

MATHEMATICS

MATH-0031 (0) Math Access for Early/Middle

Teachers (3 hrs Lecture | 1.25 hrs Lab) This course covers selected topics from the K-12 math curriculum in preparation for the course MATH-2903. Topics include the real number system, integer and fraction arithmetic, proportions and percentages, exponents, the distributive property, solving linear equations, basic geometry, the Pythagorean theorem and the Cartesian coordinate system. This course can be used to satisfy the prerequisite for MATH-2903 but may not be used as a prerequisite for MATH-0042 or for any other mathematics course.

Note: This is a non-credit course offered over 12 weeks.

Requisite Courses: MATH-0031L (lab) (must be taken concurrently).

MATH-0041 (0) Mathematics Access I (3 hrs Lecture | 1.25 hrs Lab) This course covers mathematics from school math courses. Topics include the real number system, integer and fraction arithmetic, exponents and radicals, polynomial arithmetic and algebraic expressions, rational expressions, equation-solving techniques, coordinate geometry, lines, functions, and geometry of right-angled triangles. This course may be audited by students who have passed Applied Math 40S, Pre-Calculus 30S or Pre-Calculus 40S.

Note: This is a non-credit course offered over 12 weeks. Students who are registered in high school may not register in this course.

Requisite Courses: MATH-0041L (lab) (must be taken concurrently).

MATH-0042 (0) Mathematics Access II (3 hrs Lecture | 1.25 hrs Lab) This course covers mathematics from high school pre-calculus courses. Topics include fractional equations, factorization of polynomials, synthetic division, inequalities, relations and functions, exponential and logarithmic functions, circular functions, and trigonometry. This course may be audited by students who have passed Pre-Calculus 40S. MATH-0042 can be used in lieu of Pre-Calculus 40S Mathematics for all university prerequisites.

Note: This is a non-credit course offered over 12 weeks. Students who are registered in high school may not register in this course.

Requisite Courses: A minimum grade of 65% in Pre-Calculus 30S or a minimum grade of C+ in MATH-0041 or permission of the Department Chair [prerequisite(s)]; MATH-0042L (lab) (must be taken concurrently).

MATH-1103 (3) Introduction to Calculus I (3 hrs Lecture | 1.25 hrs Lab) This course covers differential calculus of a function of one variable. Topics include limits, continuity, and the differentiation of elementary functions (algebraic, trigonometric, inverse trigonometric, exponential and logarithmic functions). Applications include curve sketching, optimization problems, and related rate problems. The combined material from MATH-1103(3) Introduction to Calculus I and MATH-1104(3) Introduction to Calculus II is equivalent to MATH-1101(6) Introduction to Calculus.

Note: Students who have not obtained a minimum grade of 60% in Pre-Calculus 40S are strongly advised to take

MATH-0042 prior to registering in this course.

Restrictions: Students may not hold credit for this course and MATH-1101 | MATH-1102.

Requisite Courses: Pre-Calculus Mathematics 40S or MATH-0042 with a minimum grade of C or the former MATH-0040 [prerequisite(s)]; MATH-1103L (lab) (must be taken concurrently).

MATH-1104 (3) Introduction to Calculus II (3 hrs Lecture | 1.5 hrs Lab) This course covers single variable integral calculus, parametric equations and polar coordinates. Topics include: definite and indefinite integrals, L'Hôpital's rule, techniques of integration, improper integrals, parametric equations and polar coordinates. Applications covered include areas between curves, volumes of solids of revolution, and arc lengths of parametric curves. The combined material from MATH-1103(3) Introduction to Calculus I and MATH-1104(3) Introduction to Calculus II is equivalent to MATH-1101(6) Introduction to Calculus.

Restrictions: Students may not hold credit for this course and MATH-1101 | MATH-1102.

Requisite Courses: Minimum grade of C in MATH-1103 [prerequisite(s)]; MATH-1104L (lab) (must be taken concurrently).

MATH-1201 (3) Linear Algebra I (3 hrs Lecture) This course covers results related to systems of linear equations, matrices, determinants, properties of complex numbers, vector geometry, vector space properties of n-dimensional Euclidean space and an introduction to eigenvalues, eigenvectors and linear transformations.

Requisite Courses: Pre-Calculus Mathematics 40S or Applied Mathematics 40S or MATH-0042 [prerequisite(s)].

