



# Common Core Georgia Performance Standards CCGPS

## Mathematics

Comprehensive Course Overview

CCGPS Analytic Geometry



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*"Making Education Work for All Georgians"*

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The Comprehensive Course Overviews are designed to provide teachers with clarification of Mathematics CCGPS, grounded in GPS language when appropriate. The Comprehensive Course Overviews are for teacher use during the CCGPS transition years. These documents are the result of a nine month precision review process involving over 4,000 Georgia mathematics educators. Many thanks to those who provided comments, feedback, and time in the precision review process.

## CCGPS Analytic Geometry

The high school standards specify the mathematics that all students should study in order to be college and career ready. Additional mathematics that students should learn in fourth credit courses or advanced courses such as calculus, advanced statistics, or discrete mathematics is indicated by (+). All standards without a (+) symbol should be in the common mathematics curriculum for all college and career ready students. Standards with a (+) symbol may also appear in courses intended for all students.

The high school standards are listed in conceptual categories including **Number and Quantity, Algebra, Functions, Modeling, Geometry, and Statistics and Probability.**

Conceptual categories portray a coherent view of high school mathematics; a student’s work with functions, for example, crosses a number of traditional course boundaries, potentially up through and including calculus. Modeling is best interpreted not as a collection of isolated topics but in relation to other standards. Making mathematical models is a Standard for Mathematical Practice, and specific modeling standards appear throughout the high school standards indicated by a star symbol (★).

## Flipbooks

The Common Core “FlipBooks” are a compilation of research, “unpacked” standards from many states, instructional strategies and examples for each standard at each grade level. The intent is to show the connections to the Standards of Mathematical Practices for the content standards and to get detailed information at each level. The **High School Flipbook** is an interactive document arranged by the content domains listed on the following pages. The links on each domain and standard will take you to specific information on that standard/domain within the Flip Book.

**Mathematics | High School—Number and Quantity**

**Numbers and Number Systems.** During the years from kindergarten to eighth grade, students must repeatedly extend their conception of number. At first, “number” means “counting number”: 1, 2, 3... Soon after that, 0 is used to represent “none” and the whole numbers are formed by the counting numbers together with zero. The next extension is fractions. At first, fractions are barely numbers and tied strongly to pictorial representations. Yet by the time students understand division of fractions, they have a strong concept of fractions as numbers and have connected them, via their decimal representations, with the base-ten system used to represent the whole numbers. During middle school, fractions are augmented by negative fractions to form the rational numbers. In Grade 8, students extend this system once more, augmenting the rational numbers with the irrational numbers to form the real numbers. In high school, students will be exposed to yet another extension of number, when the real numbers are augmented by the imaginary numbers to form the complex numbers. With each extension of number, the meanings of addition, subtraction, multiplication, and division are extended. In each new number system—integers, rational numbers, real numbers, and complex numbers—the four operations stay the same in two important ways: They have the commutative, associative, and distributive properties and their new meanings are consistent with their previous meanings. Extending the properties of whole-number exponents leads to new and productive notation. For example, properties of whole-number exponents suggest that  $(5^{1/3})^3$  should be  $5^{(1/3) \cdot 3} = 5^1 = 5$  and that  $5^{1/3}$  should be the cube root of 5. Calculators, spreadsheets, and computer algebra systems can provide ways for students to become better acquainted with these new number systems and their notation. They can be used to generate data for numerical experiments, to help understand the workings of matrix, vector, and complex number algebra, and to experiment with non-integer exponents.

**Quantities.** In real world problems, the answers are usually not numbers but quantities: numbers with units, which involves measurement. In their work in measurement up through Grade 8, students primarily measure commonly used attributes such as length, area, and volume. In high school, students encounter a wider variety of units in modeling, e.g., acceleration, currency conversions, derived quantities such as person-hours and heating degree days, social science rates such as per-capita income, and rates in everyday life such as points scored per game or batting averages. They also encounter novel situations in which they themselves must conceive the attributes of interest. For example, to find a good measure of overall highway safety, they might propose measures such as fatalities per year, fatalities per year per driver, or fatalities per vehicle-mile traveled. Such a conceptual process is sometimes called quantification. Quantification is important for science, as when surface area suddenly “stands out” as an important variable in evaporation. Quantification is also important for companies, which must conceptualize relevant attributes and create or choose suitable measures for them.

**The Real Number System**

N.RN

**Extend the properties of exponents to rational exponents.**

**MCC9-12.N.RN.1** Explain how the definition of the meaning of rational exponents follows from extending the properties of integer exponents to those values, allowing for a notation for radicals in terms of rational exponents. *For example, we define  $5^{(1/3)}$  to be the cube root of 5 because we want  $[5^{(1/3)}]^3 = 5^{[(1/3) \cdot 3]}$  to hold, so  $[5^{(1/3)}]^3$  must equal 5.*

- During 8<sup>th</sup> grade, students explore integer exponents, including using scientific notation

**MCC9-12.N.RN.2** Rewrite expressions involving radicals and rational exponents using the properties of exponents.

**Use properties of rational and irrational numbers.**

**MCC9-12.N.RN.3** Explain why the sum or product of rational numbers is rational; that the sum of a rational number and an irrational number is irrational; and that the product of a nonzero rational number and an irrational number is irrational.

**The Complex Number System**

N.CN

**Perform arithmetic operations with complex numbers.**

**MCC9-12.N.CN.1** Know there is a complex number  $i$  such that  $i^2 = -1$ , and every complex number has the form  $a + bi$  with  $a$  and  $b$  real.

**MCC9-12.N.CN.2** Use the relation  $i^2 = -1$  and the commutative, associative, and distributive properties to add, subtract, and multiply complex numbers.

**MCC9-12.N.CN.3 (+)** Find the conjugate of a complex number; use conjugates to find moduli and quotients of complex numbers.

- Determine quotients of complex numbers only.

**Use complex numbers in polynomial identities and equations.**

**MCC9-12.N.CN.7** Solve quadratic equations with real coefficients that have complex solutions.

**Mathematics | High School—Algebra**

**Expressions.** An expression is a record of a computation with numbers, symbols that represent numbers, arithmetic operations, exponentiation, and, at more advanced levels, the operation of evaluating a function. Conventions about the use of parentheses and the order of operations assure that each expression is unambiguous. Creating an expression that describes a computation involving a general quantity requires the ability to express the computation in general terms, abstracting from specific instances.

Reading an expression with comprehension involves analysis of its underlying structure. This may suggest a different but equivalent way of writing the expression that exhibits some different aspect of its meaning. For example,  $p + 0.05p$  can be interpreted as the addition of a 5% tax to a price  $p$ . Rewriting  $p + 0.05p$  as  $1.05p$  shows that adding a tax is the same as multiplying the price by a constant factor.

Algebraic manipulations are governed by the properties of operations and exponents, and the conventions of algebraic notation. At times, an expression is the result of applying operations to simpler expressions. For example,  $p + 0.05p$  is the sum of the simpler expressions  $p$  and  $0.05p$ . Viewing an expression as the result of operation on simpler expressions can sometimes clarify its underlying structure.

A spreadsheet or a computer algebra system (CAS) can be used to experiment with algebraic expressions, perform complicated algebraic manipulations, and understand how algebraic manipulations behave.

**Equations and inequalities.** An equation is a statement of equality between two expressions, often viewed as a question asking for which values of the variables the expressions on either side are in fact

equal. These values are the solutions to the equation. An identity, in contrast, is true for all values of the variables. Identities are often developed by rewriting an expression in an equivalent form.

The solutions of an equation in one variable form a set of numbers. The solutions of an equation in two variables form a set of ordered pairs of numbers, which can be plotted in the coordinate plane. Two or more equations and/or inequalities form a system. A solution for such a system must satisfy every equation and inequality in the system.

An equation can often be solved by successively deducing from it one or more simpler equations. For example, one can add the same constant to both sides without changing the solutions, but squaring both sides might lead to extraneous solutions. Strategic competence in solving includes looking ahead for productive manipulations and anticipating the nature and number of solutions.

Some equations have no solutions in a given number system, but have a solution in a larger system. For example, the solution of  $x + 1 = 0$  is an integer, not a whole number; the solution of  $2x + 1 = 0$  is a rational number, not an integer; the solutions of  $x^2 - 2 = 0$  are real numbers, not rational numbers; and the solutions of  $x^2 + 2 = 0$  are complex numbers, not real numbers.

The same solution techniques used to solve equations can be used to rearrange formulas. For example, the formula for the area of a trapezoid,  $A = \left(\frac{b_1 + b_2}{2}\right)h$ , can be solved for  $h$  using the same deductive process. Inequalities can be solved by reasoning about the properties of inequality. Many, but not all, of the properties of equality continue to hold for inequalities and can be useful in solving them.

**Connections to Functions and Modeling.** Expressions can define functions, and equivalent expressions define the same function. Asking when two functions have the same value for the same input leads to an equation; graphing the two functions allows for finding approximate solutions of the equation. Converting a verbal description to an equation, inequality, or system of these is an essential skill in modeling.

## Seeing Structure in Expressions

A.SSE

### Interpret the structure of expressions

**MCC9-12.A.SSE.1** Interpret expressions that represent a quantity in terms of its context.★

**MCC9-12.A.SSE.1a** Interpret parts of an expression, such as terms, factors, and coefficients.★

**MCC9-12.A.SSE.1b** Interpret complicated expressions by viewing one or more of their parts as a single entity. For example, interpret  $P(1+r)^n$  as the product of  $P$  and a factor not depending on  $P$ .★

**MCC9-12.A.SSE.2** Use the structure of an expression to identify ways to rewrite it. For example, see  $x^4 - y^4$  as  $(x^2)^2 - (y^2)^2$ , thus recognizing it as a difference of squares that can be factored as  $(x^2 - y^2)(x^2 + y^2)$ .

### Write expressions in equivalent forms to solve problems

**MCC9-12.A.SSE.3** Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.★

MCC9-12.A.SSE.3a Factor a quadratic expression to reveal the zeros of the function it defines.★

MCC9-12.A.SSE.3b Complete the square in a quadratic expression to reveal the maximum or minimum value of the function it defines.★

### Arithmetic with Polynomials and Rational Expressions

A.APR

#### Perform arithmetic operations on polynomials

**MCC9-12.A.APR.1** Understand that polynomials form a system analogous to the integers, namely, they are closed under the operations of addition, subtraction, and multiplication; add, subtract, and multiply polynomials.

- Students will simplify and operate with polynomials.
- Division of polynomials is optional

### Creating Equations★

A.CED

#### Create equations that describe numbers or relationships

**MCC9-12.A.CED.1** Create equations and inequalities in one variable and use them to solve problems. Include equations arising from ~~linear and~~ quadratic functions, ~~and simple rational and exponential functions.~~★

- Use all available types of functions to create equations, but constrain to simple cases.

**MCC9-12.A.CED.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.★

**MCC9-12.A.CED.4** Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. *For example, rearrange Ohm's law  $V = IR$  to highlight resistance  $R$ .*★

- Extend to include ~~linear, exponential~~ and quadratic.

