Students electing a second minor in managerial studies must complete at least 12 credit hours counted solely toward the second minor.

Financial Economics

Course descriptions begin on page 177.

Managerial Studies

Course descriptions begin on page 193.

Mathematics

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SENIOR LECTURER EMERITA Jo Ann W. Staples
SENIOR LECTURERS Derek Bruff, Linda Hutchison, Pamela Pigg, John Rafter, Lori Rafter, Jakayla Robbins

THE Department of Mathematics offers an undergraduate major with a high degree of flexibility. A solid background in mathematics provides an excellent foundation for any quantitative discipline as well as many professions—many students go on to professional studies in law, medicine, or business.

Program of Concentration in Mathematics

Three tracks are available.

Program I (Standard Track) is intended for most mathematics majors in the College of Arts and Science, Blair School of Music, and Peabody College.

Program II (Applied Track) is intended for students in the School of Engineering who elect a second major in mathematics, but is also available for other students.

Program III (Honors Track) is intended for highly qualified students who either plan for graduate studies in mathematics or plan to graduate with departmental honors. Students who complete this program and, in addition, complete a senior thesis will graduate with departmental honors.

Requirements for the three tracks are summarized below.

Program I (Standard Track).

At least 32 hours in mathematics, as follows.
1. A calculus sequence: 150a–150b–170–175, or 155a–155b–175, or 155a–155b–205a–205b.
2. Linear algebra and differential equations: 204 or 205a–205b, and 208.
3. At least 15 additional hours from 200, 210, or above 210.
4. The remainder of the hours must be chosen from 200, 210, or above 210.

Program II (Applied Track).

At least 29 hours in mathematics and 6 hours outside the department, as follows.
1. A calculus sequence as in Program I.
2. Linear algebra and differential equations—one of the following:
   (a) one of 194, 204, or 205a–205b, and one of 198 or 208; or
   (b) 196 and either 204 or 205a–205b.
3. At least 12 additional hours from 200, 210, or above 210, excluding 252.
4. The remainder of the hours in mathematics must be chosen from 200, 210, or above 210.
5. At least 6 hours of advanced, mathematically based science or engineering courses approved by the director of undergraduate studies. This requirement is automatically fulfilled by students who complete a physics major or a major in the School of Engineering.

Program III (Honors Track).

At least 38 hours in mathematics, as follows.
1. A calculus sequence as in Program I.
2. Linear algebra and differential equations as in Program I.
3. At least 21 additional hours of advanced coursework, (a) including four courses taken from the following three categories, at least one from each category:
   1) Algebra: 223, 283a, 283b.
   (b) The remainder of the 21 hours must be chosen from 200, 210, or above 210, excluding 269.
4. The remainder of the hours must be chosen from 200, 210, or above 210.

Students who complete Program III and, in addition, complete a senior thesis will graduate with departmental honors.

Students planning to teach in secondary school should contact the director of secondary education programs in the Department of Teaching and Learning at Peabody College for course recommendations.

Honors Program

The Honors Program in Mathematics is designed to afford superior students the opportunity to pursue more intensive work within their major field. The program requires:
1. Completion of all the requirements of Program III (Honors Track).
2. A minimum grade point average of 3.6 in mathematics.
3. Completion of a senior thesis in Math 269 (3 credit hours) in the second semester of the senior year. With approval of the director of undergraduate studies, the thesis may be based on research initiated or completed at another academic institution, such as during an NSF-sponsored REU program.
4. Oral examination on the senior thesis. A committee of at least three faculty members—at least two from the Department of Mathematics, one being the thesis advisor—shall evaluate the thesis and the oral examination. Exceptional achievement on the thesis will earn highest honors.

Interested students may apply to the director of undergraduate studies for admission to the Honors Program in their junior year or the first semester of their senior year. Applicants must meet college requirements for entry to the Honors Program, and must carry a minimum grade point average of 3.6 in mathematics.

The application includes a one- to two-page proposal of the planned thesis and the signature of the faculty member who will be the thesis adviser.