MATH-1301 (3) Applied Mathematics for Business & Administration (3 hrs Lecture) This is an applied course covering several standard methods in mathematics that are relevant to students majoring in business or administration. The course provides an introduction to the time value of money, matrices, linear programming and regression analysis with applications to business and administration. **Note:** This course cannot be used towards the major, minor, teachable major or teachable minor requirement for a degree in Mathematics.

Restrictions: Students who have already received credit for a 2000-level course in mathematics, with the exception of MATH-2901(3), MATH-2902(3), MATH-2903(3), and MATH-2904(3), cannot enroll in MATH-1301(3).

Requisite Courses: Applied Mathematics 40S or Precalculus Mathematics 40S or MATH-0042 [prerequisite(s)].

MATH-1401 (3) Discrete Mathematics (3 hrs Lecture | 1.5 hrs Lab) MATH-1401 introduces abstract mathematical thinking and proof techniques in mathematics. This course covers logic (simple and compound statements, truth tables, logical equivalencies, quantifiers); proof methods (direct, contrapositive, contradiction); elementary set theory (subsets, unions, intersections, set difference, power sets, Cartesian products); basic number theory

(divisibility, the division algorithm); mathematical induction; relations (binary, equivalence - including congruence modulo n , partial orders); functions (well-defined, one-to-one, onto, bijective, compositions, inverses). This course is intended for students planning to major in Mathematics.

Requisite Courses: Pre-Calculus Mathematics 40S or Applied Mathematics 40S or MATH-0042 [prerequisite(s)]; MATH-1401L (lab) (must be taken concurrently).

MATH-2102 (3) Differential Equations I (3 hrs Lecture)

This is an introduction to differential equations including the following topics: solution of first order equations, reduction techniques, solution of n th order linear differential equations, and the Laplace transform method.

Note: Students who have already completed MATH-1201(3) or the former MATH-2201(6) should inform registration staff that they have standing in one of the corequisite courses.

Requisite Courses: MATH-1101, or MATH-1103 and MATH-1104 [prerequisite(s)]; MATH-1201 (must be taken previously or at the same time as this course).

MATH-2103 (3) Differential Equations II (3 hrs Lecture)

This course covers further concepts and methods of solving differential equations. The contents include: power and Frobenius series solutions, matrix methods for systems of linear differential equations, and an introduction to partial differential equations (including Fourier series and the method of separation of variables).

Restrictions: Students may not hold credit for this course and MATH-2112.

Requisite Courses: MATH-2102 [prerequisite(s)]; MATH-2106 and MATH-2203 (must be taken previously or at the same time as this course).

MATH-2105 (3) Intermediate Calculus I (3 hrs Lecture)

Topics covered include sequences (including the formal definition of a convergent sequence); infinite series (convergence tests, power series, Taylor's theorem); and multivariable functions (limits and continuity, partial derivatives, chain rule, tangent planes, gradient and directional derivatives).

Note: Mathematics majors are strongly advised to take this course in their second year.

Restrictions: A student may not receive credit for both MATH-2105(3) and the former MATH-2101(6).

Requisite Courses: A minimum grade of C in MATH-1101(6) or in MATH-1104(3) [prerequisite(s)]; MATH-1201(3) or the former MATH-2201(6) (must be taken previously or at the same time as this course).

MATH-2106 (3) Intermediate Calculus II (3 hrs Lecture)

Topics covered include polar coordinates; optimization of multivariable functions (extrema, Lagrange multipliers); multiple integrals (double and triple integrals, applications, change of variable, cylindrical and spherical coordinates, Jacobians); vector functions; vector calculus (including line integrals and Green's theorem). Additional topics from vector calculus, such as Stokes' theorem and the Divergence theorem, will be taught if time permits.

Note: Mathematics majors are strongly advised to take this course in their second year.

Requisite Courses: MATH-2105 and MATH-1201 [prerequisite(s)].

MATH-2202 (3) Cryptography and Other Applications of Algebra (3 hrs Lecture)

This course will introduce students to modern applications of algebraic structures. It begins with a study of the fundamental properties of finite fields and their relationship with geometry. The course continues by studying such applications as error-correcting codes, cryptography, design of experiments and fast arithmetic.

Requisite Courses: MATH-1201 and MATH-1401 or permission of instructor [prerequisite(s)].

MATH-2203 (3) Linear Algebra II (3 hrs Lecture)

This course covers finite dimensional vector spaces; linear transformations and matrices; change of bases; eigenvalues and eigenvectors; and diagonalization; and inner product spaces.

