**MATH-MATHEMATICS**

A student may not receive credit for a lower-division mathematics course if it serves as a prerequisite to a lower-division math course that the student had previously passed with a grade of C- or better.

Students without adequate placement to enroll in MATH 111, MATH 120 or MATH 210G can gain admission to the course by earning a C- or better in CCDM 114 N at an NMSU Community College campus, or in A S 103.

Students wishing to enroll in MATH 121G, MATH 142G, MATH 190G, MATH 191G, MATH 235, or STAT 251G must satisfy one of the following:

1. have passed the stated prerequisite course or an equivalent transfer course with a C- or better
2. have placed into the course with an adequate ACT Math score or through the Mathematics Placement Examination (MPE), the results of which will be made available to the student’s advisor. The MPE is given daily in Walden Hall when school is in session and during new student orientation programs.

**MATH 101. General Supplemental Instruction I**
1 Credit
Corequisite(s): MATH 120.

**MATH 102. General Supplemental Instruction II**
1 Credit
Corequisite(s): MATH 121G.

**MATH 107. Topics in Mathematics**
1-3 Credits
Topics to be announced in the Schedule of Classes. Maximum of 3 credits per semester. Total credit not to exceed 6 credits. Community Colleges only.
Prerequisite: consent of instructor.

**MATH 111. Fundamentals of Elementary Mathematics I**
3 Credits
Numbers and the four operations of arithmetic. Understanding and comparing multiple representations of numbers and operations, in particular how these representations build from whole numbers to integers to fractions and decimals. Applying properties of numbers and operations in contextual situations. Reasoning, communicating, and problem solving with numbers and operations. Applications to ratio, and connections with algebra. Taught primarily through student activities and investigations. Restricted to: EDUC,EPAR,E ED,ECED majors.
Prerequisite(s): ENGL 111G and grade of C or better in MATH 120.

**MATH 112G. Fundamentals of Elementary Math II**
3 Credits
Geometry and measurement. Multiple approaches to solving problems and understanding concepts in geometry. Analyzing and constructing two- and three-dimensional shapes. Measurable attributes, including angle, length, area, and volume. Understanding and applying units and unit conversions. Transformations, congruence, and symmetry. Scale factor and similarity. Coordinate geometry and connections with algebra. Reasoning and communicating about geometric concepts. Taught primarily through student activities and investigations.
Prerequisite(s): C or better in MATH 111.

**MATH 120. Intermediate Algebra**
3 Credits
Linear and algebraic functions as they arise in real world problems. Exponential and logarithmic functions. Equations and inequalities and their solutions considered symbolically, graphically and numerically.
Prerequisite: adequate score on the Mathematics Placement Examination.

**MATH 121G. College Algebra**
3 Credits
Fundamental concepts of functions, including algebraic and graphical properties. Fitting functions to data. Finding zeroes and extreme values. Solving systems of equations.
Prerequisites: Adequate math placement score or C or better in MATH 120.

**MATH 142G. Calculus for the Biological and Management Sciences**
3 Credits (2+2P)
Review of functions. Derivatives, exponential and logarithmic functions, antiderivatives and indefinite integrals, basic ordinary differential equations and growth models, with an emphasis on applications. Includes a significant writing component.
Prerequisite(s): C or better in MATH 121G.

**MATH 190G. Trigonometry and Precalculus**
4 Credits (3+2P)
Elementary functions used in the sciences with emphasis on trigonometric functions and their inverses. Polar coordinates. Complex numbers and Euler’s formula. Analytic geometry and vectors.
Prerequisite: adequate score on Mathematics placement exam or a C or better in MATH 121G.

**MATH 191G. Calculus and Analytic Geometry I**
4 Credits
Limits and continuity, theory and computation of derivatives, applications of derivatives, extreme values, critical points, derivative tests, L'Hopital's Rule.
Prerequisite(s): C or better in MATH 190G.

**MATH 192G. Calculus and Analytic Geometry II**
4 Credits
Riemann sums, the definite integral, antiderivatives, fundamental theorems, techniques of integration, applications of integrals, improper integrals, Taylor polynomials, sequences and series, power series and Taylor series.
Prerequisite(s): C or better in MATH 191G.