The thesis must be submitted no later than two weeks before the end of classes in the semester of graduation. The oral examination will take place by the last day of classes in the semester of graduation. Highest honors will be awarded for a thesis that contains original high-quality research results in combination with an oral defense at the highest quality level.

Students may sign up for Math 269 during one semester of their senior year. Math 269 will not count toward the 21 hours requirement in Program III.

Students who declared their mathematics major prior to fall 2010 may complete the Honors Program under the old regulations. Please consult the director of undergraduate studies for details.

**Minor in Mathematics**

The minor in mathematics requires at least 15 hours in mathematics, including:

1. Completion of a calculus sequence: 175 or 205a–205b.
2. Linear algebra and differential equations: as in the Program II major.
3. At least 6 hours not used to satisfy item 2 from 200, 210, or above 210.

Completion of a single-variable sequence (150a–150b–170, or 155a–155b) is a prerequisite for the minor, but does not count toward the hours of the minor.

**Licensure for Teaching**

Candidates for teacher licensure at the secondary level in mathematics should refer to the chapter on Licensure for Teaching in the Peabody College section of this catalog.

**Calculus**

Several calculus sequences are available: 140; 150a–150b–170–175; 155a–155b–175.

The courses in these sequences cover similar material, but at different rates, and therefore overlap in content and credit. Students should not switch from one to another without approval of the department. Such switching may result in loss of credit. Students intending to take mathematics classes beyond one year of calculus are advised to enroll in the 155a–155b–175 sequence. The chart below shows how these sequences relate to each other.

First-year students with test scores of 5 on the Calculus BC advanced placement examination, thereby earning AP credit for 155a–155b, may choose to enroll in the 205a–205b sequence. The combination of 205a–205b is a blend of multivariable calculus and linear algebra, with an emphasis on rigorous proofs.

For example, students who earned credit for 150a (3 cr.) and also complete 155a (4 cr.) will lose 2 hours of duplicate credit (see Duplicate Credit Policies to understand which credits would be affected).

**Duplicate Credit Policies**

Deduction of credit caused by duplication proceeds as follows. Students who earned math credit

1. through Advanced Placement/International Baccalaureate in one sequence and complete a course at Vanderbilt from another sequence that duplicates this credit will lose credit from the Advanced Placement/International Baccalaureate earnings.
2. by transfer in one sequence and complete a course at Vanderbilt from another sequence that duplicates this credit will lose credit from the Vanderbilt course.
3. at Vanderbilt in one sequence and complete a course at Vanderbilt from another sequence that duplicates this credit will lose credit from the second Vanderbilt course.

Below is a chart that outlines the credit loss based on the courses taken:

<table>
<thead>
<tr>
<th>First course</th>
<th>Second course</th>
<th>Credit lost</th>
</tr>
</thead>
<tbody>
<tr>
<td>170 or old 170a</td>
<td>170</td>
<td>ALL 3</td>
</tr>
<tr>
<td>old 170a</td>
<td>170 (before Fo8)</td>
<td>ALL 3</td>
</tr>
<tr>
<td>old 170b</td>
<td>170 (Fo8 or later)</td>
<td>ALL 3</td>
</tr>
<tr>
<td>175</td>
<td>old 170b</td>
<td>ALL 3</td>
</tr>
</tbody>
</table>

Courses in Mathematics are classified as follows:

**210–239: Intermediate Undergraduate Courses**

**240–269: Advanced Undergraduate Courses**

**270–299: Introductory Graduate or Advanced Undergraduate Courses**

In course prerequisites, “multivariable calculus” means Math 175 or 205a–205b; “linear algebra” means Math 194, 204, or 205a–205b; and “ordinary differential equations” means Math 196, 198, or 208.

Course descriptions begin on page 194.