Requisite Courses: MATH-1201(3) [prerequisite(s)].

MATH-2405 (3) Real Analysis I (3 hrs Lecture)

This course lays the theoretical foundation of single-variable calculus by providing a careful introduction to several fundamental concepts of analysis on the real line, and it provides a gateway to more advanced studies in analysis, topology and set theory. Topics covered include: functions acting on sets; countable and uncountable sets; suprema and infima; properties of the real numbers including completeness, the Archimedean property and density of the rational numbers in the real numbers; sequence convergence, monotone sequences, subsequences, the Bolzano-Weierstrass theorem and Cauchy sequences; limits of functions; continuous functions including proofs of the extreme and intermediate value theorems.

Requisite Courses: Minimum grade of C in both MATH-1104 and MATH-1401 [prerequisite(s)].

MATH-2413 (3) Introduction to Mathematical Finance

(3 hrs Lecture) This course gives an introduction to the mathematics of finance, an area of applied mathematics concerned with financial markets. Topics include present value analysis; geometric Brownian motion and its suitability as a model of stock prices; option pricing; the Arbitrage Theorem; derivations of the Black-Scholes formula; and portfolio selection. The approach emphasizes underlying mathematical tools and their derivation.

Requisite Courses: MATH-1201, either STAT-1301, STAT-1401 or STAT-1501, and either MATH-1103, MATH1101, or MATH-1102 [prerequisite(s)].

MATH-2501 (3) Introduction to Number Theory (3 hrs

Lecture) This course explores properties of integers, linear Diophantine equations, Fermat's Theorem, congruences, and quadratic residues.

Requisite Courses: MATH-1401 and at least 3 additional credit hours in Mathematics at the 1000 level or above [prerequisite(s)].

MATH-2612 (3) Mathematical Statistics I (3 hrs

Lecture) This course provides students with a firm foundation in probability theory, which is necessary for a complete understanding of advanced statistics. Topics

include combinatorial methods, probability, random variables, probability distributions and densities, joint and conditional distributions, mathematical expectation, special discrete probability distributions, and the continuous uniform and exponential distributions. Exam, term tests and assignments are utilized for student evaluation.

Cross-listed: STAT-2612

Restrictions: Students may not hold credit for this course and MATH-3611 | STAT-2612 | STAT-3611.

Requisite Courses: STAT-1302(3) or STAT-2001(3) [prerequisite(s)]; MATH-2105(3) (must be taken previously or at the same time as this course).

MATH-2903 (3) Mathematics for Early/Middle Years

Teachers I (3 hrs Lecture | 1.25 hrs Lab) This course is for prospective elementary or middle years teachers who wish to gain a thorough understanding of the mathematics underpinning many of the topics taught in the K-8 curriculum. Topics include discrete math (logic and deductive reasoning, proof techniques, sets), properties of number systems (natural numbers, rational numbers, irrational numbers, real numbers), number theory (algorithms, numeration systems, Euclidean algorithm, prime factorization, modular arithmetic, divisibility, greatest common factors and least common multiples), ratios and proportional reasoning and the role of algebra and functions in problem solving.

Restrictions: This course may not be used towards the major or minor requirement for a degree in Mathematics. Only students registered in the Faculty of Education program may register in this course.

Requisite Courses: At least one of Pre-Calculus Mathematics 40S or MATH-0042 or the former MATH-0040 or a grade of 65% or higher in Applied Mathematics 40S or a grade of C+ or higher in MATH-0041 or a grade of C+ or higher in MATH-0031 [prerequisite(s)]; MATH-2903L (lab) (must be taken concurrently).

MATH-2904 (3) Mathematics for Early/Middle Years

Teachers II (3 hrs Lecture | 2 hrs Lab) This course is for prospective elementary and middle years teachers who wish to gain a thorough understanding of the mathematics underpinning many of the topics in the K-8 curriculum. Topics include probability and statistics (measures of centre and variation, permutations and combinations, probability rules, expected value), measurement (metric system and US measurement system, perimeter, area, volume, Pythagorean theorem), and Euclidean geometry (angles, polygons and 3-dimensional shapes, Euclid's axioms, congruence, coordinate geometry, transformations of the plane).