### Reasoning with Equations and Inequalities

A.REI

#### Solve equations and inequalities in one variable

**MCC9-12.A.REI.4** Solve quadratic equations in one variable.

MCC9-12.A.REI.4a Use the method of completing the square to transform any quadratic equation in  $x$  into an equation of the form  $(x - p)^2 = q$  that has the same solutions. Derive the quadratic formula from this form.

MCC9-12.A.REI.4b Solve quadratic equations by inspection (e.g., for  $x^2 = 49$ ), taking square roots, completing the square, the quadratic formula and factoring, as appropriate to the initial form of the equation. Recognize when the quadratic formula gives complex solutions and write them as  $a \pm bi$  for real numbers  $a$  and  $b$ .

## Solve systems of equations

**MCC9-12.A.REI.7** Solve a simple system consisting of a linear equation and a quadratic equation in two variables algebraically and graphically. *For example, find the points of intersection between the line  $y = -3x$  and the circle  $x^2 + y^2 = 3$ .*

- Include systems that lead to work with fractions

## Mathematics | High School—Functions

Functions describe situations where one quantity determines another. For example, the return on \$10,000 invested at an annualized percentage rate of 4.25% is a function of the length of time the money is invested. Because we continually make theories about dependencies between quantities in nature and society, functions are important tools in the construction of mathematical models.

In school mathematics, functions usually have numerical inputs and outputs and are often defined by an algebraic expression. For example, the time in hours it takes for a car to drive 100 miles is a function of the car's speed in miles per hour,  $v$ ; the rule  $T(v) = 100/v$  expresses this relationship algebraically and defines a function whose name is  $T$ .

The set of inputs to a function is called its domain. We often infer the domain to be all inputs for which the expression defining a function has a value, or for which the function makes sense in a given context. A function can be described in various ways, such as by a graph (e.g., the trace of a seismograph); by a verbal rule, as in, "I'll give you a state, you give me the capital city;" by an algebraic expression like  $f(x) = a + bx$ ; or by a recursive rule. The graph of a function is often a useful way of visualizing the relationship of the function models, and manipulating a mathematical expression for a function can throw light on the function's properties.

Functions presented as expressions can model many important phenomena. Two important families of functions characterized by laws of growth are linear functions, which grow at a constant rate, and exponential functions, which grow at a constant percent rate. Linear functions with a constant term of zero describe proportional relationships.

A graphing utility or a computer algebra system can be used to experiment with properties of these functions and their graphs and to build computational models of functions, including recursively defined functions.

### **Connections to Expressions, Equations, Modeling, and Coordinates.**

Determining an output value for a particular input involves evaluating an expression; finding inputs that yield a given output involves solving an equation. Questions about when two functions have the same value for the same input lead to equations, whose solutions can be visualized from the intersection of their graphs. Because functions describe relationships between quantities, they are frequently used in modeling. Sometimes functions are defined by a recursive process, which can be displayed effectively using a spreadsheet or other technology.



**Interpreting Functions**

F.IF

**Interpret functions that arise in applications in terms of the context**

**MCC9-12.F.IF.4** For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. Key features include: intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimums; symmetries; end behavior; ~~and periodicity.~~★

- Students should be able to interpret the intercepts; intervals where the function is increasing, decreasing, positive, or negative; and end behavior (including equations of asymptotes) of exponential functions.
- Compare and graph characteristics of a function represented in a variety of ways. Characteristics include domain, range, vertex, axis of symmetry, zeros, intercepts, extrema, points of discontinuity, intervals of increase and decrease, and rates of change.

**MCC9-12.F.IF.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes. *For example, if the function  $h(n)$  gives the number of person-hours it takes to assemble  $n$  engines in a factory, then the positive integers would be an appropriate domain for the function.*★

**MCC9-12.F.IF.6** Calculate and interpret the average rate of change of a function (presented symbolically or as a table) over a specified interval. Estimate the rate of change from a graph.★

**Analyze functions using different representations**

**MCC9-12.F.IF.7** Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases.★

**MCC9-12.F.IF.7a** Graph ~~linear and~~ quadratic functions and show intercepts, maxima, and minima.★

**MCC9-12.F.IF.8** Write a function defined by an expression in different but equivalent forms to reveal and explain different properties of the function.

**MCC9-12.F.IF.8a** Use the process of factoring and completing the square in a quadratic function to show zeros, extreme values, and symmetry of the graph, and interpret these in terms of a context.

**MCC9-12.F.IF.9** Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions). *For example, given a graph of one quadratic function and an algebraic expression for another, say which has the larger maximum.*

**Building Functions**

F-BF

**Build a function that models a relationship between two quantities**

**MCC9-12.F.BF.1** Write a function that describes a relationship between two quantities.★

**MCC9-12.F.BF.1a** Determine an explicit expression, a recursive process, or steps for calculation from a context.

**MCC9-12.F.BF.1b** Combine standard function types using arithmetic operations. *For example, build a function that models the temperature of a cooling body by adding a constant function to a decaying exponential, and relate these functions to the model.*

### **Build new functions from existing functions**

**MCC9-12.F.BF.3** Identify the effect on the graph of replacing  $f(x)$  by  $f(x) + k$ ,  $k f(x)$ ,  $f(kx)$ , and  $f(x + k)$  for specific values of  $k$  (both positive and negative); find the value of  $k$  given the graphs. Experiment with cases and illustrate an explanation of the effects on the graph using technology. Include recognizing even and odd functions from their graphs and algebraic expressions for them.

- Note the effect of multiple transformations on a single graph and the common effect of each transformation across function types.

### **Linear, Quadratic, and Exponential Models**<sup>★</sup>

F.LE

### **Construct and compare linear, quadratic, and exponential models and solve problems**

**MCC9-12.F.LE.3** Observe using graphs and tables that a quantity increasing exponentially eventually exceeds a quantity increasing linearly, quadratically, or (more generally) as a polynomial function.<sup>★</sup>

- Explore rates of change, comparing rates of change.

### **Mathematics | High School—Modeling**

Modeling links classroom mathematics and statistics to everyday life, work, and decision-making. Modeling is the process of choosing and using appropriate mathematics and statistics to analyze empirical situations, to understand them better, and to improve decisions. Quantities and their relationships in physical, economic, public policy, social, and everyday situations can be modeled using mathematical and statistical methods. When making mathematical models, technology is valuable for varying assumptions, exploring consequences, and comparing predictions with data.

A model can be very simple, such as writing total cost as a product of unit price and number bought, or using a geometric shape to describe a physical object like a coin. Even such simple models involve making choices. It is up to us whether to model a coin as a three-dimensional cylinder, or whether a two-dimensional disk works well enough for our purposes. Other situations—modeling a delivery route, a production schedule, or a comparison of loan amortizations—need more elaborate models that use other tools from the mathematical sciences. Real-world situations are not organized and labeled for analysis; formulating tractable models, representing such models, and analyzing them is appropriately a creative process. Like every such process, this depends on acquired expertise as well as creativity. Some examples of such situations might include:

- Estimating how much water and food is needed for emergency relief in a devastated city of 3 million people, and how it might be distributed.
- Planning a table tennis tournament for 7 players at a club with 4 tables, where each player plays against each other player.
- Designing the layout of the stalls in a school fair so as to raise as much money as possible.

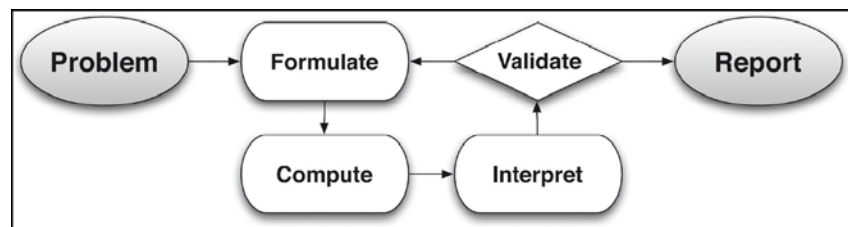
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- Analyzing stopping distance for a car.
- Modeling savings account balance, bacterial colony growth, or investment growth.
- Engaging in critical path analysis, e.g., applied to turnaround of an aircraft at an airport.
- Analyzing risk in situations such as extreme sports, pandemics, and terrorism.
- Relating population statistics to individual predictions.

In situations like these, the models devised depend on a number of factors: How precise an answer do we want or need? What aspects of the situation do we most need to understand, control, or optimize? What resources of time and tools do we have? The range of models that we can create and analyze is also constrained by the limitations of our mathematical, statistical, and technical skills, and our ability to recognize significant variables and relationships among them. Diagrams of various kinds, spreadsheets and other technology, and algebra are powerful tools for understanding and solving problems drawn from different types of real-world situations.

One of the insights provided by mathematical modeling is that essentially the same mathematical or statistical structure can sometimes model seemingly different situations. Models can also shed light on the mathematical structures themselves, for example, as when a model of bacterial growth makes more vivid the explosive growth of the exponential function.

The basic modeling cycle is summarized in the diagram. It involves (1) identifying variables in the situation and selecting those that represent essential features, (2) formulating a model by creating and selecting geometric,



graphical, tabular, algebraic, or statistical representations that describe relationships between the variables, (3) analyzing and performing operations on these relationships to draw conclusions, (4) interpreting the results of the mathematics in terms of the original situation, (5) validating the conclusions by comparing them with the situation, and then either improving the model or, if it is acceptable, (6) reporting on the conclusions and the reasoning behind them. Choices, assumptions, and approximations are present throughout this cycle.

In descriptive modeling, a model simply describes the phenomena or summarizes them in a compact form. Graphs of observations are a familiar descriptive model— for example, graphs of global temperature and atmospheric CO<sub>2</sub> over time.

Analytic modeling seeks to explain data on the basis of deeper theoretical ideas, albeit with parameters that are empirically based; for example, exponential growth of bacterial colonies (until cut-off mechanisms such as pollution or starvation intervene) follows from a constant reproduction rate. Functions are an important tool for analyzing such problems.

Graphing utilities, spreadsheets, computer algebra systems, and dynamic geometry software are powerful tools that can be used to model purely mathematical phenomena (e.g., the behavior of polynomials) as well as physical phenomena.

**Modeling Standards** *Modeling is best interpreted not as a collection of isolated topics but rather in relation to other standards. Making mathematical models is a Standard for Mathematical Practice, and specific modeling standards appear throughout the high school standards indicated by a star symbol (★).*

## Mathematics | High School—Geometry

An understanding of the attributes and relationships of geometric objects can be applied in diverse contexts—interpreting a schematic drawing, estimating the amount of wood needed to frame a sloping roof, rendering computer graphics, or designing a sewing pattern for the most efficient use of material.

Although there are many types of geometry, school mathematics is devoted primarily to plane Euclidean geometry, studied both synthetically (without coordinates) and analytically (with coordinates). Euclidean geometry is characterized most importantly by the Parallel Postulate that states that through a point not on a given line there is exactly one parallel line. (Spherical geometry, in contrast, has no parallel lines.) During high school, students begin to formalize their geometry experiences from elementary and middle school, using more precise definitions and developing careful proofs. Later in college some students develop Euclidean and other geometries carefully from a small set of axioms.

