UR Mathematics: Undergraduate Course Catalog

MATH 140: Foundations of Calculus

Class info: Must register for recitation when registering for main course.

This course covers pre-calculus material and is intended for students lacking the algebra and trigonometry background necessary to perform successfully in MATH 141. Topics include MATH 140 covers algebra and properties of polynomial, root, rational functions, exponential, logarithmic, and trigonometric functions. After completing this course students are ready to take MATH 141. MATH 140 cannot be taken after completing MATH 141 or MATH 161 or higher.

Offered: Fall

MATH 141: Calculus I

Class info: You must register for a recitation when registering for the main course.

Prerequisites: MATH 140 or a precalculus course in high school.

Analysis of the elementary real functions: algebraic, trigonometric, exponentials and their inverses and composites. Their graphs and derivatives. Topics include limits, continuity, asymptotes, the definition of the derivative, derivatives and derivative rules for algebraic, trigonometric, exponentials, and logarithms. Implicit differentiation, related rates, linear approximation, differentials, mean value theorem, maxima and minima, curve sketching, l'Hospital's rule. MATH 141, 142, and 143 is a three-semester sequence that covers, at a slower pace, exactly the same material as the two-semester sequence, MATH 161 and 162. This course uses the Tuesday/Thursday 08:00-09:30am Common Exam time. This course cannot be taken for credit after completing any of MATH 141, 142, 143, 161, or 162. Students who want to repeat a course for a grade need to discuss their situation with CCAS in Lattimore 312 before registering for the course.

Offered: Fall/Spring/Summer

MATH 142: Calculus II

Class info: You must register for a recitation when registering for the main course.

Prerequisites: MATH 141.

Calculus of algebraic, logarithmic, exponential, and trigonometric functions and their inverses. The definite integral, the fundamental theorem of calculus, geometric and physical applications

including areas, volumes, work, and arc length. Techniques of integration including substitution rule, integration by parts, trigonometric substitution, partial fractions. Improper integrals. This course uses the Tuesday/Thursday 08:00-09:30am Common Exam time. This course cannot be taken for credit after completing MATH 143 or 162. Students who want to repeat a course for a grade need to discuss their situation with CCAS in Lattimore 312 before registering for the course.

Offered: Fall/Spring/Summer

MATH 143: Calculus III

Class info: You must register for a recitation when registering for the main course.

Prerequisites: MATH 141 and 142.

This is the third semester of a three-semester calculus sequence. Calculus with parametric curves and polar coordinates. Sequences, series, tests for convergence including comparison tests, integral test, alternating series test, ratio test, root test. Taylor and Maclaurin series. This course uses the Tuesday/Thursday 08:00-09:30am Common Exam time. This course cannot be taken for credit after completing MATH 162. Students who want to repeat a course for a grade need to discuss their situation with CCAS in Lattimore 312 before registering for the course.

Offered: Fall/Spring/Summer

MATH 150: Discrete Mathematics

Logic, introduction to proofs, mathematical induction, set operations, algorithms and Big-O, introduction to number theory, recurrence relations, techniques of counting, graphs, as well as specific questions given by the "Towers of Hanoi," and Euler's "7 bridges of Konigsberg problem." Required for majors in Computer Science and Data Science. This course uses the Tuesday/Thursday 08:00-09:30am Common Exam time.

Offered: Fall/Spring/Summer

MATH 150A: Discrete Mathematics Module for MATH 171

Prerequisites: Permission of instructor required. This module is only open to students in Honors Calculus.

Passing the course will grant a waiver to the MATH 150 requirement for the Computer Science program, but does not fulfill any other requirements that MATH 150 may fulfill. This course uses the Tuesday/Thursday 08:00-09:30am Common Exam time.

Offered: Fall/Spring

MATH 161: Calculus IA

Class Info: YOU MUST REGISTER FOR A RECITATION WHEN REGISTERING FOR THE MAIN COURSE.

Prerequisites: MATH 140 completed with at least an A- or a precalculus course in high school.

Analysis of the elementary real functions: algebraic, trigonometric, exponentials and their inverses and composites. Their graphs and derivatives. Topics include limits, continuity, asymptotes, the definition of the derivative, derivatives and derivative rules for algebraic, trigonometric, exponentials, and logarithms. Implicit differentiation, related rates, linear approximation, differentials, mean value theorem, maxima and minima, curve sketching, l'Hospital's rule, the definite integral, the fundamental theorem of calculus, and the substitution rule for integration. This course uses the Tuesday/Thursday 08:00-09:30am Common Exam time. Students can drop from MATH 161 to MATH 141 up to one week following the first exam in MATH 161. Interested students should speak with their professor for details. This course cannot be taken for credit after completing any of MATH 141, 142, 143, or 162. Students who want to repeat a course for a grade need to discuss their situation with CCAS in Lattimore 312 before registering for the course.

