Nexus Mathematics Signature
Calculus & Advanced Modeling

Two-Year Advanced Syllabus

A rigorous two-year advanced mathematics sequence covering full AP Calculus AB/BC and extending into multivariable calculus, vector calculus, differential equations, and mathematical modeling.

Program Level	Nexus Mathematics Signature
Recommended Student Profile	Strong Grade 9-12 students, or exceptional younger students with strong algebra, trigonometry, and precalculus foundations.
Program Length	Two academic years; approximately 50-55 sessions per year for full depth.
Academic Positioning	Year 1 completes AP Calculus AB/BC and rigorous single-variable calculus; Year 2 extends into multivariable calculus, vector calculus, and advanced modeling.
Nexus Emphasis	First-principles reasoning, precise mathematical communication, disciplined problem setup, structural understanding, and modeling.

Program Overview

Nexus Mathematics Signature: Calculus & Advanced Modeling is a two-year advanced mathematics program for students who want calculus with depth, clarity, and real STEM purpose. The course fully prepares students for AP Calculus AB/BC in Year 1 and then moves beyond AP into early college-level multivariable calculus, vector calculus, differential equations, and modeling.

Core Nexus Message
Calculus is a language for change, accumulation, approximation, motion, and multidimensional systems. Students learn not only how to calculate, but also how to build models, justify methods, interpret results, and recognize when a formula applies.

Connection with Nexus Physics Signature

Mathematics as the Language of Physics
This course is the mathematical companion to Nexus Physics Signature. Students connect derivatives with velocity, acceleration, and instantaneous change; integrals with displacement, work, energy, and accumulation; differential equations with drag, cooling, growth, and oscillation; and vector calculus with force fields, flux, circulation, and advanced AP Physics C readiness. Students taking both tracks learn physics equations as models built from interactions and constraints, not as formulas to memorize.

Reference Framework

Reference Tradition	How It Supports the Course
AP Calculus AB/BC	Full Year 1 mastery target; all AP AB and BC topics are included.
MIT Single Variable Calculus	Conceptual spine for limits, derivatives, integrals, applications, differential equations, and series.
Thomas' Calculus, Ch. 1-16	Year 1 follows the single-variable sequence through series; Year 2 extends through vectors, partial derivatives, multiple integrals, and vector fields.
Gilbert Strang Calculus	Supports the course emphasis on conceptual interpretation and mathematical modeling.
Tongji Higher Mathematics, Vol. I-II	Provides an engineering-calculus structure: single-variable calculus, differential equations, vectors, multivariable calculus, multiple integrals, line integrals, and surface integrals.

Two-Year Architecture

Year	Main Identity	Student Outcome
Year 1	Single-Variable Calculus and AP BC Mastery	Students complete AP Calculus AB/BC and build a rigorous single-variable calculus foundation through limits, derivatives, integrals, differential equations, polar/parametric calculus, and infinite series.
Year 2	Multivariable Calculus, Vector Calculus, and Advanced Modeling	Students move beyond AP into vectors, motion in space, partial derivatives, gradients, multiple integrals, vector fields, line/surface integrals, and advanced modeling.

What Makes the Course Signature-Level

- **First-principles reasoning:** students learn where formulas come from and when they apply.
- **Technical fluency:** students build speed and accuracy across AP and college-style problems.
- **Modeling:** students translate physical, geometric, engineering, economic, and data-driven contexts into mathematical structure.
- **Proof awareness:** theorem meaning, assumptions, and limitations are discussed throughout.
- **Communication:** students write complete solutions and explain the meaning of their answers.

Year 1: AP Calculus AB/BC and Single-Variable Calculus

Year 1 purpose: Students complete the full AP Calculus AB/BC curriculum while studying single-variable calculus with greater conceptual depth than a test-prep-only course. The year is designed to make students AP BC-ready and to prepare them for advanced STEM courses.