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**Medicine, Health, and Society**

DIRECTOR Jonathan M. Metzl

ASSISTANT DIRECTORS JuLeigh Petty, Elisabeth H. Sandberg

DIRECTOR OF UNDERGRADUATE STUDIES Courtney S. Muse

DIRECTOR OF GRADUATE STUDIES Jonathan M. Metzl

ADJOINT PROFESSOR Daniel L. Howard

ASSOCIATE PROFESSORS Dominique Béhague, Derek Griffith

ASSISTANT PROFESSORS Kenneth MacLeish, Laura Stark

SENIOR LECTURERS Courtney S. Muse, JuLeigh Petty, Marian V. Yagel

Affiliated Faculty

ASSOCIATE PROFESSORS Gregory Barz (Ethnomusicology), Mark Bilton (Medicine), Tony N. Brown (Sociology), Karen Campbell (Sociology), Laura Carpenter (Sociology), André Christie-Mizell (Sociology), Beth Conkin (Anthropology), Elizabeth Heitman (Medicine), Kathleen Hoover-Dempsey (Psychology and Human Development), Sarah Igo (History), Melanie Lutenbacher (Nursing), Terry A. Maroney (Law), Ifeoma Nwankwo (English), Scott Pearson (Surgery), Matthew Ramsey (History), Ruth Rogaski (History), Norbert Ross (Anthropology), Russell Rothman (Medicine), David Schlundt (Psychology), Tiffiny Tung (Anthropology), David W. Wright (Chemistry)

RESEARCH ASSOCIATE PROFESSOR Melissa McPheeters (Medicine)

ASSISTANT PROFESSORS Carolyn Audet (Preventive Medicine), Tyson Brown (Sociology), Barbara Clinton (Nursing and Medicine), Carol Etherington (Nursing), Joseph B. Fanning (Medicine), Jill A. Fisher (Medicine), Julian F. Hillyer (Biological Sciences), Rolanda Johnson (Nursing), Chase Lesane-Brown (Psychology and Human Development), Amy Non (Anthropology), Chandara Y. Osborn (Medicine), Evelyn Patterson (Sociology), Michele Salisbury (Nursing), Kevin T. Seale (Biomedical Engineering), Lijun Song (Sociology), Timothy J. Vogus (Management and Organization Studies)

SENIOR LECTURERS Lorraine Catanzaro (Spanish), Russell M. McIntire Jr. (Philosophy), Elisabeth H. Sandberg (Psychology)

LECTURER Kyle Brothers (Pediatrics)

THE Center for Medicine, Health, and Society offers an interdisciplinary major (36 hours) and minor (18 hours) for students interested in studying health-related beliefs and practices in their social and cultural contexts. An honors program

MGRL 195. Entrepreneurial Challenge. Simulation of the entrepreneurial experience from idea generation to funding. Development of a complete business plan, including financial projections, and competition for funding from investors. Offered on a graded basis only. Prerequisite: 194. [3] (SBS)


MGRL 235. Selected Topics in Managerial Studies. May be repeated for credit more than once if there is no duplication in topic. Students may enroll in more than one section of this course each semester. [3] (No AXLE credit)

MGRL 245. Independent Study in Managerial Studies. A program of independent reading in consultation with an adviser. Written permission of an instructor and the program director required. [Variable credit: 1-3; may not be repeated] (No AXLE credit)

MGRL 290. Directed Study. Directed readings and related field research toward a scholarly project conceived and executed under the supervision of a faculty member. Limited to juniors and seniors. [3] (No AXLE credit)

Mathematics

MATH 115F. First-Year Writing Seminar. Topics Vary. [3]

MATH 127a. Probability and Statistical Inference. For students not planning to major in science, engineering, or mathematics. Discrete and continuous probability models (exponential, binomial, Poisson, normal). Law of large numbers; conditional probability and Bayes theorem; counting techniques and combinatorics. Descriptive statistics: measures of central tendency and dispersion, histograms. [3] (No AXLE credit)

MATH 127b. Probability and Statistical Inference. For students not planning to major in science, engineering, or mathematics. Linear regression, correlation, hypothesis testing. Confidence intervals, sampling distributions, statistical inference. Prerequisite: 127a. [3] (MNS)

MATH 133. Pre-calculus Mathematics. Inequalities, functions and graphs, trigonometric identities, theory of equations. Designed for students who plan to take either 150a-150b or 155a-155b but need a stronger background in algebra and trigonometry. [3] (No AXLE credit)