**MATH 192GH. Calculus and Analytic Geometry II Honors**
4 Credits (3+1P)
A more advanced treatment of the material of MATH 192G with additional topics. Consent of Instructor required. Restricted to Las Cruces campus only.
Prerequisite(s): Consent of Department.

**MATH 200. Directed Study**
1-3 Credits
May be repeated for a maximum of 6 credits. Graded S/U.
Prerequisite: consent of the instructor.

**MATH 210G. Mathematics Appreciation**
3 Credits
Mathematics and its role in the development and maintenance of civilization.
Prerequisites: High school algebra, and an adequate score on the Mathematics Placement Examination.
MATH 215. Fundamentals of Elementary Mathematics III
3 Credits
Probability, statistics, ratios, and proportional relationships. Experimental and theoretical probability. Collecting, analyzing, and displaying data, including measurement data. Multiple approaches to solving problems involving proportional relationships, with connections to number and operation, geometry and measurement, and algebra. Understanding data in professional contexts of teaching. Taught primarily through student activities and investigations.
Prerequisite(s): C or better in MATH 112.

MATH 235. Calculus for the Technical Student I
3 Credits
Intuitive differential and integral calculus with applications to engineering.
Prerequisite: C or better in MATH 190G.

MATH 236. Calculus for the Technical Student II
3 Credits
A continuation and extension of the material in MATH 235.
Prerequisites: C or better in MATH 235 or in MATH 192G.

MATH 279. Introduction to Higher Mathematics
3 Credits
Logic; sets, relations, and functions; introduction to mathematical proofs.
Prerequisite(s): C- or better in MATH 192.

MATH 280. Introduction to Linear Algebra
3 Credits
Systems of equations, matrices, vector spaces and linear transformations. Applications to computer science.
Prerequisite(s): Grade of C- or better in MATH 192G.

MATH 291G. Calculus and Analytic Geometry III
3 Credits
Vector algebra, directional derivatives, approximation, max-min problems, multiple integrals, applications, cylindrical and spherical coordinates, change of variables.
Prerequisite: grade of C or better in MATH 192G.

MATH 300. Readings
1-3 Credits
A selection of readings and reports in the mathematical sciences, the breadth and depth of which is deemed to fit the needs of the student. Graded S/U.
Prerequisite: consent of instructor.

MATH 316. Calculus with Hands-on Applications
3 Credits
This course, primarily for prospective teachers, is taught in an interactive laboratory format. Students design and construct physical objects for which the planning stage requires calculus techniques. All numerical computations are carried out on graphing calculators. Meets simultaneously with MATH 516, primarily for practicing teachers. Secondary math education majors may take course as a math elective. MATH 316 does not fulfill requirements for majors in mathematics.
Prerequisite(s): C or better in STAT 371 and either MATH 280 or MATH 480 or consent of instructor.
MATH 422. Financial Mathematics II
3 Credits
Bonds, swaps, exotic options, barrier options, Asian options, look back options, options with transaction costs, Fokker Plank theory, computing expectations, the Heath-Jarrow- Morton theorem, the Ho-Lee model, stochastic volatility models, exponential-affine models, numerical methods. This course is offered simultaneously with MATH 522.
Prerequisite: C or better in MATH 421 or consent of instructor

MATH 450. Introduction to Topology
3 Credits
Topological spaces: general spaces and specific examples such as metric spaces, Hausdorff spaces and/or normed vector spaces; separation axioms; continuity, compactness, connectedness; related theorems. Crosslisted with: MATH 520.
Prerequisite(s): MATH 332.

MATH 451. Introduction to Differential Geometry
3 Credits
Applies calculus to curves and surfaces in three dimensional Euclidean space.
Prerequisite(s): C or better in each of MATH 280 and MATH 391, or consent of instructor.

MATH 452. Foundations of Geometry
3 Credits
Topics in projective, axiomatic Euclidean or non-Euclidean geometries. Restricted to: Main campus only.
Prerequisite(s): C or better in MATH 331 or MATH 332.

MATH 454. Logic and Set Theory
3 Credits
Prerequisite(s): C or better in MATH 331 or MATH 332, or consent of instructor.

MATH 455. Elementary Number Theory
3 Credits
Covers primes, congruences and related topics.
Prerequisite: grade of C or better in MATH 331 or consent of instructor.