Unit	Topic	Major Ideas
1	Preliminaries: Functions, Coordinates, and Models	Real numbers, coordinates, lines, parabolas, circles, functions, trigonometry, exponential/logarithmic functions, and graphing technology as exploration.
2	Limits and Continuity	One-sided limits, infinite limits, limits at infinity, asymptotes, squeeze theorem, continuity, IVT, and epsilon-delta introduction.
3	Differentiation from First Principles	Derivative as limit, tangent slope, instantaneous rate, local linear approximation, derivative rules, higher-order derivatives, and differentials.
4	Applications of Derivatives	Related rates, optimization, curve analysis, MVT, Rolle's Theorem, Newton's Method, L'Hopital's Rule, and contextual modeling.
5	Integration and FTC	Riemann sums, antiderivatives, definite integrals, accumulation functions, net change, substitution, average value, and the Fundamental Theorem of Calculus.
6	Applications of Definite Integrals	Area, volume, arc length, surface area, work, fluid force, mass, moments, centers of mass, and accumulated motion.
7	Transcendental Functions	Inverse, logarithmic, exponential, inverse trigonometric, and hyperbolic functions with derivatives, integrals, and applications.
8	Techniques of Integration	Integration by parts, trig integrals, trig substitution, partial fractions, numerical integration, and improper integrals.
9	Differential Equations	Slope fields, Euler's Method, separable and first-order linear equations, exponential/logistic growth, cooling, and drag models.
10	Parametric, Polar, and Conics	Parametric derivatives, polar graphs, polar area, conic sections, eccentricity, and orbit-style interpretations.
11	Infinite Sequences and Series	Convergence tests, power series, Taylor/Maclaurin series, error bounds, binomial series, and Fourier series introduction.
12	AP BC Mastery	Full AP AB/BC synthesis through multiple-choice practice, free-response writing, interpretation, justifications, and cumulative mixed problems.

Year 1 Result
Students finish Year 1 with complete AP Calculus AB/BC coverage, stronger conceptual understanding than standard AP preparation, and readiness for multivariable calculus, AP Physics C, engineering mathematics, and advanced modeling.

AP Calculus Coverage

All AP Calculus AB and BC topics are placed in Year 1: limits and continuity; derivative definitions and rules; composite, implicit, and inverse differentiation; contextual and analytical applications; integration and accumulation; differential equations; applications of integration; parametric, polar, and vector-valued functions; and infinite sequences and series.

Year 2: Multivariable Calculus, Vector Calculus, and Modeling

Year 2 purpose: Students extend beyond AP Calculus into the language of college-level STEM. The focus shifts from one-variable change to systems with multiple inputs, motion in space, spatial accumulation, and vector fields.

Unit	Topic	Major Ideas
13	Vectors and Geometry of Space	3D coordinates, dot product, cross product, projections, lines, planes, distances, cylinders, quadric surfaces, and space curves.
14	Vector-Valued Motion	Space curves, derivatives and integrals of vector-valued functions, arc length, curvature, velocity, acceleration, and motion in space.
15	Partial Derivatives	Functions of several variables, level curves and surfaces, limits, continuity, partial derivatives, tangent planes, linear approximation, and multivariable chain rule.
16	Gradients and Optimization	Directional derivatives, gradient vectors, fastest increase, saddle points, constrained optimization, and Lagrange multipliers.
17	Multiple Integrals	Double and triple integrals, polar/cylindrical/spherical coordinates, change of variables, Jacobian intuition, mass, center of mass, and moments.
18	Vector Fields and Line Integrals	Vector fields, work along a path, circulation, conservative fields, path independence, and potential functions.
19	Surface Integrals and Boundary Theorems	Green's Theorem, curl, divergence, parametrized surfaces, flux, Stokes' Theorem, and Divergence Theorem.
20	Differential Equation Modeling Extension	Second-order differential equations, harmonic motion, damping, resonance intuition, and mechanical/electrical system models.
21	Analysis Preview	Precise limit definition, theorem structure, Taylor's Theorem, convergence logic, counterexamples, and the bridge to real analysis.
22	Nexus Modeling Capstone	Extended project involving variables, assumptions, diagrams, model construction, exact or numerical solution, unit checks, interpretation, and limitations.

Learning Path, Progress, and Placement

Recommended Pace

The full program is designed for approximately 50-55 sessions per year for complete depth. Families may also choose a school-year-plus-summer rhythm when a student wants both AP readiness and the advanced extension topics. Pacing is adjusted based on readiness, course goals, and the student's school calendar.

How Student Progress Is Supported

Students receive regular skill checks, unit assessments, and cumulative milestones. Assessments are designed to measure computational accuracy, conceptual understanding, modeling setup, written explanation, and method selection. At the end of Year 1, students complete an AP Calculus BC-style milestone. At the end of Year 2, students complete a multivariable/vector calculus milestone and an advanced modeling capstone.

Placement in the Nexus Mathematics Ladder

This course follows the Analytics track and leads into rigorous single-variable calculus in Year 1, then multivariable/vector calculus and modeling in Year 2. Students seeking further depth may continue into Real Analysis or Probability, Statistics & Data Modeling.