Offered: Fall/Spring/Summer

MATH 162: Calculus IIA

Class info: YOU MUST REGISTER FOR A RECITATION WHEN REGISTERING FOR THE MAIN COURSE.

Prerequisites: MATH 161 or equivalent.

Applications of integration including areas, volumes, work, and arc length. Techniques of integration including integration by parts, trigonometric substitution, partial fractions. Improper integrals. Calculus with parametric curves and polar coordinates. Sequences, series, tests for convergence including comparison tests, integral test, alternating series test, ratio test, root test. Taylor and Maclaurin series. NOTE: Either MATH 164 or 165 can be taken after MATH 162 or 143. This course uses the Tuesday/Thursday 08:00 am to 09:30 am common exam time. Students can drop from MATH 162 to MATH 142 up to one week following the first exam in MATH 162. Interested students should speak with their professor for details. This course cannot be taken for credit after completing MATH 143. Students who want to repeat a course for a grade need to discuss their situation with CCAS in Lattimore 312 before registering for the course.

Offered: Fall/Spring/Summer

MATH 164: Multivariable Calculus

Class info: You must register for a recitation when registering for the main course.

Prerequisites: MATH 143, 162, or 172.

Equations of lines and planes, quadric surfaces, space curves, partial derivatives, linear approximation, directional derivatives, extrema, Lagrange multipliers, double/triple integrals including cylindrical and spherical coordinates. Line, surface, and volume integrals, divergence theorem, Stokes' theorem. MATH 162 (or equivalent) is a strict prerequisite and must be completed before taking 164. MATH 162 and 164 cannot be taken concurrently. This course uses the Tuesday/Thursday 08:00-09:30am Common Exam time.

Offered: Fall/Spring/Summer

MATH 165: Linear Algebra with Differential Equations

Prerequisites: MATH 143, 162 or 172. NOTE: MATH 164 is not a prerequisite for MATH 165.

Matrix algebra and inverses, Gaussian elimination and solving systems of linear equations, determinants, vector spaces, linear dependence, bases, dimension, eigenvalue problems. First order differential equations including separable equations and linear equations. Linear nth order differential equations with constant coefficients, undetermined coefficients, first order linear homogenous systems of differential equations. Applications of differential equations to physical, engineering, and life sciences. MATH 162 (or equivalent) is a strict prerequisite and must be completed before taking 165. MATH 162 and 165 cannot be taken concurrently. This course uses the Tuesday/Thursday 08:00-09:30am Common Exam time.

Offered: Fall/Spring/Summer

MATH 171: Honors Calculus I

Students with strong mathematical ability should consider taking the honors calculus sequence, MATH 171-174, designed for students interested in mathematics. These courses teach calculus as an interesting subject in its own right and place an emphasis on theoretical understanding as well as on mastering technical skills. Students completing the MATH 171-174 sequence earn 20 credit hours (24 if they received AP credit) and will have completed all of the foundation requirements for a major or minor in mathematics (MATH 161-165), as well as MATH 235. Students taking MATH 171 who are interested in majoring in computer science should also register for the one credit course MATH 150A in order to satisfy the Computer Science's MATH 150 requirement. This course uses the Tuesday/Thursday 08:00-09:30am Common Exam time.

Offered: Fall

MATH 172: Honors Calculus II

Prerequisites: MATH 171

This course is a continuation of MATH 171. Note: The honors calculus sequence regulation requires that students earn at least a B- in honors calculus to continue to the next course in sequence. This course uses the Tuesday/Thursday 08:00-09:30am Common Exam time.

Offered: Spring

MATH 173: Honors Calculus III

Prerequisites: MATH 172 or permission of instructor.

Third course in the honors sequence, MATH 171-174. These courses teach calculus as an interesting subject in its own right and place an emphasis on theoretical understanding as well as on mastering technical skills. Students completing the MATH 171-174 sequence earn 20 credit hours (24 if they received AP credit) and will have completed all of the foundation requirements for a major or minor in mathematics (MATH 161-165), as well as MATH 235. This course uses the Tuesday/Thursday 08:00-09:30am Common Exam time.