MATH 456. Abstract Algebra I: Groups and Rings
3 Credits
Group theory, including cyclic groups, homomorphisms, cosets, quotient groups and Lagrange's theorem. Introduction to rings: ring homomorphisms, ideals, quotient rings, polynomial rings, and principal ideal domains. Crosslisted with: MATH 526.
Prerequisite(s): MATH 331 or consent of instructor.

MATH 459. Survey of Geometry
3 Credits
Basic concepts of Euclidean geometry, ruler and compass constructions. May include topics in non-Euclidean geometry. For non-math majors. Restricted to: Main campus only.
Prerequisite(s): C or better in MATH 331 or MATH 332.

MATH 471. Complex Variables
3 Credits
A first course in complex function theory, with emphasis on applications.
Prerequisite(s): C- or better in MATH 391 or C- or better in both MATH 392 and MATH 291.

MATH 472. Fourier Series and Boundary Value Problems
3 Credits
Fourier series and methods of solution of the boundary value problems of applied mathematics.
Prerequisite(s): C- or better in MATH 392.

MATH 473. Calculus of Variations and Optimal Control
3 Credits
Euler's equations, conditions for extrema, direct methods, dynamic programming, and the Pontryagin maximal principle.
Prerequisite(s): C- or better in MATH 392.

MATH 474. Matrix Theory and Applied Linear Algebra
3 Credits
An application driven course, whose topics include rectangular systems, matrix algebra, vector spaces and linear transformations, inner products, and eigenvalues and eigenvectors. Applications may include LU factorization, least squares, data compression, QR factorization, singular value decomposition, and search engines.
Prerequisite(s): C or better in any 300-level course with a MATH or STAT prefix.

MATH 475. Advanced Linear Algebra
3 Credits
Rigorous treatment of vector spaces and linear transformations including canonical forms, spectral theory, inner product spaces and related topics.
Prerequisite: grade of C or better in MATH 331.

MATH 491. Introduction to Real Analysis I
3 Credits
Rigorous discussion of the topics introduced in calculus. Sequences, series, limits, continuity, differentiation.
Prerequisite: grade of C or better in MATH 332 or consent of instructor.

MATH 492. Introduction to Real Analysis II
3 Credits
Continuation of MATH 491. Integration, metric spaces and selected topics.
Prerequisite(s): C- or better in MATH 491 or consent of instructor.

MATH 498. Directed Reading
1-6 Credits
May be repeated for a maximum of 6 credits. Graded S/U.

MATH 499. Complex Analysis
3 Credits
Rigorous treatment of complex differentiation and integration, properties of analytic functions, series and Cauchy's integral representations. Crosslisted with: MATH 529.
Prerequisite(s): MATH 332.

MATH 501. Introduction to Differential Geometry
3 Credits
Same as MATH 451 with additional work for graduate students.

MATH 502. Foundations of Geometry
3 Credits
Same as MATH 452 with additional assignments for graduate students.

MATH 505. Elementary Number Theory
3 Credits
Same as MATH 455 with additional assignments for graduate students.
MATH 511. Fundamentals of Elementary Mathematics I
3 Credits (3+1P)
Topics from real numbers, geometry, measurement, and algorithms, incorporating calculator technology. Intended for K-8 teachers. As part of course students mentor MATH 111 undergraduates. Does not fulfill degree requirements for M.S. in mathematics.

MATH 512. Fundamentals of Elementary Mathematics II
3 Credits (3+1P)
Real numbers, geometry, and statistics, incorporating calculator technology. Intended for K-8 teachers. Students serve as mentors to MATH 112 undergraduates. Does not fulfill degree requirements for M.S. in mathematics.

MATH 513. Fundamentals of Algebra and Geometry I
3 Credits (3+1P)
Algebra and metric geometry, incorporating appropriate calculator technology. Intended for K-8 teachers. Students serve as mentors to MATH 313 undergraduates. Does not fulfill degree requirements for M.S. in mathematics.

