

Apex Learning® Tutorials provide teachers with a solution to support all students in rising to the expectations established by Illinois Learning Standards (ILS). Tutorials offer direct instruction, practice, review, and assessment to build the knowledge and skills required to prepare students for PARCC assessments and the Illinois Science Assessment (ISA).

Math Tutorials offer targeted instruction, practice and review designed to develop computational fluency, deepen conceptual understanding, and apply mathematical practices. They automatically identify and address learning gaps down to elementary-level content, using adaptive remediation to bring students to grade-level no matter where they start. Students engage with the content in an interactive, feedback-rich environment as they progress through standards-aligned modules. By constantly honing the ability to apply their knowledge in abstract and real world scenarios, students build the depth of knowledge and higher order skills required to demonstrate their mastery when put to the test.

In each module, the Learn It and Try It make complex ideas accessible to students through focused content, modeled logic and process, multi-modal representations, and personalized feedback as students reason through increasingly challenging problems. The Review It offers a high impact summary of key concepts and relates those concepts to students' lives. The Test It assesses students' mastery of the module's concepts, providing granular performance data to students and teachers after each attempt. To help students focus on the content most relevant to them, unit-level pretests and posttests can quickly identify where students are strong and where they're still learning.

## 1. EXPRESSIONS, EQUATIONS, AND INEQUALITIES

### • LITERAL EQUATIONS

- **CCSS.Math.Content.HSA-CED.A.1** Create equations and inequalities in one variable and use them to solve problems.
- **CCSS.Math.Content.HSA-REI.B.3** Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.
- **CCSS.Math.Content.HSA-CED.A.4** Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.

### • FORMULATING AND SOLVING EQUATIONS FROM WORD PROBLEMS

- **CCSS.Math.Content.HSA-CED.A.1** Create equations and inequalities in one variable and use them to solve problems.
- **CCSS.Math.Content.HSA-CED.A.3** Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or non-viable options in a modeling context.
- **CCSS.Math.Content.HSA-SSE.A.1a** Interpret parts of an expression, such as terms, factors, and coefficients.
- **CCSS.Math.Content.HSF-LE.A.2** Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table).
- **CCSS.Math.Content.HSF-BF.A.1a** Determine an explicit expression, a recursive process, or steps for calculation from a context.
- **CCSS.Math.Content.HSF-LE.A.1b** Recognize situations in which one quantity changes at a constant rate per unit interval relative to another.
- **CCSS.Math.Content.HSF-IF.B.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.

### • FORMULATING AND SOLVING INEQUALITIES FROM WORD PROBLEMS

- **CCSS.Math.Content.HSA-CED.A.1** Create equations and inequalities in one variable and use them to solve problems.
- **CCSS.Math.Content.HSA-CED.A.3** Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or non-viable options in a modeling context.
- **CCSS.Math.Content.HSA-REI.B.3** Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.
- **CCSS.Math.Content.HSA-SSE.A.1a** Interpret parts of an expression, such as terms, factors, and coefficients.

- **CCSS.Math.Content.HSA-SSE.A.1b** Interpret complicated expressions by viewing one or more of their parts as a single entity.

- **SUMS OF GEOMETRIC SEQUENCES**

- **CCSS.Math.Content.HSA-SSE.B.4** Derive the formula for the sum of a finite geometric series (when the common ratio is not 1), and use the formula to solve problems.

## 2. FUNCTIONS

- **FUNCTIONS AND RELATIONS**

- **CCSS.Math.Content.HSF-IF.A.2** Use function notation, evaluate functions for inputs in their domains, and interpret statements that use function notation in terms of a context.
- **CCSS.Math.Content.HSF-IF.A.1** Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If  $f$  is a function and  $x$  is an element of its domain, then  $f(x)$  denotes the output of  $f$  corresponding to the input  $x$ . The graph of  $f$  is the graph of the equation  $y = f(x)$ .
- **CCSS.Math.Content.HSF-IF.B.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.
- **CCSS.Math.Content.HSF-LE.A.2** Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table).
- **CCSS.Math.Content.HSF-IF.C.7b** Graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions.

