's Axioms. Prereq: Math 204.
3 hr./wk.; 3 cr.

367: Mathematical Modeling Problems in Industrial Mathematics
Problems from industry, mathematical models, process of mathematical abstraction problem-solving techniques, application of solutions. Prereq: Math 246, 275, 291.
3 hr./wk.; 3 cr.

370: Operations Research I
Linear programming models, the graphical and simplex methods. Duality, sensitivity analysis. Computer solutions using IMSL software. The Transportation, Assignment and Transshipment problems. Network Analysis: Shortest route, minimal spanning tree and maximal flow in networks. Prereq: Math 246 (or 203 and 294). Specialization credit will not be given for both Math 370 and CSc 446.
3 hr./wk.; 3 cr.

371: Operations Research II
Dynamic Programming, deterministic and probabilistic models, basic ideas in Game and Decision Theory, Queuing Theory, Markov Processes. Prereq: Math 275.
3 hr./wk.; 3 cr.

376: Mathematical Statistics
The gamma, chi-square, T, F, and bivariate normal distributions; Central Limit Theorem; confidence intervals and tests of hypothesis; the Neymen-Pearson Theorem; likelihood ratio test; estimation; sufficiency, unbiasedness, completeness; the Rao-Blackwell Theorem; the Rao-Cramer inequality; the method of maximum likelihood; the chi-square test; introduction to the analysis of variance and regression. Prereq: Math 275.
4 hr./wk.; 4 cr.

388: Actuarial Mathematics II
Special aspects of probability and statistics which are found on the second actuarial examination. Prereq: Math 376. In order to receive specialization credit, a student must be in the actuarial mathematics option and either must receive at least a grade of B or pass the actuarial examination.
1 hr./wk.; 1 cr.

389: Actuarial Mathematics III
Special aspects of numerical analysis with emphasis on finite differences, and topics which are found on the third actuarial examination. Prereq: Math 328. In order to receive specialization credit, a student must be in the actuarial mathematics option and must either receive at least the grade of B or pass the actuarial examination.
1 hr./wk.; 1 cr.

392: Linear Algebra and Vector Analysis for Engineers
Matrix theory, linear equations, Gauss elimination, determinants, eigenvalue problems and first order systems of ordinary differential equations, vector field theory, theorems of Green, Stokes, and Gauss. Prereq: Math 203 or 208; coreq: Math 291. No specialization credit will be given for both Math 325 and 392.
3 hr./wk.; 3 cr.

393: Laplace and Fourier Transforms for Scientists and Engineers
Basic properties of and calculations with Laplace transforms, Fourier series and Fourier transforms; introduction to impulse (delta) functions; applications to electric circuits, diffusion and steady-state phenomena, standing waves, Huygens' principle, elementary diffraction, CATscan, Gibbs' phenomenon. Prereq: Math 291.
4 hr./wk.; 4 cr.

395: Complex Variables for Scientists and Engineers
Complex numbers, functions, power series; Cauchy-Riemann equations; Cauchy integral theorem and formula, and their consequences; residues and contour integrals. Topics selected from: relation to fluid mechanics and electrostatics, inverse z-transform and inverse Laplace transform, Kelvin's method of images, introduction to asymptotic expansions. Prereq: Math 291. After completion of Math 432, only 2 credits will be given for Math 395.
4 hr./wk.; 4 cr.

397: Topics in Advanced Calculus for Students of Physics II
Matrix algebra, series solutions to ordinary differential equations, special functions, Bessel and Legendre functions, Fourier series and integral. (Part of sequence 296, 397 and 398). Prereq: Math 296.
3 hr./wk.; 3 cr.

398: Topics in Advanced Calculus for Students of Physics III
Complex variables, evaluation of integrals by residues, separation of variable methods for partial differential equations. (Part of sequence 296, 397 and 398). Prereq: Math 397 or 392. Specialization credit will not be given for both 395 and 398.
3 hr./wk.; 3 cr.

432: Theory of Functions of a Complex Variable
A more rigorous treatment of complex variables than given in 395 or 398. Cauchy-Riemann equations; conformal mapping; elementary, entire, meromorphic, multiple-valued functions; Cauchy integral theorems; series expansion. Prereq: Math 325. After completion of Math 395, only 2 credits will be given for Math 432.
4 hr./wk.; 4 cr.

434: Theory of Functions of a Real Variable
Lebesgue measure and integration on the real line, differentiation of real functions and the relation with integration, classical Lp Spaces. Prereq: Math 325.
4 hr./wk.; 4 cr.