Requisite Courses: MATH-2903 or 3 credit hours of mathematics at the 1000 level or above, excluding courses MATH-2901 and MATH-2902 [prerequisite(s)]; MATH-2904L (lab) (must be taken concurrently).

MATH-3101 (6) Introduction to Mathematical Analysis

(3 hrs Lecture) This course provides a careful treatment of the basic concepts of mathematical analysis including properties of the real numbers, countable and uncountable sets, the topology of metric spaces including compactness, connectedness, sequence/series convergence, continuity, and complete metric spaces. Rigorous proofs of the

Heine-Borel theorem, the extreme value theorem, and the intermediate value theorem are given. Other topics studied include differentiation, Riemann-Stieltjes integration, normed linear spaces, uniform convergence and the Stone-Weierstrass theorem, and Fourier analysis.

Requisite Courses: MATH-2405(3) and MATH-2106(3), and MATH-2203(3) or MATH-2221(3) [prerequisite(s)].

MATH-3103 (3) Methods in Advanced Calculus

(3 hrs Lecture) This course covers methods and applications of advanced calculus. Topics are chosen from: differentiation and integration of vector valued functions; arc length and speed; curvature and general motion in 3-dimensional space; vector fields, line integrals and surface integrals; the fundamental theorems of vector analysis (Green's Theorem, Stokes' Theorem, and the Divergence Theorem); Fourier series and other topics in harmonic analysis.

Requisite Courses: MATH-2106 [prerequisite(s)].

MATH-3202 (3) Group Theory

(3 hrs Lecture) This course studies symmetry groups of regular polygons and Platonic solids, permutations and permutation groups; abstract groups, cosets, homomorphisms, subgroups, normal subgroups and quotient groups; isomorphism theorems, Sylow theorems, classification of finitely generated Abelian groups; group actions and counting with Burnside's lemma.

Restrictions: Students may not hold credit for this course and MATH-3201 | MATH-4201.

Requisite Courses: MATH-1401 and MATH-2203 or the former MATH-2221 or the former MATH-2201 [prerequisite(s)].

MATH-3203 (3) Linear Algebra III

(3 hrs Lecture) This course introduces students to inner product spaces; properties of Hermitian and normal matrices; unitary matrices; factorization theorems; Schur's Theorem; the Spectral Theorem; the Cayley-Hamilton Theorem; and quadratic forms. At the discretion of the instructor, other advanced topics in linear algebra may be covered.

Requisite Courses: MATH-1401(3) and MATH-2203(3) and either MATH-1101(6) or MATH-1104(3) [prerequisite(s)].

MATH-3401 (3) Graph Theory

(3 hrs Lecture) This course includes the following topics: graph isomorphism, shortest path problem, Euler tours, trees, graph colourings and bipartite matchings.

Restrictions: Students may not hold credit for this course and MATH-2011 | MATH-3403.

Requisite Courses: MATH-1401 or permission of the instructor [prerequisite(s)].

MATH-3402 (3) Combinatorics

(3 hrs Lecture) This course includes the following topics: counting (inclusion-exclusion principle, addition and multiplication principles, pigeonhole principle, permutations, combinations, the binomial theorem), generating functions and recurrence relations.

Requisite Courses: MATH-1401 and one of MATH-1102 or MATH-1101 or MATH-1103 or MATH-1104 [prerequisite(s)].

MATH-3412 (3) Introduction to Operations Research

(3 hrs Lecture) This course provides a practical introduction to the formulation and solution of some economics and industrial problems using Operations Research models. It emphasizes model-building and problem-solving using computer packages. Topics covered are chosen from linear programming, transportation, assignment and transshipment problems, network models, integer programming, nonlinear programming, decision making, inventory models, and queuing theory.

Cross-listed: STAT-3412(3).

Restrictions: Students may not hold credit for this course and STAT-3412.

Requisite Courses: MATH-1201 or MATH-2201 or ECON-3201 or permission of the instructor [prerequisite(s)].

MATH-3612 (3) Mathematical Statistics II (3 hrs

Lecture) This course studies the continuous probability distributions and their general properties, distributions of functions of random variables, sampling distributions, including t and F and introduction to estimation and theory of hypotheses testing.

Cross-listed: STAT-3612(3).

Restrictions: Students may not hold credit for this course and STAT-3612.

Requisite Courses: MATH-2612|STAT-2612 (or the former MATH-3611|STAT-3611) [prerequisite(s)]; MATH-2106 (Intermediate Calculus II) (must be taken previously or at the same time as this course).