Offered: Fall

MATH 174: Honors Calculus IV

Prerequisites: MATH 173

This course is a continuation of MATH 173.

Offered: Spring

MATH 190: Topics in Problem Solving

Prerequisites: MATH 165 or instructor permission

General techniques and approaches to solving difficult nonstandard problems such as those on the Putnam examination.

Offered: Fall

MATH/PHIL 199: The Infinite

In this interdisciplinary seminar course, we will try to understand "the infinite", one of the most fascinating and elusive concepts in human culture. It plays a vital role in biblical thought, ancient Greek philosophy and mysticism, scholastic theology, nineteenth century romantic literature, ancient and modern mathematics, and physics. A small sample of the questions we will explore are: 1) How is it possible to even think about the infinite? 2) What does it mean for God to be infinite? 3) The infinite or the finite, which is better, and why has the answer differed in different cultures? Readings will be from numerous sources, including Plato, Aristotle, Euclid, Aquinas, Nicholas of Cusa, Newton, Berkeley, Wordsworth, Cantor, and Borges, as time permits.

Offered: Irregular Schedule

MATH 200: Transition to Advanced Mathematics

Prerequisites: MATH 162 or equivalent.

Techniques and methods of proof used in mathematics and computer science. Logical reasoning, mathematical induction, relations, functions. Applications to group theory or real analysis. A significant focus of this course is developing proof writing skills, which are central to the transition to higher mathematics. Students cannot take MATH 200 for credit after completion of MATH 172 or 235. Students wishing an exception can petition the mathematics department undergraduate committee by emailing mathdugs@lists.rochester.edu.

Offered: Fall/Spring

***Course section Math 200WM*: Writing module for Math 200. Concurrent registration in Math 200 is required.

Offered: Fall/Spring

MATH/STAT 201: Introduction to Probability

Cross Listed: MATH 201 (P), STAT 201

Prerequisites: MATH 162 or equivalent. MATH 164 recommended.

Probability spaces; combinatorial problems; discrete and continuous distributions; independence and dependence; moment generating functions; joint distributions; expectation and variance; sums of random variables; central limit theorem; laws of large numbers. MATH 162 (or equivalent) is a strict prerequisite and must be completed before taking 201. MATH 162 and 201

cannot be taken concurrently. This course uses the Tuesday/Thursday 08:00-09:30am Common Exam time.

Offered: Fall/Spring/Summer

MATH 202: Introduction to Stochastic Processes

Prerequisites: (MATH 201 or STAT 201) and (MATH 165 or MATH 173)

Theory and applications of random processes, including Markov chains, Poisson processes, birth-and-death processes, random walks.

Offered: Spring

MATH 208: Operations Research I: Linear Programming and Deterministic Models

Prerequisites: MATH 165 (or MATH 173) and MATH 164 (or MATH 174)

Linear programming is emphasized – including the simplex algorithm, sensitivity analysis, dual problems, and related techniques. Integer programming, network models, Dynamic programming, and the KKT conditions are also discussed.

Offered: Fall

MATH 209: Operations Research II: Stochastic Models and Queueing Theory

Prerequisites: MATH 208 and MATH 201. MATH 202 is helpful but not necessary.

Have you ever wondered how large companies are able to send such a vast array of products to your doorstep in a day or two, at negligible cost to the consumer? In this course you will learn how. This course covers stochastic models, queueing theory, and decision making in the presence of uncertainty. Applications, such as supply-chain modeling, vaccine distribution, and the newsvendor problem are explored extensively. Topics covered: Newsvendor problem, Little's law, queueing theory, Markov decision processes, supply-chain modeling and pooling, multi-echelon systems, effects of uncertainty and the bullwhip effect.

Offered: Spring

MATH 210: Introduction to Financial Mathematics

Prerequisites: FIN 205 and 206 and (MATH 143 or 162) and (one of STAT 211, 212, 213, ECO 230, or MATH 201).

Mathematical concepts and techniques underlying finance theory; arbitrage pricing theory and option pricing. Finance track and FEC students should take FIN 205/206 before MATH 210. Other students can seek instructor permission.

Offered: Fall/Spring

MATH 215: Fractals and Chaotic Dynamics

Prerequisites: MATH 162 or MATH 143 or MATH 171. A course with proofs such as MATH 200 or MATH 235 is recommended if you have not taken MATH 171.