MATH 516. Calculus with Hands-on Application
3 Credits
This course, primarily for in-service teachers, is taught in an interactive laboratory format. Students design and construct physical objects for which the planning stage requires calculus techniques. All numerical computations are carried out on graphing calculators. Meets simultaneously with Math 316, primarily for prospective teachers. Does not fulfill degree requirements for M.S. in Mathematics.
Prerequisite(s): MATH 511 and MATH 512 or consent of instructor.

MATH 521. Financial Mathematics I: Portfolio Optimization
3 Credits
Complete and incomplete markets, optimal investment paths, dynamic optimization, the Black-Scholes model, European options, American options. May be repeated up to 3 credits.
Prerequisite(s): STAT 515.

MATH 522. Financial Mathematics II
3 Credits
Prerequisite: MATH 521.

MATH 523. Numerical Optimization and Applications to Financial Mathematics
3 Credits
Dynamic optimization of a monopolist, trading off inflation and unemployment, the optimal adjustment of labor demand, infinite planning horizon, the optimal investment path of a firm, the optimal social saving behavior, phase-diagram analysis, optimal control theory, the political business cycle, the dynamics of a revenue-maximizing firm, economic examples of state-space constraints. This course is offered simultaneously with MATH 423.
Prerequisite: MATH 521.

MATH 524. Logic and Set Theory
3 Credits
Same as MATH 454 with additional assignments for graduate students. Crosslisted with: MATH 454.
Prerequisite(s): consent of instructor.

MATH 525. Advanced Linear Algebra
3 Credits
Same as MATH 481 with additional work for graduate students. May be repeated up to 3 credits.

MATH 526. Abstract Algebra I: Groups and Rings
3 Credits
Same as MATH 456 with additional work for graduate students. Crosslisted with: MATH 456.
Prerequisite(s): consent of instructor.

MATH 527. Introduction to Real Analysis I
3 Credits
Same as MATH 491 with additional work for graduate students.

MATH 528. Introduction to Real Analysis II
3 Credits
Same as MATH 492 with additional work for graduate students.

MATH 529. Complex Analysis
3 Credits
Same as Math 499 with additional work for graduate students.
Prerequisite(s): MATH 528.

MATH 530. Special Topics
1-3 Credits
Specific subjects to be announced in the Schedule of Classes. May be for unlimited credit with approval of the department.

MATH 531. Ordinary Differential Equations
3 Credits
Linear algebra and linear ordinary differential equations, existence and uniqueness of solution, smooth dependence on initial conditions, flows, introduction to smooth dynamical systems. May be repeated up to 3 credits.
Prerequisite(s): MATH 527, or consent of instructor.

MATH 532. Nonlinear Dynamics
3 Credits
Introduction to nonlinear dynamics and deterministic chaos. Core topics include stability and bifurcations; chaos in one dimensional maps; universality and re-normalization group. Further topics include symbolic dynamics, fractals, sensitive dependence on initial data, self-organization and complexity and cellular automata. Knowledge of differential equations and linear algebra is desired.
MATH 540. Directed Reading
1-6 Credits
May be repeated for a maximum of 6 credits. Consent of instructor required. Graded: S/U.

MATH 541. Topology I
3 Credits
Connectedness and compactness of topological spaces, introduction to the quotient topology, elementary homotopy theory, the fundamental group, the Seifert-van Kampen theorem.
Prerequisite(s): MATH 525 and MATH 528, or consent of instructor.

MATH 542. Topology II
3 Credits
Covering spaces and their classification, singular homology, degree theory, Brouwer’s fixed point theorem, CW-complexes and cellular homology, and other applications.
Prerequisite(s): MATH 541 or consent of instructor.

MATH 551. Mathematical Structures in Logic
3 Credits
Prerequisite(s): MATH 524.

MATH 552. Universal Algebra and Model Theory
3 Credits
Prerequisite(s): MATH 524.

MATH 555. Differentiable Manifolds
3 Credits
Differentiable structures, tangent bundles, vector fields and differential equations. Additional topics may include differential forms, De Rham cohomology, Riemannian geometry, and topics chosen by the instructor. May be repeated for a maximum of 9 credits. Consent of instructor required.
Prerequisite(s): MATH 525 and MATH 528, or consent of instructor.