435: Partial Differential Equations, Integral Equations, Boundary Value Problems
First order equations, shock waves; classification and canonical forms of higher order equations, characteristics, the Cauchy problem for the wave equation: Huygens' principle; the heat equation; Laplace's equation; the Dirichlet and Neuman problems; harmonic functions; eigenvalue expansions; Green's functions. Prereq: Math 325 and 291 or permission of the instructor.
4 hr./wk.; 4 cr.

438: Calculus of Variations
Extreme problems for one or several functions; the necessary conditions of Euler, Legendre, Weierstrass, Jacobi; problems in parametric form; Hamilton-Jacobi theory; isoperimetric problems; Sturm-Liouville theory as applied to the calculus of variations; applications to physics. Prereq: Math 325 or permission of the instructor.
4 hr./wk.; 4 cr.

443: Set Theory
Axioms of Zermelo-Fraenkel set theory; relations functions, equivalences and orderings; cardinal numbers and cardinal arithmetic; well-ordered sets; ordinal numbers, transfinite induction and recursion; The Axiom of Choice and the Continuum Hypothesis. Prereq: Math 223 or permission of the instructor.
4 hr./wk.; 4 cr.

444: Mathematical Logic
The propositional calculus, the sentential calculus, normal forms, first order theories, consistency, categoricity, decidability, Godel's completeness theorem, the Loewenheim-Skolem theorem. Prereq: Math 223 or permission of the instructor. Credit is given for only one of the following courses: Math 444, Philo 240, Philo 347.
4 hr./wk.; 4 cr.

449: Introduction to Modern Algebra
Groups, rings, fields. Prereq: Math 223. With departmental permission, partial credit may be given for Math 449 after completion of Math 347.
4 hr./wk.; 4 cr.

461: Differential Geometry
The theory of curves and surfaces in three-dimensional space: frames, fundamental forms, geodesics; curvature of surfaces; surface area; surfaces with boundary, the Gauss-Bonnet Theorem; Introduction to Riemannian metrics. Prereq: Math 325 or permission of the instructor.
4 hr./wk.; 4 cr.

463: Topology
A course in general topology. Sets of points on the real line and in general abstract spaces, relations between sets of points and between a set and the space containing it, operations with sets, open sets, countability, compactness, connectedness, maps, continuity, metric spaces, general topological spaces. Prereq: Math 325 or permission of the instructor.
4 hr./wk.; 4 cr.

477: Probability Theory II
Special topics in probability such as stochastic processes, Markov chains, etc. Prereq: Math 246, 275; pre- or coreq: Math 325.
4 hr./wk.; 4 cr.

478: Mathematical Statistics II
The multivariate normal distribution, multiple and partial correlation, regression and least squares, the analysis of variance. Prereq: Math 246 and 376.
3 hr./wk.; 3 cr.

511: Selected Topics in Pure Mathematics
Topics to be chosen from the areas of algebra, analysis, topology, geometry, and logic. Prereq: to be determined by the instructor.
3 hr./wk.; 4 cr.

512: Selected Topics in Classical Analysis
Topics to be chosen from applied mathematics and related fields. Typical subjects are: asymptotic methods, wave propagation, mathematical biology. Prereq: Math 246, 291, and 325 or 327, and other requirements to be determined by the instructor.
3 hr./wk.; 4 cr.

513: Selected Topics in Probability, Statistics, and Operations Research
Topics to be chosen from the areas of probability, statistics, game theory, combinatorial analysis, etc. Prereq: to be determined by the instructor.
3 hr./wk.; 4 cr.

301-04: Honors I-IV
Approval of Dean and Department Honors Supervisor required. Apply in NAC 4/160 no later than December 10 in the Fall term or May 1 in the Spring term. Credit flexible but usually 3 credits per term.

310: Independent Study
A program of independent study under the direction of a member of the Department with the approval of the Vice Chair. *Credit may be from 1-4 credits, as determined before registration by the instructor with the approval of the Vice Chair.*

311-20: Selected Topics in Mathematics
Topics not covered in the usual department offerings. Topics vary from semester to semester, depending on student and instructor interest. Prerequisites as determined by the instructor. *Credits and hours will be determined by the instructor and the department, with a maximum of 4 credits per course.*

Graduate Courses Open to Undergraduates

Qualified students may take, with departmental approval, any course available in the Master's program in Mathematics or the first year of the doctoral program in Mathematics. These courses are described in the appropriate catalogs.

Faculty

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