Precalculus | Mathematics Standards of Learning for Virginia Public Schools Correlation to *Eureka Math*®

About *Eureka Math*

Created by Great Minds®, a mission-driven Public Benefit Corporation, *Eureka Math*® helps teachers deliver unparalleled math instruction that provides students with a deep understanding and fluency in math. Crafted by teachers and math scholars, the curriculum carefully sequences the mathematical progressions to maximize coherence from Prekindergarten through Precalculus—a principle tested and proven to be essential in students' mastery of math.

Teachers and students using *Eureka Math* find the trademark "Aha!" moments in *Eureka Math* to be a source of joy and inspiration, lesson after lesson, year after year.

Aligned

Great Minds offers detailed analyses that demonstrate how each grade of *Eureka Math* aligns with specific state standards. Access these free alignment studies at greatminds.org/state-studies.

Data

Schools and districts nationwide are experiencing student growth and impressive test scores after using *Eureka Math*. See their stories and data at greatminds.org/data.

Full Suite of Resources

Great Minds offers the *Eureka Math* curriculum as PDF downloads for free, noncommercial use. Access the free PDFs at greatminds.org/math/curriculum.

The teacher–writers who created the curriculum have also developed essential resources, available only from Great Minds, including the following:

- Printed material in English and Spanish
- Digital resources
- Professional development
- Classroom tools and manipulatives
- Teacher support materials
- Parent resources

Mathematical Process Goals for Students	Aligned Components of *Eureka Math*
Mathematical Problem Solving	Lessons in every module engage students in mathematical processes.
Mathematical Communication	
Mathematical Reasoning	
Mathematical Connections	
Mathematical Representations	

Characteristics of Functions

MA.CF.1 The student will identify and analyze the properties of polynomial, rational, piecewise-defined, absolute value, radical, and step functions and sketch the graphs of the functions.

Mathematics Standards of Learning for Virginia Public Schools	Aligned Components of *Eureka Math*
MA.CF.1.a Use mathematical reasoning to identify polynomial, rational, piecewise-defined, absolute value, radical, and step functions, given an equation or graph.	*Supplemental material is necessary to address this standard.*
MA.CF.1.b Given multiple representations of a polynomial, rational, piecewise-defined, absolute value, radical, and step function, analyze:	*This standard is addressed by the lessons aligned to its subsections.* *Supplemental material is necessary to address piecewise-defined, absolute value, radical, and step functions.*
MA.CF.1.b.i domain and range;	Precalculus and Advanced Topics M3 Lesson 14: Graphing Rational Functions *Supplemental material is necessary to address range.*
MA.CF.1.b.ii roots (including complex roots);	Algebra II M1 Lesson 14: Graphing Factored Polynomials Algebra II M1 Lesson 40: Obstacles Resolved—A Surprising Result Precalculus and Advanced Topics M3 Lesson 1: Solutions to Polynomial Equations
MA.CF.1.b.iii intercepts;	Algebra II M1 Lesson 14: Graphing Factored Polynomials Precalculus and Advanced Topics M3 Lesson 1: Solutions to Polynomial Equations Precalculus and Advanced Topics M3 Lesson 14: Graphing Rational Functions

Mathematics Standards of Learning for Virginia Public Schools	Aligned Components of *Eureka Math*
MA.CF.1.b.iv symmetry (including even and odd functions);	Algebra II M1 Lesson 15: Structure in Graphs of Polynomial Functions Precalculus and Advanced Topics M3 Lesson 12: End Behavior of Rational Functions
MA.CF.1.b.v asymptotes (horizontal, vertical, and oblique/slant);	Precalculus and Advanced Topics M3 Lesson 13: Horizontal and Vertical Asymptotes of Graphs of Rational Functions Precalculus and Advanced Topics M3 Lesson 14: Graphing Rational Functions *Supplemental material is necessary to address oblique/slant asymptotes.*
MA.CF.1.b.vi points of discontinuity;	*Supplemental material is necessary to address this standard.*
MA.CF.1.b.vii intervals for which the function is increasing, decreasing or constant;	*Supplemental material is necessary to address this standard.*
MA.CF.1.b.viii end behavior; and	Algebra II M1 Lesson 15: Structure in Graphs of Polynomial Functions Precalculus and Advanced Topics M3 Lesson 12: End Behavior of Rational Functions Precalculus and Advanced Topics M3 Lesson 14: Graphing Rational Functions
MA.CF.1.b.ix relative and/or absolute maximum and minimum points.	Algebra II M1 Lesson 14: Graphing Factored Polynomials