MATH 556. From Number to Algebra
3 Credits
The progression from Number to Algebra in the K-12 curriculum as a concrete-to-abstract progression. Key concepts considered across the grade levels include the different uses of variables, equivalence in different contexts, patterns, and ratios. Does not fulfill requirements for degrees in mathematics. Consent of instructor required.
Prerequisite(s): Admittance into the MC2-LIFT program.

MATH 557. From Measurement to Geometry
3 Credits
The progression from Measurement to Geometry in the K-12 curriculum as a concrete-to-abstract progression. Important concepts such as angle, length, and area progress from concrete, measurable situations to more abstract problems which require reasoning and proof. Does not fulfill requirements for degrees in mathematics. Consent of instructor required.
Prerequisite(s): Admittance into the MC2-LIFT program.

MATH 558. Using Number Throughout the Curriculum
3 Credits
Understand number concepts more deeply by seeing many examples of those concepts applied in other content strands. Develop mathematical knowledge and understanding to build a repertoire of ways for students to practice and review basic number skills and concepts as part of later, more advanced courses. Does not fulfill requirements for degrees in mathematics. Consent of instructor required.
Prerequisite(s): Admittance into the MC2-LIFT program.

MATH 559. Geometry with Connections
3 Credits
Connections between Geometry and other K-12 curriculum strands, especially Geometry and Probability / Data Analysis. Apply algebraic modeling and reasoning to a variety of mathematical problem solving situations. Does not fulfill requirements for degrees in mathematics. Consent of instructor required.
Prerequisite(s): Admittance into the MC2-LIFT program.

MATH 560. Partial Differential Equations I
3 Credits
The basic equations of mathematical physics. Laplace, Heat and Wave Equations. The method of characteristics, introduction to conservation laws, special solutions.
Prerequisite(s): MATH 518 and MATH 528 or consent of instructor.

MATH 561. Partial Differential Equations II
3 Credits
Sobolev spaces theory: basic definitions and properties, embedding theorems, weak solutions of boundary value problems and variational methods for partial differential equations.
Prerequisite(s): MATH 593 or consent of instructor.
MATH 581. Abstract Algebra II: Fields, Rings and Modules
3 Credits
Topics covered include field extensions; algebraic closure; polynomials rings; irreducibility criteria; Noetherian rings; algebraic sets; Nullstellensatz; modules; applications to linear algebra.
Prerequisite(s): MATH 526 or consent of instructor.

MATH 582. Module Theory and Homological Algebra
3 Credits
Introductory concepts of homological algebra, including projective, injective and flat modules; projective and injective resolutions; exactness of functors; homology of chain complexes; derived functors.
Prerequisite(s): MATH 581 or consent of instructor.

MATH 583. Introduction to Commutative Algebra and Algebraic Geometry
3 Credits
Introduction to the basic notions and techniques of modern algebraic geometry, including the necessary commutative algebra foundation. Topics likely to include algebraic and projective varieties, Nullstellensatz, morphisms, rational and regular functions, local properties. Other topics may include Noether normalization, dimension theory, singularities, sheaves, schemes, Grobner bases.
Prerequisite(s): MATH 581 or consent of instructor.

MATH 593. Measure and Integration
3 Credits
Measure spaces, measurable functions, extension and decomposition theorems for measures, integration on measure spaces, absolute continuity, iterated integrals.
Prerequisite: MATH 528 or consent of instructor.

MATH 594. Real Analysis
3 Credits
Differentiation, Lp spaces, Banach spaces, measure and topology, other selected topics.
Prerequisite: MATH 593.

MATH 595. Introduction to Functional Analysis
3 Credits
Banach spaces. The three basic principles: uniform boundedness principle, closed graph/open mapping theorems, Hahn-Banach theorem.
Prerequisite(s): MATH 594, or consent of instructor.

MATH 599. Master's Thesis
1-15 Credits
Thesis.

MATH 600. Doctoral Research
1-15 Credits
Research.

MATH 643. Topology III
3 Credits
Topics may include higher homotopy groups, fibrations, cohomology operations and obstruction theory, spectral sequences, or others chosen by instructor. May be repeated for a maximum of 9 credits.
Prerequisites: MATH 542 or consent of instructor.

MATH 698. Selected Topics
1-15 Credits
Selected topics.

MATH 700. Doctoral Dissertation
1-15 Credits
Dissertation.