MATH 140. Survey of Calculus. A basic course in the rudiments of analytic geometry and differential and integral calculus with emphasis on applications. Designed for students who do not plan further study in calculus. [4] (MNS)

MATH 150a. Single-Variable Calculus I. Review of algebra and trigonometry. Exponential functions; inverse functions and logarithms. Limits; differentiation of algebraic and transcendental functions; rules of differentiation; related rates. Three hours of lecture and one hour of recitation period per week. [3] (MNS)

MATH 150b. Single-Variable Calculus II. Maximum and minimum values; curve sketching. Antiderivatives; the Fundamental Theorem of Calculus; areas and volumes; techniques of integration. Three hours of lecture and one hour of recitation period per week. Prerequisite: 150a. [3] (MNS)


MATH 155b. Accelerated Single-Variable Calculus II. Differentiation and integration of transcendental functions, applications, methods of integration, coordinate geometry, polar coordinates, infinite series. Prerequisite: 155a or 150b. [4] (MNS)

MATH 170. Single-Variable Calculus III. Analytic geometry, parametric equations, polar coordinates, infinite series, Taylor series. Prerequisite: 150b. Serves as repeat credit for students who completed 170a prior to fall 2008. [3] (MNS)

MATH 175. Multivariable Calculus. Vectors, curves, and surfaces in space. Functions of several variables, partial derivatives, multiple integrals. Vector integral calculus, including line and surface integrals. Prerequisite: 155b or 170. No credit for students who have completed 205a-205b. Serves as repeat credit for students who completed 170b prior to fall 2008. [3] (MNS)

MATH 194. Methods of Linear Algebra. Vectors and matrix operations. Linear transformations and fundamental properties of finite dimensional vector spaces. Numerical solutions of systems of linear equations. Eigenvalues and eigenvectors. Selected basic elements of linear programming. Pre-or Corequisite: 175. Credit is not given for both 194 and 196 or 204 or 205a-205b. [3] (MNS)


MATH 198. Methods of Ordinary Differential Equations. Linear first-order differential equations, applications, higher order linear differential equations, complementary and particular solutions, applications, Laplace transform methods, series solutions, numerical techniques. Prerequisite: multivariable calculus. Credit is not given for both 198 and 196 or 208. [3] (MNS)

MATH 200. Intensive Problem Solving and Exposition. Intended to develop widely-applicable mathematical skills. Basic principles such as induction, the pigeonhole principle, symmetry, parity, and generating functions. Prerequisite: 175 or 205a. [3] (MNS)


MATH 205a. Multivariable Calculus and Linear Algebra. Vector algebra and geometry; linear transformations and matrix algebra. Real and complex vector spaces, systems of linear equations, inner product spaces. Functions of several variables and vector-valued functions: limits, continuity, the derivative. Extremum and nonlinear problems, manifolds. Multiple integrals, line and surface integrals, differential forms, integration on manifolds, theorems of Green, Gauss, and Stokes. Eigenvectors and eigenvalues. Emphasis on rigorous proofs. No credit for students who have earned credit for 205b, 175, 194, or 204. Open only to first-year students with a test score of 5 on the Calculus-BC Advanced Placement examination. [4] (MNS)

MATH 205b. Multivariable Calculus and Linear Algebra. Continuation of 205a. Vector algebra and geometry; linear transformations and matrix algebra. Real and complex vector spaces, systems of linear equations, inner product spaces. Functions of several variables and vector-valued functions: limits, continuity, the derivative. Extremum and nonlinear problems, manifolds. Multiple integrals, line and surface integrals, differential forms, integration on manifolds, theorems of Green, Gauss, and Stokes. Eigenvectors and eigenvalues. Emphasis on rigorous proofs. No credit for students who have earned credit for 205b, 175, 194, or 204. Prerequisite: 205a and first-year standing. [4] (MNS)