Mathematics Standards of Learning for Virginia Public Schools	Aligned Components of *Eureka Math*
MA.CF.1.c Sketch the graph of a polynomial, rational, piecewise-defined, absolute value, radical, and step function.	Algebra II M1 Lesson 14: Graphing Factored Polynomials Algebra II M1 Lesson 15: Structure in Graphs of Polynomial Functions Precalculus and Advanced Topics M3 Lesson 13: Horizontal and Vertical Asymptotes of Graphs of Rational Functions Precalculus and Advanced Topics M3 Lesson 14: Graphing Rational Functions Precalculus and Advanced Topics M3 Lesson 15: Transforming Rational Functions

Characteristics of Functions

MA.CF.2 The student will determine the limit of a function if it exists.

Mathematics Standards of Learning for Virginia Public Schools	Aligned Components of *Eureka Math*
MA.CF.2.a Verify estimates about the limit of a function using graphing technology.	*Supplemental material is necessary to address this standard.*
MA.CF.2.b Determine the limit of a function algebraically and verify with graphing technology.	*Supplemental material is necessary to address this standard.*
MA.CF.2.c Determine the limit of a function numerically and verify with graphing technology.	*Supplemental material is necessary to address this standard.*

Mathematics Standards of Learning for Virginia Public Schools	Aligned Components of *Eureka Math*
MA.CF.2.d Use proper limit notation, including when describing the end behavior of a function.	*Supplemental material is necessary to address this standard.*
MA.CF.2.e As the variable approaches a finite number,	*Supplemental material is necessary to address this standard.*
MA.CF.2.e.i determine the limit of a function numerically by direct substitution;	*Supplemental material is necessary to address this standard.*
MA.CF.2.e.ii determine the limit of a function using algebraic manipulation;	*Supplemental material is necessary to address this standard.*
MA.CF.2.e.iii estimate the limit of a function using a table; and	*Supplemental material is necessary to address this standard.*
MA.CF.2.e.iv determine the limit of a function from a given graph.	*Supplemental material is necessary to address this standard.*
MA.CF.2.f As the variable approaches positive or negative infinity, analyze the limit of a function to describe the end behavior.	*Supplemental material is necessary to address this standard.*

Characteristics of Functions

MA.CF.3 The student will analyze and describe the continuity of functions.

Mathematics Standards of Learning for Virginia Public Schools	Aligned Components of *Eureka Math*
MA.CF.3.a Describe continuity of a function.	*Supplemental material is necessary to address this standard.*
MA.CF.3.b Use mathematical notation to communicate and describe the continuity of functions including polynomial, rational, piecewise, absolute value, radical, and step function, using graphical and algebraic methods.	*Supplemental material is necessary to address this standard.*
MA.CF.3.c Prove continuity at a point, using the definition.	*Supplemental material is necessary to address this standard.*
MA.CF.3.d Classify types of discontinuity based on which condition of continuity is violated.	*Supplemental material is necessary to address this standard.*

Functional Relationships

MA.FR.1 The student will analyze compositions of functions to determine and verify inverses of functions.

Mathematics Standards of Learning for Virginia Public Schools	Aligned Components of *Eureka Math*
MA.FR.1.a Construct the composition of functions algebraically and graphically.	Precalculus and Advanced Topics M3 Lesson 16: Function Composition Precalculus and Advanced Topics M3 Lesson 17: Solving Problems by Function Composition
MA.FR.1.b Determine the domain and range of composite functions algebraically and graphically.	Precalculus and Advanced Topics M3 Lesson 16: Function Composition Precalculus and Advanced Topics M3 Lesson 17: Solving Problems by Function Composition
MA.FR.1.c Develop the inverse of a function algebraically and graphically.	Precalculus and Advanced Topics M3 Lesson 16: Function Composition Precalculus and Advanced Topics M3 Lesson 17: Solving Problems by Function Composition Precalculus and Advanced Topics M3 Topic C: Inverse Functions
MA.FR.1.d Compare the domain and range of the inverse of a function with the original function, both algebraically and graphically.	Precalculus and Advanced Topics M3 Lesson 18: Inverse Functions
MA.FR.1.e Use mathematical reasoning to generalize and communicate the criteria for an inverse function to exist.	Precalculus and Advanced Topics M3 Lesson 19: Restricting the Domain

Functional Relationships

MA.FR.2 The student will analyze the characteristics of exponential and logarithmic functions, and sketch the graphs of the functions.