The concepts of congruence, similarity, and symmetry can be understood from the perspective of geometric transformation. Fundamental are the rigid motions: translations, rotations, reflections, and combinations of these, all of which are here assumed to preserve distance and angles (and therefore shape in general). Reflections and rotations each explain a particular type of symmetry, and the symmetries of an object offer insight into its attributes—as when the reflective symmetry of an isosceles triangle assures that its base angles are congruent.

In the approach taken here, two geometric figures are defined to be congruent if there is a sequence of rigid motions that carries one onto the other. This is the principle of superposition. For triangles, congruence means the equality of all corresponding pairs of sides and all corresponding pairs of angles. During the middle grades, through experiences drawing triangles from given conditions, students notice ways to specify enough measures in a triangle to ensure that all triangles drawn with those measures are congruent. Once these triangle congruence criteria (ASA, SAS, and SSS) are established using rigid motions, they can be used to prove theorems about triangles, quadrilaterals, and other geometric figures.

Similarity transformations (rigid motions followed by dilations) define similarity in the same way that rigid motions define congruence, thereby formalizing the similarity ideas of "same shape" and "scale factor" developed in the middle grades. These transformations lead to the criterion for triangle similarity that two pairs of corresponding angles are congruent.

The definitions of sine, cosine, and tangent for acute angles are founded on right triangles and similarity, and, with the Pythagorean Theorem, are fundamental in many real-world and theoretical situations. The Pythagorean Theorem is generalized to non-right triangles by the Law of Cosines. Together, the Laws of Sines and Cosines embody the triangle congruence criteria for the cases where three pieces of information suffice to completely solve a triangle. Furthermore, these laws yield two possible solutions in the ambiguous case, illustrating that Side-Side-Angle is not a congruence criterion.

Analytic geometry connects algebra and geometry, resulting in powerful methods of analysis and problem solving. Just as the number line associates numbers with locations in one dimension, a pair of perpendicular axes associates pairs of numbers with locations in two dimensions. This correspondence between numerical coordinates and geometric points allows methods from algebra to be applied to geometry and vice versa. The solution set of an equation becomes a geometric curve, making visualization a tool for doing and understanding algebra. Geometric shapes can be described by equations, making algebraic manipulation into a tool for geometric understanding, modeling, and proof. Geometric transformations of the graphs of equations correspond to algebraic changes in their equations.

Dynamic geometry environments provide students with experimental and modeling tools that allow them to investigate geometric phenomena in much the same way as computer algebra systems allow them to experiment with algebraic phenomena.

**Connections to Equations.** The correspondence between numerical coordinates and geometric points allows methods from algebra to be applied to geometry and vice versa. The solution set of an equation becomes a geometric curve, making visualization a tool for doing and understanding algebra. Geometric shapes can be described by equations, making algebraic manipulation into a tool for geometric understanding, modeling, and proof.

## Congruence

G.CO

### Understand congruence in terms of rigid motions

**MCC9-12.G.CO.6** Use geometric descriptions of rigid motions to transform figures and to predict the effect of a given rigid motion on a given figure; given two figures, use the definition of congruence in terms of rigid motions to decide if they are congruent.

**MCC9-12.G.CO.7** Use the definition of congruence in terms of rigid motions to show that two triangles are congruent if and only if corresponding pairs of sides and corresponding pairs of angles are congruent.

**MCC9-12.G.CO.8** Explain how the criteria for triangle congruence (ASA, SAS, and SSS) follow from the definition of congruence in terms of rigid motions.

### Prove geometric theorems

**MCC9-12.G.CO.9** Prove theorems about lines and angles. Theorems include: vertical angles are congruent; when a transversal crosses parallel lines, alternate interior angles are congruent and corresponding angles are congruent; points on a perpendicular bisector of a line segment are exactly those equidistant from the segment's endpoints.

**MCC9-12.G.CO.10** Prove theorems about triangles. Theorems include: measures of interior angles of a triangle sum to 180 degrees; base angles of isosceles triangles are congruent; the segment joining midpoints of two sides of a triangle is parallel to the third side and half the length; the medians of a triangle meet at a point.

**MCC9-12.G.CO.11** Prove theorems about parallelograms. Theorems include: opposite sides are congruent, opposite angles are congruent, the diagonals of a parallelogram bisect each other, and conversely, rectangles are parallelograms with congruent diagonals.

### Make geometric constructions

**MCC9-12.G.CO.12** Make formal geometric constructions with a variety of tools and methods (compass and straightedge, string, reflective devices, paper folding, dynamic geometric software, etc.). Copying a segment; copying an angle; bisecting a segment; bisecting an angle; constructing perpendicular lines, including the perpendicular bisector of a line segment; and constructing a line parallel to a given line through a point not on the line.

**MCC9-12.G.CO.13** Construct an equilateral triangle, a square, and a regular hexagon inscribed in a circle.

**Similarity, Right Triangles, and Trigonometry**

G.SRT

Understand similarity in terms of similarity transformations

**MCC9-12.G.SRT.1** Verify experimentally the properties of dilations given by a center and a scale factor:

- a. A dilation takes a line not passing through the center of the dilation to a parallel line, and leaves a line passing through the center unchanged.
- b. The dilation of a line segment is longer or shorter in the ratio given by the scale factor.

**MCC9-12.G.SRT.2** Given two figures, use the definition of similarity in terms of similarity transformations to decide if they are similar; explain using similarity transformations the meaning of similarity for triangles as the equality of all corresponding pairs of angles and the proportionality of all corresponding pairs of sides.

**MCC9-12.G.SRT.3** Use the properties of similarity transformations to establish the AA criterion for two triangles to be similar.

**Prove theorems involving similarity**

**MCC9-12.G.SRT.4** Prove theorems about triangles. Theorems include: a line parallel to one side of a triangle divides the other two proportionally, and conversely; the Pythagorean Theorem proved using triangle similarity.

**MCC9-12.G.SRT.5** Use congruence and similarity criteria for triangles to solve problems and to prove relationships in geometric figures.

**Define trigonometric ratios and solve problems involving right triangles**

**MCC9-12.G.SRT.6** Understand that by similarity, side ratios in right triangles are properties of the angles in the triangle, leading to definitions of trigonometric ratios for acute angles.

**MCC9-12.G.SRT.7** Explain and use the relationship between the sine and cosine of complementary angles.

**MCC9-12.G.SRT.8** Use trigonometric ratios and the Pythagorean Theorem to solve right triangles in applied problems.

**Circles**

G.C

**Understand and apply theorems about circles**

**MCC9-12.G.C.1** Prove that all circles are similar.

**MCC9-12.G.C.2** Identify and describe relationships among inscribed angles, radii, and chords. Include the relationship between central, inscribed, and circumscribed angles; inscribed angles on a diameter are right angles; the radius of a circle is perpendicular to the tangent where the radius intersects the circle.

**MCC9-12.G.C.3** Construct the inscribed and circumscribed circles of a triangle, and prove properties of angles for a quadrilateral inscribed in a circle.

**MCC9-12.G.C.4 (+)** Construct a tangent line from a point outside a given circle to the circle.

### **Find arc lengths and areas of sectors of circles**

**MCC9-12.G.C.5** Derive using similarity the fact that the length of the arc intercepted by an angle is proportional to the radius, and define the radian measure of the angle as the constant of proportionality; derive the formula for the area of a sector.

- Use the properties of circles to solve problems involving the length of an arc and the area of a sector.

### **Expressing Geometric Properties with Equations**

G.GPE

#### **Translate between the geometric description and the equation for a conic section**

**MCC9-12.G.GPE.1** Derive the equation of a circle of given center and radius using the Pythagorean Theorem; complete the square to find the center and radius of a circle given by an equation.

- Translate between the geometric description and the equation for a circle

**MCC9-12.G.GPE.2** Derive the equation of a parabola given a focus and directrix.

#### **Use coordinates to prove simple geometric theorems algebraically**

**MCC9-12.G.GPE.4** Use coordinates to prove simple geometric theorems algebraically. *For example, prove or disprove that a figure defined by four given points in the coordinate plane is a rectangle; prove or disprove that the point  $(1, \sqrt{3})$  lies on the circle centered at the origin and containing the point  $(0, 2)$ .*

### **Geometric Measurement and Dimension**

G.GMD

#### **Explain volume formulas and use them to solve problems**

**MCC9-12.G.GMD.1** Give an informal argument for the formulas for the circumference of a circle, area of a circle, volume of a cylinder, pyramid, and cone. Use dissection arguments, Cavalieri's principle, and informal limit arguments.

**MCC9-12.G.GMD.2 (+)** Give an informal argument using Cavalieri's principle for the formulas for the volume of a sphere and other solid figures.

**MCC9-12.G.GMD.3** Use volume formulas for cylinders, pyramids, cones, and spheres to solve problems.\*

## **Mathematics | High School—Statistics and Probability**★

Decisions or predictions are often based on data—numbers in context. These decisions or predictions would be easy if the data always sent a clear message, but the message is often obscured by variability. Statistics provides tools for describing variability in data and for making informed decisions that take it into account.

Data are gathered, displayed, summarized, examined, and interpreted to discover patterns and deviations from patterns. Quantitative data can be described in terms of key characteristics: measures of shape, center, and spread. The shape of a data distribution might be described as symmetric, skewed, flat, or bell shaped, and it might be summarized by a statistic measuring center (such as mean or median) and a statistic measuring spread (such as standard deviation or interquartile range). Different distributions can be compared numerically using these statistics or compared visually using plots. Knowledge of center and spread are not enough to describe a distribution. Which statistics to compare, which plots to use, and what the results of a comparison might mean, depend on the question to be investigated and the real-life actions to be taken.

Randomization has two important uses in drawing statistical conclusions. First, collecting data from a random sample of a population makes it possible to draw valid conclusions about the whole population, taking variability into account. Second, randomly assigning individuals to different treatments allows a fair comparison of the effectiveness of those treatments. A statistically significant outcome is one that is unlikely to be due to chance alone, and this can be evaluated only under the condition of randomness. The conditions under which data are collected are important in drawing conclusions from the data; in critically reviewing uses of statistics in public media and other reports, it is important to consider the study design, how the data were gathered, and the analyses employed as well as the data summaries and the conclusions drawn.

Random processes can be described mathematically by using a probability model: a list or description of the possible outcomes (the sample space), each of which is assigned a probability. In situations such as flipping a coin, rolling a number cube, or drawing a card, it might be reasonable to assume various outcomes are equally likely. In a probability model, sample points represent outcomes and combine to make up events; probabilities of events can be computed by applying the Addition and Multiplication Rules. Interpreting these probabilities relies on an understanding of independence and conditional probability, which can be approached through the analysis of two-way tables.

Technology plays an important role in statistics and probability by making it possible to generate plots, regression functions, and correlation coefficients, and to simulate many possible outcomes in a short amount of time.

**Connections to Functions and Modeling.** Functions may be used to describe data; if the data suggest a linear relationship, the relationship can be modeled with a regression line, and its strength and direction can be expressed through a correlation coefficient.