This course covers fractal geometry with applications to chaos theory and related computer software.

Offered: Fall (odd years)

MATH 217: Mathematical Models in Political Science

Prerequisites: Some mathematical sophistication required. MATH 141 or MATH 161 or MATH 171 suggested.

Elementary game theory with applications: Nash equilibria, prisoner's dilemma, chicken; measures of voting power, social choice, Arrow's Theorem. Offered fall, even years.

Offered: Fall (even years)

MATH 218: Mathematical Modeling in Life Sciences

Prerequisites: MATH 165 or MATH 173

This course is aimed at building problem-solving ability in students through the development of mathematical models for certain real-life situations in the biological sciences. Models treated cover a variety of phenomena both discrete and continuous, linear and non-linear, deterministic and stochastic. Some topics that might be treated are Leslie Matrices in Demographics, Exponential and Logistic growth, Gompertz growth in tumors, Hardy-Weinberg Law in population genetics, Lotka-Volterra predator-prey systems, principle of competitive exclusion,

the Kermack-McKendrick model of epidemics (and variants), Markov chain models (with the requisite intro to probability) and the stochastic pure birth process and epidemic models.

Offered: Spring (odd years)

MATH 230: Introduction to Number Theory

Prerequisites: MATH 172, MATH 200 or MATH 235.

Divisibility, primes, congruences, quadratic residues and quadratic reciprocity, primitive roots, and selected topics, with applications to cryptography and computer science.

Offered: Fall

MATH 233: Mathematical Cryptography

Prerequisites: MATH 171 or MATH 200 or MATH 235. MATH 230 is recommended but not necessary.

A mathematically-oriented introduction to modern cryptography: weaknesses of historical cryptosystems, modular arithmetic, primality testing and factorization algorithms, private-key/symmetric cryptosystems, public-key/asymmetric cryptosystems and key-sharing (including RSA and Diffie-Hellman). Additional topics may include zero-knowledge protocols, digital signatures, homomorphic encryption and secured computation, elliptic curve cryptography, lattice-based cryptography, and other applications such as digital voting and cryptocurrencies.

Offered: Irregular Schedule

MATH 235: Linear Algebra

Prerequisites: MATH 165. MATH 200 recommended.

Finite-dimensional vector spaces over R and C axiomatically and with coordinate calculations. Forms, linear transformations, matrices, eigenspaces, inner products. This course uses the Tuesday/Thursday 08:00-09:30am Common Exam time.

Offered: Fall/Spring/Summer

Course section Math 235WM*: Writing module for Math 235. **Concurrent registration with Math 235 is required.

Offered: Fall/Spring

MATH 236: Abstract Algebra I

Prerequisites: MATH 173 or MATH 235

Basic algebraic structures, including groups, rings, and fields with applications to specific examples.

Offered: Fall

*Course section Math 236WM: Writing module for Math 236. **Concurrent registration with Math 236 is required.**

Offered: Fall

MATH 236H: Abstract Algebra I (Honors)

Prerequisites: MATH 173 or MATH 235

Honors version of MATH 236.

Offered: Fall

*Course section Math 236HWM: Writing module for Math 236. **Concurrent registration with Math 236H is required.**

Offered: Fall

MATH 237: Introduction to Algebra II

Prerequisites: MATH 236 or 236H.

Continuation of MATH 236 covering field theory and Galois theory including proofs of the impossibility of trisecting angles, doubling the cube, squaring the circle, and solving 5th-degree polynomials'.

Offered: Fall

MATH 238: Combinatorics

Prerequisites: MATH 200, 235 or 171.

Permutations and combinations; enumeration through recursions and generating functions; Polya's theory of counting; finite geometrics and block designs; counting in graphs.

Offered: Fall

MATH 240: Introduction to Topology

Prerequisites: (MATH 173) or (MATH 164 and MATH 235) or (MATH 164 and MATH 200)

Review of set theory; metric spaces and topological spaces; functions and continuous functions; convergence, completeness, connectedness, and compactness; applications to surfaces.

Offered: Spring

*_Course section Math 240WM_: Writing module for Math 240. **Concurrent registration with Math 240 is required.**

Offered: Spring

MATH 240H: Introduction to Topology (Honors)

Prerequisites: (MATH 173) or (MATH 164 and MATH 235) or (MATH 164 and MATH 200).

Honors version of MATH 240.