Mathematics Standards of Learning for Virginia Public Schools	Aligned Components of *Eureka Math*
MA.FR.2.a Generalize characteristics of exponential and logarithmic functions from an equation or a graph.	Algebra II M3 Lesson 18: Graphs of Exponential Functions and Logarithmic Functions Algebra II M3 Lesson 20: Transformations of the Graphs of Logarithmic and Exponential Functions
MA.FR.2.b Define e and estimate its value.	Precalculus and Advanced Topics M3 Lesson 20: Inverses of Logarithmic and Exponential Functions
MA.FR.2.c Convert between equations written in logarithmic and exponential form.	Algebra II M3 Lesson 8: The “WhatPower” Function
MA.FR.2.d Use laws of exponents and properties of logarithms to solve equations and simplify expressions.	Algebra II M3 Lesson 7: Bacteria and Exponential Growth Algebra II M3 Lesson 11: The Most Important Property of Logarithms Algebra II M3 Lesson 12: Properties of Logarithms Algebra II M3 Lesson 13: Changing the Base Algebra II M3 Lesson 14: Solving Logarithmic Equations Precalculus and Advanced Topics M3 Lesson 21: Logarithmic and Exponential Problem Solving

Mathematics Standards of Learning for Virginia Public Schools	Aligned Components of *Eureka Math*
MA.FR.2.e Represent contextual problems, using exponential and logarithmic functions, to include common and natural logarithms.	Algebra II M3 Lesson 9: Logarithms—How Many Digits Do You Need? Algebra II M3 Lesson 15: Why Were Logarithms Developed? Algebra II M3 Lesson 23: Bean Counting Algebra II M3 Lesson 24: Solving Exponential Equations Algebra II M3 Lesson 26: Percent Rate of Change Algebra II M3 Lesson 27: Modeling with Exponential Functions Algebra II M3 Lesson 28: Newton's Law of Cooling, Revisited Precalculus and Advanced Topics M3 Lesson 21: Logarithmic and Exponential Problem Solving
MA.FR.2.f Sketch the graph of exponential and logarithmic functions and identify asymptotes, end behavior, intercepts, domain, and range.	Algebra II M3 Lesson 17: Graphing the Logarithm Function Algebra II M3 Lesson 18: Graphs of Exponential Functions and Logarithmic Functions Algebra II M3 Lesson 19: The Inverse Relationship Between Logarithmic and Exponential Functions Algebra II M3 Lesson 20: Transformations of the Graphs of Logarithmic and Exponential Functions Algebra II M3 Lesson 21: The Graph of the Natural Logarithm Function Precalculus and Advanced Topics M3 Lesson 20: Inverses of Logarithmic and Exponential Functions

Functional Relationships

MA.FR.3 The student will analyze sequences and finite series, and model and solve problems in context using sequences and series.

Mathematics Standards of Learning for Virginia Public Schools	Aligned Components of *Eureka Math*
MA.FR.3.a Use and interpret the notation: Σ, n, n^{th}, and a_n.	Algebra II M3 Lesson 29: The Mathematics Behind a Structured Savings Plan

Mathematics Standards of Learning for Virginia Public Schools	Aligned Components of *Eureka Math*
MA.FR.3.b Derive the formulas associated with arithmetic and geometric sequences and series.	Algebra II M3 Lesson 25: Geometric Sequences and Exponential Growth and Decay Algebra II M3 Lesson 26: Percent Rate of Change
MA.FR.3.c Determine the n^{th} term, a_n, for an arithmetic or geometric sequence.	Algebra II M3 Lesson 25: Geometric Sequences and Exponential Growth and Decay Algebra II M3 Lesson 26: Percent Rate of Change
MA.FR.3.d Determine the sum, S_n, if it exists, of an arithmetic or geometric series.	Algebra II M3 Lesson 29: The Mathematics Behind a Structured Savings Plan
MA.FR.3.e Model and solve problems in context, using sequences and series.	Algebra II M3 Lesson 25: Geometric Sequences and Exponential Growth and Decay Algebra II M3 Lesson 26: Percent Rate of Change Algebra II M3 Lesson 29: The Mathematics Behind a Structured Savings Plan
MA.FR.3.f Distinguish between a convergent and divergent series.	*Supplemental material is necessary to address this standard.*
MA.FR.3.g Describe convergent series in relation to the concept of a limit.	*Supplemental material is necessary to address this standard.*

Analytic Geometry

MA.AG.1 The student will identify and analyze the properties of conic sections and sketch a graph given an equation.