### **Interpreting Categorical and Quantitative Data**

**S.ID**

#### **Summarize, represent, and interpret data on two categorical and quantitative variables**

**MCC9-12.S.ID.6** Represent data on two quantitative variables on a scatter plot, and describe how the variables are related.★



MCC9-12.S.ID.6a Fit a function to the data; use functions fitted to data to solve problems in the context of the data. Use given functions or choose a function suggested by the context. Emphasize linear, quadratic, and exponential models.★

### Conditional Probability and the Rules of Probability

S.CP

#### Understand independence and conditional probability and use them to interpret data

**MCC9-12.S.CP.1** Describe events as subsets of a sample space (the set of outcomes) using characteristics (or categories) of the outcomes, or as unions, intersections, or complements of other events (“or,” “and,” “not”).★

**MCC9-12.S.CP.2** Understand that two events A and B are independent if the probability of A and B occurring together is the product of their probabilities, and use this characterization to determine if they are independent.★

**MCC9-12.S.CP.3** Understand the conditional probability of A given B as  $P(A \text{ and } B)/P(B)$ , and interpret independence of A and B as saying that the conditional probability of A given B is the same as the probability of A, and the conditional probability of B given A is the same as the probability of B.★

**MCC9-12.S.CP.4** Construct and interpret two-way frequency tables of data when two categories are associated with each object being classified. Use the two-way table as a sample space to decide if events are independent and to approximate conditional probabilities. *For example, collect data from a random sample of students in your school on their favorite subject among math, science, and English. Estimate the probability that a randomly selected student from your school will favor science given that the student is in tenth grade. Do the same for other subjects and compare the results.*★

**MCC9-12.S.CP.5** Recognize and explain the concepts of conditional probability and independence in everyday language and everyday situations. *For example, compare the chance of having lung cancer if you are a smoker with the chance of being a smoker if you have lung cancer.*★

#### Use the rules of probability to compute probabilities of compound events in a uniform probability model

**MCC9-12.S.CP.6** Find the conditional probability of A given B as the fraction of B’s outcomes that also belong to A, and interpret the answer in terms of the model.★

**MCC9-12.S.CP.7** Apply the Addition Rule,  $P(A \text{ or } B) = P(A) + P(B) - P(A \text{ and } B)$ , and interpret the answer in terms of the model.★

## **Mathematics | Standards for Mathematical Practice**

*Mathematical Practices are listed with each grade's mathematical content standards to reflect the need to connect the mathematical practices to mathematical content in instruction.*

The Standards for Mathematical Practice describe varieties of expertise that mathematics educators at all levels should seek to develop in their students. These practices rest on important “processes and proficiencies” with longstanding importance in mathematics education. The first of these are the NCTM process standards of problem solving, reasoning and proof, communication, representation, and connections. The second are the strands of mathematical proficiency specified in the National Research Council’s report *Adding It Up*: adaptive reasoning, strategic competence, conceptual understanding (comprehension of mathematical concepts, operations and relations), procedural fluency (skill in carrying out procedures flexibly, accurately, efficiently and appropriately), and productive disposition (habitual inclination to see mathematics as sensible, useful, and worthwhile, coupled with a belief in diligence and one’s own efficacy).

### **1 Make sense of problems and persevere in solving them.**

High school students start to examine problems by explaining to themselves the meaning of a problem and looking for entry points to its solution. They analyze givens, constraints, relationships, and goals. They make conjectures about the form and meaning of the solution and plan a solution pathway rather than simply jumping into a solution attempt. They consider analogous problems, and try special cases and simpler forms of the original problem in order to gain insight into its solution. They monitor and evaluate their progress and change course if necessary. Older students might, depending on the context of the problem, transform algebraic expressions or change the viewing window on their graphing calculator to get the information they need. By high school, students can explain correspondences between equations, verbal descriptions, tables, and graphs or draw diagrams of important features and relationships, graph data, and search for regularity or trends. They check their answers to problems using different methods and continually ask themselves, “Does this make sense?” They can understand the approaches of others to solving complex problems and identify correspondences between different approaches.

### **2 Reason abstractly and quantitatively.**

High school students seek to make sense of quantities and their relationships in problem situations. They abstract a given situation and represent it symbolically, manipulate the representing symbols, and pause as needed during the manipulation process in order to probe into the referents for the symbols involved. Students use quantitative reasoning to create coherent representations of the problem at hand; consider the units involved; attend to the meaning of quantities, not just how to compute them; and know and flexibly use different properties of operations and objects.

### **3 Construct viable arguments and critique the reasoning of others.**

High school students understand and use stated assumptions, definitions, and previously established results in constructing arguments. They make conjectures and build a logical progression of statements to explore the truth of their conjectures. They are able to analyze situations by breaking them into cases, and can recognize and use counterexamples. They justify their conclusions, communicate them to others, and respond to the arguments of others. They reason inductively about data, making plausible arguments that take into account the context from which the data arose. High school students are also able to compare the effectiveness of two plausible arguments, distinguish correct logic or reasoning from that which is flawed, and—if there is a flaw in an argument—explain what it is. High school students learn to determine domains to which an argument applies, listen or read the arguments of others, decide whether they make sense, and ask useful questions to clarify or improve the arguments.

#### **4 Model with mathematics.**

High school students can apply the mathematics they know to solve problems arising in everyday life, society, and the workplace. By high school, a student might use geometry to solve a design problem or use a function to describe how one quantity of interest depends on another. High school students making assumptions and approximations to simplify a complicated situation, realizing that these may need revision later. They are able to identify important quantities in a practical situation and map their relationships using such tools as diagrams, two-way tables, graphs, flowcharts and formulas. They can analyze those relationships mathematically to draw conclusions. They routinely interpret their mathematical results in the context of the situation and reflect on whether the results make sense, possibly improving the model if it has not served its purpose.

#### **5 Use appropriate tools strategically.**

High school students consider the available tools when solving a mathematical problem. These tools might include pencil and paper, concrete models, a ruler, a protractor, a calculator, a spreadsheet, a computer algebra system, a statistical package, or dynamic geometry software. High school students should be sufficiently familiar with tools appropriate for their grade or course to make sound decisions about when each of these tools might be helpful, recognizing both the insight to be gained and their limitations. For example, high school students analyze graphs of functions and solutions generated using a graphing calculator. They detect possible errors by strategically using estimation and other mathematical knowledge. When making mathematical models, they know that technology can enable them to visualize the results of varying assumptions, explore consequences, and compare predictions with data. They are able to identify relevant external mathematical resources, such as digital content located on a website, and use them to pose or solve problems. They are able to use technological tools to explore and deepen their understanding of concepts.

#### **6 Attend to precision.**

High school students try to communicate precisely to others by using clear definitions in discussion with others and in their own reasoning. They state the meaning of the symbols they choose, specifying units of measure, and labeling axes to clarify the correspondence with quantities in a problem. They calculate accurately and efficiently, express numerical answers with a degree of precision appropriate for the problem context. By the time they reach high school they have learned to examine claims and make explicit use of definitions.

#### **7 Look for and make use of structure.**

By high school, students look closely to discern a pattern or structure. In the expression  $x^2 + 9x + 14$ , older students can see the 14 as  $2 \times 7$  and the 9 as  $2 + 7$ . They recognize the significance of an existing line in a geometric figure and can use the strategy of drawing an auxiliary line for solving problems. They also can step back for an overview and shift perspective. They can see complicated things, such as some algebraic expressions, as single objects or as being composed of several objects. For example, they can see  $5 - 3(x - y)^2$  as 5 minus a positive number times a square and use that to realize that its value cannot be more than 5 for any real numbers  $x$  and  $y$ . High school students use these patterns to create equivalent expressions, factor and solve equations, and compose functions, and transform figures.

#### **8 Look for and express regularity in repeated reasoning.**

High school students notice if calculations are repeated, and look both for general methods and for shortcuts. Noticing the regularity in the way terms cancel when expanding  $(x - 1)(x + 1)$ ,  $(x - 1)(x^2 + x + 1)$ , and  $(x - 1)(x^3 + x^2 + x + 1)$  might lead them to the general formula for the sum of a geometric series. As they work to solve a problem, derive formulas or make generalizations, high school students maintain oversight of the process, while attending to the details. They continually evaluate the reasonableness of their intermediate results.

## Connecting the Standards for Mathematical Practice to the Content Standards

The Standards for Mathematical Practice describe ways in which developing student practitioners of the discipline of mathematics increasingly ought to engage with the subject matter as they grow in mathematical maturity and expertise throughout the elementary, middle and high school years. Designers of curricula, assessments, and professional development should all attend to the need to connect the mathematical practices to mathematical content in mathematics instruction.

The Standards for Mathematical Content are a balanced combination of procedure and understanding. Expectations that begin with the word “understand” are often especially good opportunities to connect the practices to the content. Students who lack understanding of a topic may rely on procedures too heavily. Without a flexible base from which to work, they may be less likely to consider analogous problems, represent problems coherently, justify conclusions, apply the mathematics to practical situations, use technology mindfully to work with the mathematics, explain the mathematics accurately to other students, step back for an overview, or deviate from a known procedure to find a shortcut. In short, a lack of understanding effectively prevents a student from engaging in the mathematical practices.

In this respect, those content standards which set an expectation of understanding are potential “points of intersection” between the Standards for Mathematical Content and the Standards for Mathematical Practice. These points of intersection are intended to be weighted toward central and generative concepts in the school mathematics curriculum that most merit the time, resources, innovative energies, and focus necessary to qualitatively improve the curriculum, instruction, assessment, professional development, and student achievement in mathematics.

## CCGPS Analytic Geometry: Unit Descriptions

The focus of Analytic Geometry on the coordinate plane is organized into 6 critical areas. Transformations on the coordinate plane provide opportunities for the formal study of congruence and similarity. The study of similarity leads to an understanding of right triangle trigonometry and connects to quadratics through Pythagorean relationships. The study of circles uses similarity and congruence to develop basic theorems relating circles and lines. The need for extending the set of rational numbers arises and real and complex numbers are introduced so that all quadratic equations can be solved. Quadratic expressions, equations, and functions are developed; comparing their characteristics and behavior to those of linear and exponential relationships from Coordinate Algebra. Circles return with their quadratic algebraic representations on the coordinate plane. The link between probability and data is explored through conditional probability. The Mathematical Practice Standards apply throughout each course and, together with the content standards, prescribe that students experience mathematics as a coherent, useful, and logical subject that makes use of their ability to make sense of problem situations.

**Unit 1:** Students apply their earlier experience with transformations and proportional reasoning to build a formal understanding of similarity and congruence. They identify criteria for similarity and congruence of triangles and use them to solve problems. It is in this unit that students develop facility with geometric proof. They use what they know about congruence and similarity to prove theorems involving lines, angles, triangles, and other polygons. They explore a variety of formats for writing proofs.

**Unit 2:** Students apply similarity in right triangles to understand right triangle trigonometry, with particular attention to special right triangles and the Pythagorean Theorem.