Offered: Spring

*_Course section Math 240HWM_: Writing module for Math 240. **Concurrent registration with Math 240H is required.**

Offered: Spring

MATH 246: Set Theory

Prerequisites: MATH 200 or MATH 235 or MATH 171

Sets, relations, and mappings; cardinals and ordinals; axiom of choice and equivalents.

Offered: Irregular Schedule

MATH 248: Graph Theory

Prerequisites: (MATH 173 or MATH 235) or (MATH 165 and MATH 200).

Paths, trees, circuits. Bipartite graphs, matching problems, flow problems, coloring problems. Connectivity and Menger's theorem. Independent paths and sets. Planar graphs and Kuratowski's theorem.

Offered: Spring

MATH 250: Introduction to Geometry

Prerequisites: (MATH 173 or MATH 235 or MATH 235W) or (MATH 165 and MATH 200 or MATH 200W).

Foundations of geometry; isometry, similarity, inversions; introductions to affine, projective, and non-Euclidean geometries.

Offered: Irregular schedule

MATH 255: Differential Geometry

Prerequisites: MATH 164 and 235, or MATH 174.

Torsion, curvature; curves and surfaces in 3-space.

Offered: Fall

MATH 263: Theory of Ordinary Differential Equations

Prerequisites: MATH 165 or MATH 173

Theoretical approach to ordinary differential equations and the qualitative behavior of their solutions.

Offered: Spring (odd years)

MATH 265: Real Analysis I

Prerequisites: MATH 164 and MATH 235, or MATH 164 and MATH 200, or MATH 174

Real number system, continuity and uniform continuity, mean value theorems, bounded variation, Riemann-Stieltjes integral, sequences of functions.

Offered: Fall

*_Course section Math 265WM_: Writing module for Math 265. **Concurrent registration in Math 265 is required**

MATH 265H: Real Analysis I (Honors)

Prerequisites: MATH 164 and 235, or MATH 164 and 200, or MATH 174.

Honors version of MATH 265.

Offered: Fall

*_Course section Math 265HWM_: Writing module for Math 265H. **Concurrent registration in Math 265H is required.**

MATH 266: Real Analysis II

Prerequisites: MATH 265 or MATH 265H

Continuation of MATH 265/265H. Possible topics: a rigorous exposition of Fourier analysis; multivariable analysis; elementary theory of Hilbert and Banach spaces.

Offered: Irregular Schedule

MATH 272: Mathematical Theory of Quantum Computing

Prerequisites: (MATH 173 or 165) and (MATH 164 or 174)

An introduction to quantum computing from a mathematical perspective. This course provides a bridge to the field for students with a background in rigorous linear algebra; no prior knowledge of computing or quantum mechanics is necessary. Foundations of quantum mechanics are presented axiomatically, along with mathematical notions such as Hilbert spaces, tensor products, density operators, and mixed states. Also discussed are entanglement swapping, the EPR paradox, impossible devices, quantum gates, and algorithms, such as Shor's factorization and Grover's search.

Offered: Irregular Schedule

MATH 280: Introduction to Numerical Analysis

Prerequisites: MATH 235 or MATH 173.

Analyzes numerical methods for approximation, interpolation and integration of functions, solving ordinary differential equations, finding zeros.

Offered: Fall

MATH 282: Introduction to Complex Analysis

Prerequisites: MATH 164 or MATH 174 (MATH 200 or MATH 235 recommended unless you have taken MATH 174).

Complex differentiation and integration, analytic functions, singularities, residues, poles, power series, conformal mapping, with some applications.

Offered: Spring

MATH 282H: Introduction to Complex Analysis (Honors)

Prerequisites: (MATH 164 or MATH 174) and (MATH 240 or MATH 265H)

Honors version of MATH 282.

Offered: Spring

MATH 285: Partial Differential Equations

Prerequisites: (MATH 164 and MATH 165) or MATH 174

An introduction to mathematical methods and theory of partial differential equations.

Offered: Spring (even years)

MATH 300W: History of Mathematics

Prerequisites: MATH 171 or MATH 200 or MATH 235

The nature and style of mathematics in ancient Babylonia, Egypt, and Greece; medieval and Renaissance Europe; seventeenth-century Europe; and some aspects of the development of abstraction and rigor in analysis and set theory since 1700. This course has a limited number of seats. Students that need an upper-level writing course in mathematics can explore Writing Module (WM) courses or MATH 391W. See the Math Department website for more information.

Offered: Spring