MATH 215. Discrete Mathematics. Elementary combinatorics including permutations and combinations, the principle of inclusion and exclusion, and recurrence relations. Graph theory including Eulerian and Hamiltonian graphs, trees, planarity, coloring, connectivity, network flows, some algorithms and their complexity. Selected topics from computer science and operations research. Prerequisite: Linear algebra. [3] (MNS)


MATH 218. Introduction to Probability and Mathematical Statistics. Discrete and continuous probability models, mathematical expectation, joint densities. Laws of large numbers, point estimation, confidence intervals. Hypothesis testing, nonparametric techniques, applications. Students taking 218 are encouraged to take 218L concurrently. Prerequisite: Multivariable calculus. No credit for students who have completed 216. [3] (MNS)

MATH 218L. Statistics Laboratory. Applications of the theory developed in 218. Emphasis on data analysis and interpretation. Topics include the one- and two-sample problems, paired data, correlation and regression, chi-square, and model building. Pre- or corequisite: 216 or 218. [1] (No AXLE credit)

MATH 219. Introduction to Applied Statistics. A brief review of basic applied statistics followed by a development of the analysis of variance as a technique for interpreting experimental data. The generalized likelihood ratio principle, completely randomized designs, nested designs, orthogonal contrasts, multiple comparisons, randomized block designs, Latin squares, factorial designs, 2n designs, fractional factorials, confounding, introduction to response surface methodology. Applications will be emphasized. Prerequisite: 216 or 218. [3] (MNS)


MATH 226. Introduction to Numerical Mathematics. Numerical solution of linear and nonlinear equations, interpolation and polynomial approximation, non-numerical differentiation and integration. Least-squares curve fitting and approximation theory, numerical solution of differential equations, errors and floating point arithmetic. Application of the theory to problems in science, engineering, and economics. Student use of the computer is emphasized. Familiarity with computer programming is expected. Prerequisite: Linear algebra and ordinary differential equations. [3] (MNS)


MATH 234. Introduction to Partial Differential Equations. Initial- and boundary-value problems for partial differential equations using separation of variables in conjunction with Fourier series and integrals. Explicit solutions of problems involving the heat equation, the wave equation, and Laplace’s equation. Prerequisite: Ordinary differential equations, linear algebra. [3] (MNS)

MATH 240. Transformation Geometry. Transformations of the plane, groups of transformations, reflections, glide reflections, classification of the isometries of the plane, frieze groups, analysis of frieze patterns, wall paper groups, and analysis of wall paper patterns. Especially recommended for prospective teachers of mathematics. Prerequisite: Linear algebra. [3] (MNS)


MATH 243. Differentiable Manifolds. Manifolds in n-dimensional Euclidean space, smooth maps; inverse and implicit function theorems. Regular value theorem, immersions and submersions, Sard’s theorem, and transversality. Degree of a map; winding numbers and the Fundamental Theorem of Algebra; intersection theory modulo 2. Prerequisite: Multivariable calculus, linear algebra. [3] (MNS)

MATH 246a. Introduction to Actuarial Mathematics. Applications of calculus and probability to actuarial science. The foundations of financial mathematics, including the theory of interest. Prerequisite: Multivariable calculus. Pre- or corequisite: 216, 218, or 247. [3] (MNS)


MATH 247. Probability. Combinatorics, probability models (binomial, Poisson, normal, gamma, etc.) Stochastic independence, generating functions, limit theorems and types of convergence, bivariate distributions, transformations of variables. Markov processes, applications. Prerequisite: Multivariable calculus and linear algebra. Except for students with extremely strong backgrounds, 218 should be taken prior to 247. [3] (MNS)


MATH 252. History of Mathematics. Major developments in mathematics from ancient times to the early twentieth century. Emphasis both on the historical perspective and the mathematics; assignments include many exercises and theorems. Highly recommended for teacher candidates. Prerequisite: Multivariable calculus and Linear algebra. [3] (MNS)

MATH 253. Error-Correcting Codes and Cryptography. Applications of algebra to reliability and secrecy of information transmission. Error-correcting codes, including linear, Hamming, and cyclic codes, and possibly BCH or Reed-Solomon codes. Cryptography, including symmetric-key, DES and RSA encryption. Prerequisite: Linear algebra. [3] (MNS)