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**Unit 3:** In this unit students prove basic theorems about circles, such as a tangent line is perpendicular to a radius, inscribed angle theorem, and theorems about chords, secants, and tangents dealing with segment lengths and angle measures. Students develop informal arguments justifying common formulas for circumference, area, and volume of geometric objects, especially those related to circles.

**Unit 4:** Students extend the laws of exponents to rational exponents and explore distinctions between rational and irrational numbers by considering their decimal representations. In Unit 5, students learn that when quadratic equations do not have real solutions the number system must be extended so that solutions exist, analogous to the way in which extending the whole numbers to the negative numbers allows  $x+1 = 0$  to have a solution. Students explore relationships between number systems: whole numbers, integers, rational numbers, real numbers, and complex numbers. The guiding principle is that equations with no solutions in one number system may have solutions in a larger number system. Students also focus on the structure of expressions, rewriting expressions to clarify and reveal aspects of the relationship they represent in working with polynomial arithmetic.

**Unit 5:** Students consider quadratic functions, comparing the key characteristics of quadratic functions to those of linear and exponential functions. They select from among these functions to model phenomena. Students learn to anticipate the graph of a quadratic function by interpreting various forms of quadratic expressions. In particular, they identify the real solutions of a quadratic equation as the zeros of a related quadratic function. When quadratic equations do not have real solutions, students learn that the graph of the related quadratic function does not cross the horizontal axis.

**Unit 6:** In the Cartesian coordinate system, students use the distance formula to write the equation of a circle when given the radius and the coordinates of its center, and the equation of a parabola with vertical axis when given an equation of its directrix and the coordinates of its focus. Given an equation of a circle, they draw the graph in the coordinate plane, and apply techniques for solving quadratic equations to determine intersections between lines and circles or a parabola and between two circles.

**Unit 7:** Building on probability concepts that began in the middle grades, students use the languages of set theory to expand their ability to compute and interpret theoretical and experimental probabilities for compound events, attending to mutually exclusive events, independent events, and conditional probability. Students should make use of geometric probability models wherever possible.

## Classroom Routines

The importance of continuing the established classroom routines cannot be overstated. Daily routines must include such obvious activities as estimating, analyzing data, describing patterns, and answering daily questions. They should also include less obvious routines, such as how to select materials, how to use materials in a productive manner, how to put materials away, and how to access classroom technology such as computers and calculators. An additional routine is to allow plenty of time for students to explore new materials before attempting any directed activity with these new materials. The regular use of routines is important to the development of students' number sense, flexibility, fluency, collaborative skills and communication. These routines contribute to a rich, hands-on standards based classroom and will support students' performances on the tasks in this unit and throughout the school year.

## Strategies for Teaching and Learning

- Students should be actively engaged by developing their own understanding.
- Mathematics should be represented in as many ways as possible by using graphs, tables, pictures, symbols and words.
- Interdisciplinary and cross curricular strategies should be used to reinforce and extend the learning activities.
- Appropriate manipulatives and technology should be used to enhance student learning.
- Students should be given opportunities to revise their work based on teacher feedback, peer feedback, and metacognition which includes self-assessment and reflection.
- Students should write about the mathematical ideas and concepts they are learning.
- Consideration of all students should be made during the planning and instruction of this unit. Teachers need to consider the following:
  - What level of support do my struggling students need in order to be successful with this unit?
  - In what way can I deepen the understanding of those students who are competent in this unit?
  - What real life connections can I make that will help my students utilize the skills practiced in this unit?

Information and instructional strategies for gifted students, English Language Learners and students with disabilities is available at <http://education.ohio.gov/Topics/Academic-Content-Standards/New-Learning-Standards>.

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### Tasks

The following tasks represent the level of depth, rigor, and complexity expected of all Analytic Geometry students. These tasks, or tasks of similar depth and rigor, should be used to demonstrate evidence of learning. It is important that all elements of a task be addressed throughout the learning process so that students understand what is expected of them. While some tasks are identified as a performance task, they may also be used for teaching and learning (learning/scaffolding task).

<b>Scaffolding Task</b>	Tasks that build up to the learning task.
<b>Learning Task</b>	Constructing understanding through deep/rich contextualized problem solving tasks.
<b>Practice Task</b>	Tasks that provide students opportunities to practice skills and concepts.
<b>Performance Task</b>	Tasks which may be a formative or summative assessment that checks for student understanding/misunderstanding and or progress toward the standard/learning goals at different points during a unit of instruction.
<b>Culminating Task</b>	Designed to require students to use several concepts learned during the unit to answer a new or unique situation. Allows students to give evidence of their own understanding toward the mastery of the standard and requires them to extend their chain of mathematical reasoning.
<b>Short Cycle Task</b>	Designed to exemplify the performance targets that the standards imply. The tasks, with the associated guidance, equip teachers to monitor overall progress in their students' mathematics.
<b>Formative Assessment Lesson (FAL) *more information on page 24</b>	Lessons that support teachers in formative assessment which both reveal and develop students' understanding of key mathematical ideas and applications. These lessons enable teachers and students to monitor in more detail their progress towards the targets of the standards.
<b>3-Act Task *more information on page 25</b>	A Three-Act Task is a whole group mathematics task consisting of 3 distinct parts: an engaging and perplexing Act One, an information and solution seeking Act Two, and a solution discussion and solution revealing Act Three.
<b>Achieve CCSS- CTE Classroom Tasks</b>	Designed to demonstrate how the Common Core and Career and Technical Education knowledge and skills can be integrated. The tasks provide teachers with realistic applications that combine mathematics and CTE content.

## Formative Assessment Lessons (FALs)

The **Formative Assessment Lesson** is designed to be part of an instructional unit typically implemented approximately two-thirds of the way through the instructional unit. The results of the tasks should then be used to **inform** the instruction that will take place for the remainder of the unit.

Formative Assessment Lessons are intended to support teachers in formative assessment. They both reveal and develop students' understanding of key mathematical ideas and applications. These lessons enable teachers and students to monitor in more detail their progress towards the targets of the standards. They assess students' understanding of important concepts and problem solving performance, and help teachers and their students to work effectively together to move each student's mathematical reasoning forward.

Videos of Georgia Teachers implementing FALs can be accessed [HERE](#) and a sample of a FAL lesson may be seen [HERE](#)

More information on types of Formative Assessment Lessons, their use, and their implementation may be found on the [Math Assessment Project](#)'s guide for teachers.

**Formative Assessment Lessons can also be found at the following sites:**

[Mathematics Assessment Project](#)

[Kenton County Math Design Collaborative](#)

[MARS Tasks by grade level](#)

A **sample FAL** with extensive dialog and suggestions for teachers may be found [HERE](#). This resource will help teachers understand the flow and purpose of a FAL.

The [Math Assessment Project](#) has developed Professional Development Modules that are designed to help teachers with the practical and pedagogical challenges presented by these lessons.

[Module 1](#) introduces the model of *formative assessment* used in the lessons, its theoretical background and practical implementation. [Modules 2](#) & [3](#) look at the two types of *Classroom Challenges* in detail. [Modules 4](#) & [5](#) explore two crucial pedagogical features of the lessons: asking probing questions and collaborative learning.

Georgia RESA's may be contacted about professional development on the use of FALs in the classroom. The request should be made through the teacher's local RESA and can be referenced by asking for more information on the Mathematics Design Collaborative (MDC).

Sources of Information:

Vicki Mixon, Former MDC (Math Design Collaborative) trainer

<http://www.reneeyates2math.com/>

[The Mathematics Assessment](#)

[Project http://melissatabor.wikispaces.com/Formative+Assessment+Lessons+%28FALs%29](http://melissatabor.wikispaces.com/Formative+Assessment+Lessons+%28FALs%29)



## Spotlight Tasks

A Spotlight Task has been added to each CCGPS mathematics unit in the Georgia resources for middle and high school. The Spotlight Tasks serve as exemplars for the use of the Standards for Mathematical Practice, appropriate unit-level Common Core Georgia Performance Standards, and research-based pedagogical strategies for instruction and engagement. Each task includes teacher commentary and support for classroom implementation. Some of the Spotlight Tasks are revisions of existing Georgia tasks and some are newly created. Additionally, some of the Spotlight Tasks are 3-Act Tasks based on 3-Act Problems from Dan Meyer and Problem-Based Learning from Robert Kaplinsky.

## 3-Act Tasks

A Three-Act Task is a whole group mathematics task consisting of 3 distinct parts: an engaging and perplexing Act One, an information and solution seeking Act Two, and a solution discussion and solution revealing Act Three.

### **Guidelines for 3-Act Tasks and Patient Problem Solving (Teaching without the Textbook)**

*Adapted from Dan Meyer*

#### **Developing the mathematical Big Idea behind the 3-Act task:**

- Create or find/use a clear visual which tells a brief, perplexing mathematical story. Video or live action works best. (See resource suggestions in the Guide to 3-Act Tasks)
- Video/visual should be real life and allow students to see the situation unfolding.
- Remove the initial literacy/mathematics concerns. Make as few language and/or math demands on students as possible. You are posing a mathematical question without words.
- The visual/video should inspire curiosity or perplexity which will be resolved via the mathematical big idea(s) used by students to answer their questions. You are creating an intellectual need or cognitive dissonance in students.

#### **Enacting the 3-Act in the Classroom**

##### **Act 1 (The Question):**

Set up student curiosity by sharing a scenario:

- Teacher says, “I’m going show you something I came across and found interesting” or, “Watch this.”
- Show video/visual.
- Teacher asks, “What do you notice/wonder?” and “What are the first questions that come to mind?”
- Students share observations/questions with a partner first, then with the class (Think-Pair-Share). Students have ownership of the questions because they posed them.
- Leave no student out of this questioning. Every student should have access to the scenario. No language or mathematical barriers. Low barrier to entry.
- Teacher records questions (on chart paper or digitally-visible to class) and ranks them by popularity.

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- Determine which question(s) will be immediately pursued by the class. If you have a particular question in mind, and it isn't posed by students, you may have to do some skillful prompting to orient their question to serve the mathematical end. However, a good video should naturally lead to the question you hope they'll ask. You may wish to pilot your video on colleagues before showing it to students. If they don't ask the question you are after, your video may need some work.
- Teacher asks for estimated answers in response to the question(s). Ask first for best estimates, then request estimates which are too high and too low. Students are not defining and defending parameters for making sense of forthcoming answers.
- Teacher asks students to record their actual estimation for future reference.

### Act 2 (Information Gathering):

Students gather information, draw on mathematical knowledge, understanding, and resources to answer the big question(s) from Act-1:

- Teacher asks, "What information do you need to answer our *main question*?"
- Students think of the important information they will need to answer their questions.
- Ask, "What mathematical tools do you have already at your disposal which would be useful in answering this question?"
- What mathematical tools might be useful which students don't already have? Help them develop those.
- Teacher offers smaller examples and asks probing questions.
  - What are you doing?
  - Why are you doing that?
  - What would happen if...?
  - Are you sure? How do you know?

### Act 3 (The Reveal):

The payoff.

- Teacher shows the answer and validates students' solutions/answer.
- Teacher revisits estimates and determines closest estimate.
- Teacher compares techniques, and allows students to determine which is most efficient.