Mathematics Standards of Learning for Virginia Public Schools	Aligned Components of *Eureka Math*
MA.AG.1.a Given a translation or rotation matrix, determine an equation for the transformed function or conic section.	*Supplemental material is necessary to address this standard.*
MA.AG.1.b Convert between standard and general forms of conic equations by completing the square.	*Supplemental material is necessary to address this standard.*
MA.AG.1.c Graph conic sections from equations written in general or standard form using transformations.	Precalculus and Advanced Topics M3 Lesson 7: Curves from Geometry Precalculus and Advanced Topics M3 Lesson 8: Curves from Geometry
MA.AG.1.d Identify characteristics of conic sections including center, vertices, axes, symmetry, foci, directrix, eccentricity, and asymptotes.	Precalculus and Advanced Topics M3 Lesson 6: Curves in the Complex Plane Precalculus and Advanced Topics M3 Lesson 7: Curves from Geometry Precalculus and Advanced Topics M3 Lesson 8: Curves from Geometry
MA.AG.1.e Represent applications of conic sections.	*Supplemental material is necessary to address this standard.*

Analytic Geometry

MA.AG.2 The student will use parametric equations to model and solve problems in context.

Mathematics Standards of Learning for Virginia Public Schools	Aligned Components of *Eureka Math*
MA.AG.2.a Graph and analyze parametric equations and use the graph to determine solutions.	*Supplemental material is necessary to address this standard.*
MA.AG.2.b Use parametric equations to model contextual problems, including motion over time.	*Supplemental material is necessary to address this standard.*

Analytic Geometry

MA.AG.3 The student will perform operations with vectors in the coordinate plane.

Mathematics Standards of Learning for Virginia Public Schools	Aligned Components of *Eureka Math*
MA.AG.3.a Use vector notation.	Precalculus and Advanced Topics M2 Topic D: Vectors in Plane and Space
MA.AG.3.b Perform the operations of addition, subtraction, and scalar multiplication, graphically and algebraically on vectors.	Precalculus and Advanced Topics M2 Lesson 5: Coordinates of Points in Space Precalculus and Advanced Topics M2 Lesson 6: Linear Transformations as Matrices Precalculus and Advanced Topics M2 Lesson 17: Vectors in the Coordinate Plane Precalculus and Advanced Topics M2 Lesson 18: Vectors and Translation Maps Precalculus and Advanced Topics M2 Lesson 19: Directed Line Segments and Vectors Precalculus and Advanced Topics M2 Lesson 20: Vectors and Stone Bridges Precalculus and Advanced Topics M2 Lesson 23: Why Are Vectors Useful? Precalculus and Advanced Topics M2 Lesson 24: Why Are Vectors Useful?

Mathematics Standards of Learning for Virginia Public Schools	Aligned Components of *Eureka Math*
MA.AG.3.c Find the dot (inner) product of two vectors and use it to determine the angle between two vectors.	*Supplemental material is necessary to address this standard.*
MA.AG.3.d Determine if two vectors are orthogonal.	*Supplemental material is necessary to address this standard.*
MA.AG.3.e Express complex numbers in vector notation.	Precalculus and Advanced Topics M1 Lesson 6: Complex Numbers as Vectors
MA.AG.3.f Verify properties of the dot product.	*Supplemental material is necessary to address this standard.*
MA.AG.3.g Determine the components of a vector.	Precalculus and Advanced Topics M2 Lesson 19: Directed Line Segments and Vectors
MA.AG.3.h Determine the norm (magnitude) of a vector.	Precalculus and Advanced Topics M2 Lesson 17: Vectors in the Coordinate Plane Precalculus and Advanced Topics M2 Lesson 18: Vectors and Translation Maps Precalculus and Advanced Topics M2 Lesson 20: Vectors and Stone Bridges
MA.AG.3.i Find a unit vector in the same direction of a given vector.	*Supplemental material is necessary to address this standard.*
MA.AG.3.j Apply vectors to problems in context.	Precalculus and Advanced Topics M2 Lesson 17: Vectors in the Coordinate Plane Precalculus and Advanced Topics M2 Lesson 20: Vectors and Stone Bridges Precalculus and Advanced Topics M2 Lesson 23: Why Are Vectors Useful?