MATH 259. Advanced Calculus. Advanced treatment of multivariable calculus. Differentiation of functions of several variables, including inverse and implicit function theorems. Vector differential calculus. Integration of functions of several variables. Vector integral calculus, including Stokes’ theorem. Prerequisite: Multivariable calculus and Linear algebra. No credit for students who have completed 229. [3] (MNS)

MATH 260. Introduction to Analysis. Properties of real numbers, compactness and completeness. Limits, sequences and series, uniform convergence, and power series. Basic properties of functions on the real line,
and the elementary theory of differentiation and integration. Emphasis on methods of proof used in advanced mathematics courses. Prerequisite: multivariable calculus and linear algebra. [3] (MNS)


MATH 267. Selected Topics for Undergraduates. Topics vary. May be repeated for a total of 12 credits in 267 and 297 combined if there is no duplication in topic. Students may enroll in more than one section of this course each semester. Prerequisite: multivariable calculus and linear algebra. [1-3; maximum of 12 credits total for all semesters of MATH 267 and 297] (No AXLE credit)

MATH 269. Senior Thesis. A written presentation of research results, original for the student but not usually original in the larger sense. The regulations governing the writing of a master of arts thesis in mathematics will apply to the writing of the senior thesis. [3] (No AXLE credit)

MATH 270. Differential Topology. Manifolds; submanifolds; tangent and vector bundles. Vector fields and flows, Lie brackets, distributions, and the Frobenius theorem. Sard's theorem; transversality and intersection theory; degree theory and applications. Tensors and differential forms; the exterior derivative; Stokes' theorem and integration; de Rham cohomology. Prerequisite: linear algebra and either 242, 243, or 272a. [3] (MNS)


MATH 274. Combinatorics. Elements of enumerative analysis including permutations, combinations, generating functions, recurrence relations, the principle of inclusion and exclusion, and Polya's theorem. Some special topics will be treated as class interest and background indicate (e.g., Galois fields, theory of codes, and block designs). Students unfamiliar with permutations, combinations, and basic counting techniques should take 215 prior to 274. Prerequisite: linear algebra. [3] (MNS)


MATH 283a. Modern Algebra. Group theory through Sylow theorems and fundamental theorem of finitely generated abelian groups. Prerequisite: 223. [3] (MNS)

MATH 283b. Modern Algebra. Introductory theory of commutative rings and fields, and additional topics such as Galois theory, modules over a principal ideal domain and finite dimensional algebras. Prerequisite: 283a. [3] (MNS)


MATH 288. Linear Optimization. An introduction to linear programming and its applications. Formulation of linear programs. The simplex method, duality, complementary slackness, dual simplex method and sensitivity analysis. The ellipsoid method. Interior point methods. Possible additional topics include the primal-dual algorithm, cutting planes, or branch-and-bound. Applications to networks, management, engineering, and physical sciences. Prerequisite: linear algebra and computer programming (CS 101 or 103). [3] (MNS)


MATH 297. Selected Topics. Topics of special interest. May be repeated for a total of 12 credits in 267 and 297 combined if there is no duplication in topic. Students may enroll in more than one section of this course each semester. [1-3; maximum of 12 credits total for all semesters of MATH 267 and 297] (No AXLE credit)

MATH 299. Independent Study. Reading and independent study in mathematics under the supervision of an advisor. Designed primarily for honors candidates, but open to others with approval by department chair. [Variable credit: 1-3 each semester, not to exceed 6 without departmental permission] (No AXLE credit)

Medicine, Health, and Society

MHS 099. Commons Seminar. Topics vary. [1] (No AXLE credit)

MHS 115F. First-Year Writing Seminar. Topics Vary. [3]

MHS 201. Fundamental Issues in Medicine, Health, and Society. A multidisciplinary introduction to the study of medicine, health, and society, drawing on the perspectives of anthropology, economics, history, political science and policy studies, philosophy, religious studies, and sociology. Guest lectures by representatives of the various disciplines. [3] (P)