### The Sequel:

- Students/teacher generalize the math to any case, and "algebrafy" the problem.
- Teacher poses an extension problem- best chance of student engagement if this extension connects to one of the many questions posed by students which were not the focus of Act 2, or is related to class discussion generated during Act 2.
- Teacher revisits or reintroduces student questions that were not addressed in Act 2.

## Why Use 3-Act Tasks? A Teacher's Response

The short answer: It's what's best for kids!

If you want more, read on:

The need for students to make sense of problems can be addressed through tasks like these. The challenge for teachers is, to quote [Dan Meyer](#), “be less helpful.” (To clarify, being less helpful means to first allow students to generate questions they have about the picture or video they see in the first act, then give them information as they ask for it in act 2.) Less helpful does not mean give these tasks to students blindly, without support of any kind!

This entire process will likely cause some anxiety (for all). When jumping into 3-Act tasks for the first (second, third, . . .) time, students may not generate the suggested question. As a matter of fact, in this task about [proportions and scale](#), students may ask many questions that are curious questions, but have nothing to do with the mathematics you want them to investigate. One question might be “How is that ball moving by itself?” It’s important to record these and all other questions generated by students. This validates students' ideas. Over time, students will become accustomed to the routine of 3-act tasks and come to appreciate that there are certain kinds of mathematically answerable questions – most often related to quantity or measurement.

These kinds of tasks take time, practice and patience. When presented with options to use problems like this with students, the easy thing for teachers to do is to set them aside for any number of “reasons.” I've highlighted a few common “reasons” below with my commentary (in blue):

- This will take too long. I have a lot of content to cover. (Teaching students to think and reason is embedded in mathematical content at all levels - how can you **not** take this time)
- They need to be taught the skills first, then maybe I'll try it. (An important part of learning mathematics lies in productive struggle and learning to persevere [SMP 1]. What better way to discern what students know and are able to do than with a mathematical context [problem] that lets them show you, based on the knowledge they already have - prior to any new information. To quote John Van de Walle, “Believe in kids and they will, flat out, amaze you!”)
- My students can't do this. (Remember, whether you think they can or they can't, you're right!) (Also, this expectation of students persevering and solving problems is in every state's standards - and was there even before common core!)
- I'm giving up some control. (Yes, and this is a bit scary. You're empowering students to think and take charge of their learning. So, what can you do to make this *less* scary? **Do what we expect students to do:**
  - Persevere. Keep trying these and other open-beginning, -middle, and -ended problems. Take note of what's working and focus on it!
  - Talk with a colleague (work with a partner). Find that critical friend at school, another school, online. . .
  - Question (use #MTBoS on Twitter, or blogs, or Google: 3-act tasks).

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The benefits of students learning to question, persevere, problem solve, and reason mathematically far outweigh any of the reasons (read excuses) above. The time spent up front, teaching through tasks such as these and other open problems, creates a huge pay-off later on. However, it is important to note, that the problems themselves are worth nothing without teachers setting the expectation that students: question, persevere, problem solve, and reason mathematically on a daily basis. Expecting these from students, and facilitating the training of how to do this consistently and with fidelity is principal to success for both students and teachers.

Yes, all of this takes time. For most of my classes, mid to late September (we start school at the beginning of August) is when students start to become comfortable with what problem solving really is. It's not word problems - mostly. It's not the problem set you do after the skill practice in the textbook. Problem solving is what you do when you don't know what to do! This is difficult to teach kids and it does take time. But it is worth it! More on this in a future blog!

### **Tips:**

One strategy I've found that really helps students generate questions is to allow them to talk to their peers about what they notice and wonder first (Act 1). Students of all ages will be more likely to share once they have shared and tested their ideas with their peers. This does take time. As you do more of these types of problems, students will become familiar with the format and their comfort level may allow you to cut the amount of peer sharing time down before group sharing.

What do you do if they don't generate the question suggested? Well, there are several ways that this can be handled. If students generate a similar question, use it. Allowing students to struggle through their question and ask for information is one of the big ideas here. Sometimes, students realize that they may need to solve a different problem before they can actually find what they want. If students are way off, in their questions, teachers can direct students, carefully, by saying something like: "You all have generated some interesting questions. I'm not sure how many we can answer in this class. Do you think there's a question we could find that would allow us to use our knowledge of mathematics to find the answer to (insert quantity or measurement)?" Or, if they are really struggling, you can, again carefully, say "You know, I gave this problem to a class last year (or class, period, etc) and they asked (insert something similar to the suggested question here). What do you think about that?" Be sure to allow students to share their thoughts.

After solving the main question, if there are other questions that have been generated by students, it's important to allow students to investigate these as well. Investigating these additional questions validates students' ideas and questions and builds a trusting, collaborative learning relationship between students and the teacher.

Overall, we're trying to help our students mathematize their world. We're best able to do that when we use situations that are relevant (no dog bandanas, please), engaging (create an intellectual need to know), and perplexing. If we continue to use textbook type problems that are too helpful, uninteresting, and let's face it, perplexing in all the wrong ways, we're not doing what's best for kids; we're training them to not be curious, not think, and worst of all . . . dislike math.

More Resources like 3-Act Tasks:

- [www.estimated180.com](http://www.estimated180.com)
- [www.visualpatterns.org](http://www.visualpatterns.org)
- [101 Questions](#)
- [Dan Meyer's 3-Act Tasks](#)
- [3-Act Tasks for Elementary and Middle School](#)
- [Andrew Stadel](#)
- [Jenise Sexton](#)
- [Graham Fletcher](#)
- [Fawn Nguyen](#)
- [Robert Kaplinsky](#)
- [Open Middle](#)
- Check out the Math Twitter Blog-o-Sphere (MTBoS) - you'll find tons of support and ideas!

## Assessment Resources and Instructional Support Resources

The resource sites listed below are designed to support the instructional and assessment needs of teachers. All BLUE links will direct teachers to the site mentioned.

- [CCGPS Frameworks](#) are "models of instruction" designed to support teachers in the implementation of the Common Core Georgia Performance Standards (CCGPS). The Georgia Department of Education, Office of Standards, Instruction, and Assessment has provided an example of the Curriculum Map for each grade level and examples of Frameworks aligned with the CCGPS to illustrate what can be implemented within the grade level. School systems and teachers are free to use these models as is; modify them to better serve classroom needs; or create their own curriculum maps, units and tasks.
- [The Teacher Resource Link](#) (TRL) is an application that delivers vetted and aligned digital resources to Georgia's teachers. TRL is accessible via the GaDOE "tunnel" in conjunction with LDS using the single sign-on process. The content is aligned to Common Core Georgia Performance Standards, Georgia Performance Standards, and National Education Technology Standards and pushed to teachers based on course schedule.
- [Georgia Virtual School](#) content available on our Shared Resources Website is available for anyone to view. Courses are divided into modules and are aligned with the Georgia Performance Standards.
- [Georgia Online Assessment](#) (OAS) System Teachers can use the OAS as a tool for Assessment for Learning. Student results on assessments help teachers identify learner needs and strengths and inform instructional practices. Robust reports also allow teachers to communicate with students and parents about learner goals, intentions, and outcomes. The OAS helps with a cycle of assessments, instruction, feedback, and communication that allows teachers, students, and parents to be confident with instructional success. Teachers will be particularly interested in the [Formative Item Bank](#).
- [Webinar](#) support and links will direct teachers to archived webinars as well as links to join or view upcoming webinars.
- [Course/Grade Level WIKI](#) spaces are available to post questions about a unit, a standard, the course, or any other CCGPS math related concern. Shared resources and information are also available at the site.
- [EOCT study guides](#) are available to provide more information for the ECOT (end of course test)

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- [Georgiastandards.org](http://Georgiastandards.org) provides a gateway to a wealth of instruction links and information. Open the Common Core GPS tab at the top to access specific math resources for CCGPS.

### Webinar Information

Several webinars are available to support your instruction of Analytic Geometry. All webinars may be accessed via <https://www.georgiastandards.org/Common-Core/Pages/default.aspx>. Each of the CCGPS two-hour professional learning grade level/course overviews is available for archived viewing at the original broadcast link <http://www.gpb.org/education/common-core> and includes closed captioning. You can also choose to access the GPB links, along with resource packets, and presentation slides from the [GeorgiaStandards.org Common Core GPS Professional Learning Session](#) landing page. Unit by Unit CCGPS Professional Learning WEBINARS and recordings of archived WEBINARS may be accessed at [Mathematics CCGPS](#) landing page.

### Internet Resources

#### [Mathematics in Movies](#)

<http://www.math.harvard.edu/~knill/mathmovies/>

Short movie clips related to a variety of math topics.

#### [Mathematical Fiction](#)

<http://kasmana.people.cofc.edu/MATHFICT/browse.php>

Plays, short stories, comic books and novels dealing with math.

#### [The Shodor Educational Foundation](#)

<http://www.shodor.org/interactivate/lessons/byAudience/>

This website has extensive notes, lesson plans and applets aligned with the standards.

#### [NEA Portal Arkansas Video Lessons on-line](#)

<http://neaportal.k12.ar.us/index.php/9th-12th-grades-mathematics/>

The NEA portal has short videos aligned to each standard. This resource may be very helpful for students who need review at home.

#### [Learnzillion](#)

[http://learnzillion.com/common\\_core/math/hs](http://learnzillion.com/common_core/math/hs)

This is another good resource for parents and students who need a refresher on topics.

#### [Math Words](#)

<http://www.mathwords.com/>

This is a good reference for math terms.

#### [National Library of Virtual Manipulatives](#)

<http://nlvm.usu.edu/en/nav/vlibrary.html>

Java must be enabled for this applet to run. This website has a wealth of virtual manipulatives helpful for use in presentation. Listed by domain.

[Geogebra Download](#)

<http://www.geogebra.org/cms/download>

Free software similar to Geometer's Sketchpad. This program has applications for algebra, geometry & statistics.

## **Resources for Problem-based Learning**

[Dan Meyer's Website: http://blog.mrmeyer.com/](http://blog.mrmeyer.com/)

Dan Meyer has created many problem-based learning tasks. The tasks have great hooks for the students and are aligned to the standards in this [spreadsheet](#):

[Andrew Stadel](#)

<https://docs.google.com/spreadsheet/ccc?key=0AkLk45wwjYBudG9LeXRad0IHM0E0VFRyOEtRckVvM1E#gid=0>

Andrew Stadel has created many problem-based learning tasks using the same format as Dan Meyer.

[Robert Palinsky](#)

Robert Palinsky has created many tasks that engage students with real life situations.

<http://robertkaplinsky.com/lessons/>

[Geoff Krall's Emergent Math](#)

<http://emergentmath.com/my-problem-based-curriculum-maps/>

Geoff Krall has created a curriculum map structured around problem-based learning tasks.