Analytic Geometry

MA.AG.4 The student will investigate and identify the characteristics of the graphs of polar equations.

Mathematics Standards of Learning for Virginia Public Schools	Aligned Components of *Eureka Math*
MA.AG.4.a Classify polar equations (rose, cardioid, limaçon, lemniscate, spiral, and circle), given the graph or the equation.	*Supplemental material is necessary to address this standard.*
MA.AG.4.b Determine the effects of changes in the parameters of polar equations on the graph, using graphing technology.	*Supplemental material is necessary to address this standard.*
MA.AG.4.c Convert between polar and rectangular forms of coordinates.	*Supplemental material is necessary to address this standard.*
MA.AG.4.d Convert between complex numbers written in rectangular form and polar form.	Precalculus and Advanced Topics M1 Lesson 13: Trigonometry and Complex Numbers
MA.AG.4.e Convert equations between polar and rectangular forms.	*Supplemental material is necessary to address this standard.*
MA.AG.4.f Determine and verify the intersection of the graphs of two polar equations, using graphing technology.	*Supplemental material is necessary to address this standard.*

Analytic Geometry

MA.AG.5 The student will use matrices to organize data and will add and subtract matrices, multiply matrices, multiply matrices by a scalar, and use matrices to solve systems of equations.

Mathematics Standards of Learning for Virginia Public Schools	Aligned Components of *Eureka Math*
MA.AG.5.a Multiply matrices by a scalar.	Precalculus and Advanced Topics M2 Lesson 2: Networks and Matrix Arithmetic Precalculus and Advanced Topics M2 Lesson 3: Matrix Arithmetic in Its Own Right Precalculus and Advanced Topics M2 Lesson 4: Linear Transformations Review Precalculus and Advanced Topics M2 Lesson 5: Coordinates of Points in Space Precalculus and Advanced Topics M2 Lesson 6: Linear Transformations as Matrices Precalculus and Advanced Topics M2 Lesson 26: Projecting a 3-D Object onto a 2-D Plane Precalculus and Advanced Topics M2 Lesson 27: Designing Your Own Game
MA.AG.5.b Add, subtract, and multiply matrices.	Precalculus and Advanced Topics M1 Lesson 22: Modeling Video Game Motion with Matrices Precalculus and Advanced Topics M1 Lesson 24: Matrix Notation Encompasses New Transformations! Precalculus and Advanced Topics M1 Lesson 25: Matrix Multiplication and Addition Precalculus and Advanced Topics M2 Lesson 2: Networks and Matrix Arithmetic Precalculus and Advanced Topics M2 Lesson 3: Matrix Arithmetic in Its Own Right Precalculus and Advanced Topics M2 Topic B: Linear Transformations of Planes and Space Precalculus and Advanced Topics M2 Topic E: First-Person Video Games—Projection Matrices
MA.AG.5.c Represent problems with a system of no more than three linear equations.	Precalculus and Advanced Topics M2 Topic C: Systems of Linear Equations
MA.AG.5.d Express a system of linear equations as a matrix equation.	Precalculus and Advanced Topics M2 Topic C: Systems of Linear Equations

Mathematics Standards of Learning for Virginia Public Schools	Aligned Components of *Eureka Math*
MA.AG.5.e Solve a system of equations using matrices.	Precalculus and Advanced Topics M2 Topic C: Systems of Linear Equations
MA.AG.5.f Determine the inverse of a two-by-two or three-by-three matrix using paper and pencil.	Precalculus and Advanced Topics M1 Lesson 28: When Can We Reverse a Transformation? Precalculus and Advanced Topics M1 Lesson 29: When Can We Reverse a Transformation? *Supplemental material is necessary to address determining the inverse of three-by-three matrices using paper and pencil.*
MA.AG.5.g Verify two matrices are inverses using matrix multiplication.	Precalculus and Advanced Topics M1 Lesson 28: When Can We Reverse a Transformation? Precalculus and Advanced Topics M1 Lesson 29: When Can We Reverse a Transformation?
MA.AG.5.h Verify the commutative and associative properties for matrix addition and multiplication.	Precalculus and Advanced Topics M1 Lesson 25: Matrix Multiplication and Addition Precalculus and Advanced Topics M2 Lesson 10: Matrix Multiplication Is Not Commutative Precalculus and Advanced Topics M2 Lesson 12: Matrix Multiplication Is Distributive and Associative