MATH-4001 (3 or 6) Directed Readings in

Mathematics (3 hrs Directed Reading) This is a reading course available only to students in their third or fourth year. A topic is arranged by mutual written agreement between the student and a Supervisor. The student is required to meet the Supervisor weekly.

Note: Students must have a minimum GPA of 3.0 in all mathematics courses, at least one 3000-level course and written permission of the instructor and the Department Chair.

Restrictions: Department Permission Required. Instructor Permission Required.

Requisite Courses: A minimum GPA of 3.0 in all Mathematics courses, at least one 3000-level Mathematics course and written permission of the instructor and the Department Chair [prerequisite(s)].

MATH-4003 (3) Topics in Mathematics (3 hrs Lecture)

This course covers an area in mathematics as selected by the instructor. Possible topics may be in algebraic combinatorics, functional analysis, Galois theory, representation theory, or advanced topics in combinatorics, graph theory, measure theory, or topology. Students should consult the instructor or Department Chair for the current topic. This course may be repeated for credit when the topic varies.

MATH-4101 (3) Complex Analysis (3 hrs Lecture) This course studies construction of the complex numbers from the reals, Cauchy's theorems, Laurent Series, evaluating line integrals by means of residues, Cauchy-Riemann equations, conformal mapping, harmonic functions, Riemann sphere, Riemann surfaces, analytic continuation

and monodromy theorem.

Restrictions: Honours Form Required. Students may not hold credit for this course and MATH-3102.

Requisite Courses: MATH-2106 or permission of the instructor [prerequisite(s)].

MATH-4202 (3) Rings and Fields (3 hrs Lecture) This course is a study of field axioms, finite and infinite fields, integral domains, fraction fields, division rings, abstract rings, polynomial rings, PID's and UFD's, Galois Theory; solvability of cubic and quartic, unsolvability of the quintic and other classical mathematical problems.

Restrictions: Students may not hold credit for this course and MATH-3201 | MATH-4201.

Requisite Courses: MATH-3202 [prerequisite(s)].

MATH-4204 (3) Topics in Algebra (3 hrs Lecture) This course explores topics from one or more of the following areas: module theory, Galois theory, Sylow theory, representation theory, matrix groups. The content varies from year to year. Please consult the Department of Mathematics & Statistics for a detailed course description in any given year. This course may be repeated for credit when the topic varies.

Experimental Course - This course is offered on a trial basis to gauge interest in the topic. Students who successfully complete this course receive credit as indicated.

Restrictions: Instructor Permission Required.

Requisite Courses: MATH-3202 [prerequisite(s)].

MATH-4401 (3) Networks, Graph Theory and Combinatorial Optimization (3 hrs Lecture)

Topics in this course are chosen from algorithmic complexity and problem classification, trees, distance invariants, Steiner trees, network flows and their applications, PERT networks, connectivity, optimal matchings, packings and coverings, colourings, perfect graphs and graph classes, planar graphs, extremal graph theory, and Ramsey theory.

Restrictions: Students may not hold credit for this course and MATH-3013.

Requisite Courses: MATH-3401(3) [prerequisite(s)].

MATH-4403 (3) Set Theory (3 hrs Lecture) This course introduces concepts of set theory essential to modern mathematics. Topics include axioms for sets, infinite sets, cardinality, ordinal and cardinal numbers, and ordered sets.

Requisite Courses: One of MATH-2405, MATH-2501, MATH-3202, MATH-3401 or MATH-3402 [prerequisite(s)].

MATH-4602 (3) Measure Theory and Integration (3

hrs Lecture) Topics in this course include Lebesgue measure and integration, abstract measure theory and integration, Banach spaces and L_p spaces. Principal results such as Littlewood's three principles, Hölder's inequality, the Riesz-Rischer theorem, the Radon-Nykodym theorem and Fubini's theorem are studied.

Restrictions: Students may not hold credit for this course and MATH-3602.

Requisite Courses: MATH-3101 [prerequisite(s)].

MATH-4603 (3) Topology (3 hrs Lecture) This course is a study of topological spaces and their applications. Topics to

be studied will include separation axioms, covering properties, product spaces, quotient spaces, filters, nets, convergence, compactness and connectedness.

Restrictions: Students may not hold credit for this course and MATH-3602.

Requisite Courses: MATH-3101 (must be taken previously or at the same time as this course).