Georgia Department of Education  
Common Core Georgia Performance Standards  
High School Mathematics  
CCGPS Analytic Geometry - At a Glance

<b>Common Core Georgia Performance Standards: Curriculum Map</b>						
1 <sup>st</sup> Semester			2 <sup>nd</sup> Semester			
Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7
<b>Similarity, Congruence, and Proofs</b>	<b>Right Triangle Trigonometry</b>	<b>Circles and Volume</b>	<b>Extending the Number System</b>	<b>Quadratic Functions</b>	<b>Modeling Geometry</b>	<b>Applications of Probability</b>
MCC9-12.G.SRT.1 MCC9-12.G.SRT.2 MCC9-12.G.SRT.3 MCC9-12.G.SRT.4 MCC9-12.G.SRT.5 MCC9-12.G.CO.6 MCC9-12.G.CO.7 MCC9-12.G.CO.8 MCC9-12.G.CO.9 MCC9-12.G.CO.10 MCC9-12.G.CO.11 MCC9-12.G.CO.12 MCC9-12.G.CO.13 MCC9-12.G.GPE.4	MCC9-12.G.SRT.6 MCC9-12.G.SRT.7 MCC9-12.G.SRT.8	MCC9-12.G.C.1 MCC9-12.G.C.2 MCC9-12.G.C.3 MCC9-12.G.C.4(+) MCC9-12.G.C.5 MCC9-12.G.GMD.1 MCC9-12.G.GMD.2(+) MCC9-12.G.GMD.3  <b>Transition Standard</b> MCC8.G.9	MCC9-12.N.RN.1 MCC9-12.N.RN.2 MCC9-12.N.RN.3 MCC9-12.N.CN.1 MCC9-12.N.CN.2 MCC9-12.N.CN.3(+) MCC9-12.A.APR.1	MCC9-12.N.CN.7 MCC9-12.A.SSE.1a,b MCC9-12.A.SSE.2 MCC9-12.A.SSE.3a,b MCC9-12.A.CED.1 MCC9-12.A.CED.2 MCC9-12.A.CED.4 MCC9-12.A.REI.4a,b MCC9-12.A.REI.7 MCC9-12.F.IF.4 MCC9-12.F.IF.5 MCC9-12.F.IF.6 MCC9-12.F.IF.7a MCC9-12.F.IF.8a MCC9-12.F.IF.9 MCC9-12.F.BF.1a,b MCC9-12.F.BF.3 MCC9-12.F.LE.3 MCC9-12.S.ID.6a	MCC9-12.A.REI.7 MCC9-12.G.GPE.1 MCC9-12.G.GPE.2 MCC9-12.G.GPE.4	MCC9-12.S.CP.1 MCC9-12.S.CP.2 MCC9-12.S.CP.3 MCC9-12.S.CP.4 MCC9-12.S.CP.5 MCC9-12.S.CP.6 MCC9-12.S.CP.7
These units were written to build upon concepts from prior units, so later units contain tasks that depend upon the concepts addressed in earlier units. All units will include the Mathematical Practices and indicate skills to maintain.						

**NOTE:** Mathematical standards are interwoven and should be addressed throughout the year in as many different units and tasks as possible in order to stress the natural connections that exist among mathematical topics.

**Grade 9-12 Key:**

**Number and Quantity Strand:** RN = The Real Number System, Q = Quantities, CN = Complex Number System, VM = Vector and Matrix Quantities

**Algebra Strand:** SSE = Seeing Structure in Expressions, APR = Arithmetic with Polynomial and Rational Expressions, CED = Creating Equations, REI = Reasoning with Equations and Inequalities

**Functions Strand:** IF = Interpreting Functions, LE = Linear and Exponential Models, BF = Building Functions, TF = Trigonometric Functions

**Geometry Strand:** CO = Congruence, SRT = Similarity, Right Triangles, and Trigonometry, C = Circles, GPE = Expressing Geometric Properties with Equations, GMD = Geometric Measurement and Dimension, MG = Modeling with Geometry

**Statistics and Probability Strand:** ID = Interpreting Categorical and Quantitative Data, IC = Making Inferences and Justifying Conclusions, CP = Conditional Probability and the Rules of Probability, MD = Using Probability to Make Decisions

Specific modeling standards appear throughout the high school standards indicated by a star symbol (\*).



Georgia Department of Education  
**Common Core Georgia Performance Standards**  
**CCGPS Analytic Geometry – 1<sup>st</sup> Semester**

**Common Core Georgia Performance Standards: Curriculum Map**

**Standards for Mathematical Practice**

- |  |  |
|--|--|
| <p><b>1</b> Make sense of problems and persevere in solving them.<br/> <b>2</b> Reason abstractly and quantitatively.<br/> <b>3</b> Construct viable arguments and critique the reasoning of others.<br/> <b>4</b> Model with mathematics.</p> | <p><b>5</b> Use appropriate tools strategically.<br/> <b>6</b> Attend to precision.<br/> <b>7</b> Look for and make use of structure.<br/> <b>8</b> Look for and express regularity in repeated reasoning.</p> |
|--|--|

**1<sup>st</sup> Semester**

1 <sup>st</sup> Semester			
Unit 1	Unit 2	Unit 3	Unit 4
Similarity, Congruence, and Proofs	Right Triangle Trigonometry	Circles and Volume	Extending the Number System
<p><b><u>Understand similarity in terms of similarity transformations</u></b>  <b>MCC9-12.G.SRT.1</b> Verify experimentally the properties of dilations given by a center and a scale factor:  <b>a.</b> A dilation takes a line not passing through the center of the dilation to a parallel line, and leaves a line passing through the center unchanged.  <b>b.</b> The dilation of a line segment is longer or shorter in the ratio given by the scale factor.  <b>MCC9-12.G.SRT.2</b> Given two figures, use the definition of similarity in terms of similarity transformations to decide if they are similar; explain using similarity transformations the meaning of similarity for triangles as the equality of all corresponding pairs of angles and the proportionality of all corresponding pairs of sides.  <b>MCC9-12.G.SRT.3</b> Use the properties of similarity transformations to establish the AA criterion for two triangles to be similar.  <b><u>Prove theorems involving similarity</u></b>  <b>MCC9-12.G.SRT.4</b> Prove theorems about triangles. Theorems include: a line parallel to one side of a triangle divides the other two proportionally, and conversely; the Pythagorean Theorem proved using triangle similarity.  <b>MCC9-12.G.SRT.5</b> Use congruence and similarity criteria for triangles to solve problems and to prove relationships in geometric figures.</p>	<p><b><u>Define trigonometric ratios and solve problems involving right triangles</u></b>  <b>MCC9-12.G.SRT.6</b> Understand that by similarity, side ratios in right triangles are properties of the angles in the triangle, leading to definitions of trigonometric ratios for acute angles.  <b>MCC9-12.G.SRT.7</b> Explain and use the relationship between the sine and cosine of complementary angles.  <b>MCC9-12.G.SRT.8</b> Use trigonometric ratios and the Pythagorean Theorem to solve right triangles in applied problems.</p>	<p><b><u>Understand and apply theorems about circles</u></b>  <b>MCC9-12.G.C.1</b> Prove that all circles are similar.  <b>MCC9-12.G.C.2</b> Identify and describe relationships among inscribed angles, radii, and chords. Include the relationship between central, inscribed, and circumscribed angles; inscribed angles on a diameter are right angles; the radius of a circle is perpendicular to the tangent where the radius intersects the circle.  <b>MCC9-12.G.C.3</b> Construct the inscribed and circumscribed circles of a triangle, and prove properties of angles for a quadrilateral inscribed in a circle.  <b>MCC9-12.G.C.4 (+)</b> Construct a tangent line from a point outside a given circle to the circle.  <b><u>Find arc lengths and areas of sectors of circles</u></b>  <b>MCC9-12.G.C.5</b> Derive using similarity the fact that the length of the arc intercepted by an angle is proportional to the radius, and define the radian measure of the angle as the constant of proportionality; derive the formula for the area of a sector.  <b><u>Explain volume formulas and use them to solve problems</u></b>  <b>MCC9-12.G.GMD.1</b> Give an informal argument for the formulas for the circumference of a circle, area of a circle, volume of a cylinder, pyramid, and cone. Use</p>	<p><b><u>Extend the properties of exponents to rational exponents.</u></b>  <b>MCC9-12.N.RN.1</b> Explain how the definition of the meaning of rational exponents follows from extending the properties of integer exponents to those values, allowing for a notation for radicals in terms of rational exponents.  <b>MCC9-12.N.RN.2</b> Rewrite expressions involving radicals and rational exponents using the properties of exponents.  <b><u>Use properties of rational and irrational numbers.</u></b>  <b>MCC9-12.N.RN.3</b> Explain why the sum or product of rational numbers is rational; that the sum of a rational number and an irrational number is irrational; and that the product of a nonzero rational number and an irrational number is irrational.  <b><u>Perform arithmetic operations with complex numbers.</u></b>  <b>MCC9-12.N.CN.1</b> Know there is a complex number <math>i</math> such that <math>i^2 = -1</math>, and every complex number has the form <math>a + bi</math> with <math>a</math> and <math>b</math> real.  <b>MCC9-12.N.CN.2</b> Use the relation <math>i^2 = -1</math> and the commutative, associative, and distributive properties to add, subtract, and multiply complex numbers.  <b>MCC9-12.N.CN.3 (+)</b> Find the conjugate of a complex number; use conjugates to find moduli and quotients of complex numbers.  <b><u>Perform arithmetic operations on</u></b></p>

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<p><b><u>Understand congruence in terms of rigid motions</u></b>  <b>MCC9-12.G.CO.6</b> Use geometric descriptions of rigid motions to transform figures and to predict the effect of a given rigid motion on a given figure; given two figures, use the definition of congruence in terms of rigid motions to decide if they are congruent.  <b>MCC9-12.G.CO.7</b> Use the definition of congruence in terms of rigid motions to show that two triangles are congruent if and only if corresponding pairs of sides and corresponding pairs of angles are congruent.  <b>MCC9-12.G.CO.8</b> Explain how the criteria for triangle congruence (ASA, SAS, and SSS) follow from the definition of congruence in terms of rigid motions.  <b><u>Prove geometric theorems</u></b>  <b>MCC9-12.G.CO.9</b> Prove theorems about lines and angles. Theorems include: vertical angles are congruent; when a transversal crosses parallel lines, alternate interior angles are congruent and corresponding angles are congruent; points on a perpendicular bisector of a line segment are exactly those equidistant from the segment's endpoints.  <b>MCC9-12.G.CO.10</b> Prove theorems about triangles. Theorems include: measures of interior angles of a triangle sum to 180 degrees; base angles of isosceles triangles are congruent; the segment joining midpoints of two sides of a triangle is parallel to the third side and half the length; the medians of a triangle meet at a point.  <b>MCC9-12.G.CO.11</b> Prove theorems about parallelograms. Theorems include: opposite sides are congruent, opposite angles are congruent, the diagonals of a parallelogram bisect each other, and conversely, rectangles are parallelograms with congruent diagonals.  <b><u>Make geometric constructions</u></b>  <b>MCC9-12.G.CO.12</b> Make formal geometric constructions with a variety of tools and methods (compass and straightedge, string, reflective devices, paper folding, dynamic geometric software, etc.). Copying a segment; copying an angle; bisecting a segment;</p>		<p>dissection arguments, Cavalieri's principle, and informal limit arguments.  <b>MCC9-12.G.GMD.2 (+)</b> Give an informal argument using Cavalieri's principle for the formulas for the volume of a sphere and other solid figures.  <b>MCC9-12.G.GMD.3</b> Use volume formulas for cylinders, pyramids, cones, and spheres to solve problems.*                       Transition Standard  <b>MCC8.G.9</b> Know the formulas for the volume of <del>cones, cylinders, and</del> spheres and use them to solve real-world and mathematical problems.</p>	<p><b><u>polynomials</u></b>  <b>MCC9-12.A.APR.1</b> Understand that polynomials form a system analogous to the integers, namely, they are closed under the operations of addition, subtraction, and multiplication; add, subtract, and multiply polynomials. (<i>Focus on polynomial expressions that simplify to forms that are linear or quadratic in a positive integer power of <math>x</math>.</i>)</p>
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<p>bisecting an angle; constructing perpendicular lines, including the perpendicular bisector of a line segment; and constructing a line parallel to a given line through a point not on the line.  <b>MCC9-12.G.CO.13</b> Construct an equilateral triangle, a square, and a regular hexagon inscribed in a circle.  <u><b>Use coordinates to prove simple geometric theorems algebraically</b></u>  <b>MCC9-12.G.GPE.4</b> Use coordinates to prove simple geometric theorems algebraically.  <i>(Restrict to context of circles and parabolas)</i></p>			

Georgia Department of Education  
**Common Core Georgia Performance Standards**  
**CCGPS Analytic Geometry – 2<sup>nd</sup> Semester**

**Common Core Georgia Performance Standards: Curriculum Map**

**Standards for Mathematical Practice**

- |  |  |
|--|--|
| <p><b>1</b> Make sense of problems and persevere in solving them.<br/> <b>2</b> Reason abstractly and quantitatively.<br/> <b>3</b> Construct viable arguments and critique the reasoning of others.<br/> <b>4</b> Model with mathematics.</p> | <p><b>5</b> Use appropriate tools strategically.<br/> <b>6</b> Attend to precision.<br/> <b>7</b> Look for and make use of structure.<br/> <b>8</b> Look for and express regularity in repeated reasoning.</p> |
|--|--|

**2<sup>nd</sup> Semester**

Unit 5	Unit 6	Unit 7
<b>Quadratic Functions</b>	<b>Modeling Geometry</b>	<b>Applications of Probability</b>
<p><b><u>Use complex numbers in polynomial identities and equations.</u></b>  <b>MCC9-12.N.CN.7</b> Solve quadratic equations with real coefficients that have complex solutions.  <b><u>Interpret the structure of expressions</u></b>  <b>MCC9-12.A.SSE.1</b> Interpret expressions that represent a quantity in terms of its context.* (<i>Focus on quadratic functions; compare with linear and exponential functions studied in Coordinate Algebra.</i>)  <b>MCC9-12.A.SSE.1a</b> Interpret parts of an expression, such as terms, factors, and coefficients.* (<i>Focus on quadratic functions; compare with linear and exponential functions studied in Coordinate Algebra.</i>)  <b>MCC9-12.A.SSE.1b</b> Interpret complicated expressions by viewing one or more of their parts as a single entity.* (<i>Focus on quadratic functions; compare with linear and exponential functions studied in Coordinate Algebra.</i>)  <b>MCC9-12.A.SSE.2</b> Use the structure of an expression to identify ways to rewrite it. (<i>Focus on quadratic functions; compare with linear and exponential functions studied in Coordinate Algebra.</i>)  <b><u>Write expressions in equivalent forms to solve problems</u></b>  <b>MCC9-12.A.SSE.3</b> Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression.* (<i>Focus on quadratic functions; compare with linear and exponential functions studied in Coordinate Algebra.</i>)  <b>MCC9-12.A.SSE.3a</b> Factor a quadratic expression to reveal the zeros of the function it defines.*  <b>MCC9-12.A.SSE.3b</b> Complete the square in a quadratic expression to reveal the maximum or minimum value of the function it defines.*  <b><u>Create equations that describe numbers or relationships</u></b>  <b>MCC9-12.A.CED.1</b> Create equations and inequalities in one variable and use them to solve problems. Include equations</p>	<p><b><u>Solve systems of equations</u></b>  <b>MCC9-12.A.REI.7</b> Solve a simple system consisting of a linear equation and a quadratic equation in two variables algebraically and graphically.  <b><u>Translate between the geometric description and the equation for a conic section</u></b>  <b>MCC9-12.G.GPE.1</b> Derive the equation of a circle of given center and radius using the Pythagorean Theorem; complete the square to find the center and radius of a circle given by an equation.  <b>MCC9-12.G.GPE.2</b> Derive the equation of a parabola given a focus and directrix.  <b><u>Use coordinates to prove simple geometric theorems algebraically</u></b>  <b>MCC9-12.G.GPE.4</b> Use coordinates to prove simple geometric theorems algebraically. (<i>Restrict to context of circles and parabolas</i>)</p>	<p><b><u>Understand independence and conditional probability and use them to interpret data</u></b>  <b>MCC9-12.S.CP.1</b> Describe events as subsets of a sample space (the set of outcomes) using characteristics (or categories) of the outcomes, or as unions, intersections, or complements of other events (“or,” “and,” “not”).*  <b>MCC9-12.S.CP.2</b> Understand that two events A and B are independent if the probability of A and B occurring together is the product of their probabilities, and use this characterization to determine if they are independent.*  <b>MCC9-12.S.CP.3</b> Understand the conditional probability of A given B as <math>P(A \text{ and } B)/P(B)</math>, and interpret independence of A and B as saying that the conditional probability of A given B is the same as the probability of A, and the conditional probability of B given A is the same as the probability of B.*  <b>MCC9-12.S.CP.4</b> Construct and interpret two-way frequency tables of data when two categories are associated with each object being classified. Use the two-way table as a sample space to decide if events are independent and to approximate conditional probabilities.*  <b>MCC9-12.S.CP.5</b> Recognize and explain the concepts of conditional probability and independence in everyday language and everyday situations.*  <b><u>Use the rules of probability to compute probabilities of compound events in a uniform probability model</u></b>  <b>MCC9-12.S.CP.6</b> Find the conditional probability of A given B as the fraction of B’s outcomes that also belong to A, and interpret the answer in terms of the model.*  <b>MCC9-12.S.CP.7</b> Apply the Addition Rule, <math>P(A \text{ or } B) = P(A) + P(B) - P(A \text{ and } B)</math>, and interpret the answer in terms of the model.*</p>

arising from linear and quadratic functions, and simple rational and exponential functions. \*

**MCC9-12.A.CED.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. \* (Focus on quadratic functions; compare with linear and exponential functions studied in Coordinate Algebra.)

**MCC9-12.A.CED.4** Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. (Focus on quadratic functions; compare with linear and exponential functions studied in Coordinate Algebra.)

**Solve equations and inequalities in one variable**

**MCC9-12.A.REI.4** Solve quadratic equations in one variable.

**MCC9-12.A.REI.4a** Use the method of completing the square to transform any quadratic equation in  $x$  into an equation of the form  $(x - p)^2 = q$  that has the same solutions. Derive the quadratic formula from this form.

**MCC9-12.A.REI.4b** Solve quadratic equations by inspection (e.g., for  $x^2 = 49$ ), taking square roots, completing the square, the quadratic formula and factoring, as appropriate to the initial form of the equation. Recognize when the quadratic formula gives complex solutions and write them as  $a \pm bi$  for real numbers  $a$  and  $b$ .

**Solve systems of equations**

**MCC9-12.A.REI.7** Solve a simple system consisting of a linear equation and a quadratic equation in two variables algebraically and graphically.

**Interpret functions that arise in applications in terms of the context**

**MCC9-12.F.IF.4** For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. Key features include: intercepts; intervals where the function is increasing, decreasing, positive, or negative; relative maximums and minimums; symmetries; end behavior; and periodicity. \*

**MCC9-12.F.IF.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes. \* (Focus on quadratic functions; compare with linear and exponential functions studied in Coordinate Algebra.)

**MCC9-12.F.IF.6** Calculate and interpret the average rate of change of a function (presented symbolically or as a table) over a specified interval. Estimate the rate of change from a graph. \* (Focus on quadratic functions; compare with linear and exponential functions studied in Coordinate Algebra.)

**Analyze functions using different representations**

**MCC9-12.F.IF.7** Graph functions expressed symbolically and

show key features of the graph, by hand in simple cases and using technology for more complicated cases.\* *(Focus on quadratic functions; compare with linear and exponential functions studied in Coordinate Algebra.)*

**MCC9-12.F.IF.7a** Graph linear and quadratic functions and show intercepts, maxima, and minima.\*

**MCC9-12.F.IF.8** Write a function defined by an expression in different but equivalent forms to reveal and explain different properties of the function. *(Focus on quadratic functions; compare with linear and exponential functions studied in Coordinate Algebra.)*

**MCC9-12.F.IF.8a** Use the process of factoring and completing the square in a quadratic function to show zeros, extreme values, and symmetry of the graph, and interpret these in terms of a context.

**MCC9-12.F.IF.9** Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions). *(Focus on quadratic functions; compare with linear and exponential functions studied in Coordinate Algebra.)*

**Build a function that models a relationship between two quantities**

**MCC9-12.F.BF.1** Write a function that describes a relationship between two quantities.\* *(Focus on quadratic functions; compare with linear and exponential functions studied in Coordinate Algebra.)*

**MCC9-12.F.BF.1a** Determine an explicit expression, a recursive process, or steps for calculation from a context. *(Focus on quadratic functions; compare with linear and exponential functions studied in Coordinate Algebra.)*

**MCC9-12.F.BF.1b** Combine standard function types using arithmetic operations. *(Focus on quadratic functions; compare with linear and exponential functions studied in Coordinate Algebra.)*

**Build new functions from existing functions**

**MCC9-12.F.BF.3** Identify the effect on the graph of replacing  $f(x)$  by  $f(x) + k$ ,  $k f(x)$ ,  $f(kx)$ , and  $f(x + k)$  for specific values of  $k$  (both positive and negative); find the value of  $k$  given the graphs. Experiment with cases and illustrate an explanation of the effects on the graph using technology. Include recognizing even and odd functions from their graphs and algebraic expressions for them. *(Focus on quadratic functions; compare with linear and exponential functions studied in Coordinate Algebra.)*

**Construct and compare linear, quadratic, and exponential models and solve problems**

**MCC9-12.F.LE.3** Observe using graphs and tables that a quantity increasing exponentially eventually exceeds a quantity increasing linearly, quadratically, or (more generally) as a polynomial function.\*

**Summarize, represent, and interpret data on two categorical and quantitative variables**

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<p><b>MCC9-12.S.ID.6</b> Represent data on two quantitative variables on a scatter plot, and describe how the variables are related.* <b>MCC9-12.S.ID.6a</b> Fit a function to the data; use functions fitted to data to solve problems in the context of the data. Use given functions or choose a function suggested by the context. Emphasize <del>linear</del>, quadratic, and <del>exponential</del> models.*</p>		
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