- **DOMAIN AND RANGE**

- **CCSS.Math.Content.HSF-IF.A.1** Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If  $f$  is a function and  $x$  is an element of its domain, then  $f(x)$  denotes the output of  $f$  corresponding to the input  $x$ . The graph of  $f$  is the graph of the equation  $y = f(x)$ .
- **CCSS.Math.Content.HSF-IF.B.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.

- **INVERSE FUNCTIONS**

- **CCSS.Math.Content.HSF-BF.B.4c** Read values of an inverse function from a graph or a table, given that the function has an inverse.
- **CCSS.Math.Content.HSF-BF.B.4a** Solve an equation of the form  $f(x) = c$  for a simple function  $f$  that has an inverse and write an expression for the inverse.
- **CCSS.Math.Content.HSF-BF.B.4d** Produce an invertible function from a non-invertible function by restricting the domain.

## 3. LINEAR FUNCTIONS, EQUATIONS, AND INEQUALITIES

- **SLOPE**

- **CCSS.Math.Content.HSF-IF.B.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.
- **CCSS.Math.Content.HSF-IF.A.1** Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If  $f$  is a function and  $x$  is an element of its domain, then  $f(x)$  denotes the output of  $f$  corresponding to the input  $x$ . The graph of  $f$  is the graph of the equation  $y = f(x)$ .
- **CCSS.Math.Content.HSF-IF.B.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.
- **CCSS.Math.Content.HSG-GPE.B.5** Prove the slope criteria for parallel and perpendicular lines and use them to solve geometric problems (e.g., find the equation of a line parallel or perpendicular to a given line that passes through a given point).

- **GRAPHING AND ANALYZING LINEAR FUNCTIONS**

## GRAPHING AND ANALYZING LINEAR FUNCTIONS

- **CCSS.Math.Content.HSF-IF.A.1** Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If  $f$  is a function and  $x$  is an element of its domain, then  $f(x)$  denotes the output of  $f$  corresponding to the input  $x$ . The graph of  $f$  is the graph of the equation  $y = f(x)$ .
- **CCSS.Math.Content.HSF-LE.A.2** Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table).
- **CCSS.Math.Content.HSF-IF.B.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.
- **CCSS.Math.Content.HSF-IF.B.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.
- **CCSS.Math.Content.HSF-IF.B.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.
- **CCSS.Math.Content.HSF-IF.C.7a** Graph linear and quadratic functions and show intercepts, maxima, and minima.

## GRAPHING AND MANIPULATING $Y = MX + B$

- **CCSS.Math.Content.HSA-CED.A.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- **CCSS.Math.Content.HSF-IF.A.1** Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If  $f$  is a function and  $x$  is an element of its domain, then  $f(x)$  denotes the output of  $f$  corresponding to the input  $x$ . The graph of  $f$  is the graph of the equation  $y = f(x)$ .
- **CCSS.Math.Content.HSF-LE.A.2** Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table).
- **CCSS.Math.Content.HSF-IF.C.7a** Graph linear and quadratic functions and show intercepts, maxima, and minima.
- **CCSS.Math.Content.HSF-IF.B.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.
- **CCSS.Math.Content.HSS-ID.C.7** Interpret the slope (rate of change) and the intercept (constant term) of a linear model in the context of the data.
- **CCSS.Math.Content.HSF-IF.B.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.
- **CCSS.Math.Content.HSF-LE.A.1b** Recognize situations in which one quantity changes at a constant rate per unit interval relative to another.
- **CCSS.Math.Content.HSF-LE.B.5** Interpret the parameters in a linear or exponential function in terms of a context.

## 4. EXPONENTIAL EQUATIONS, FUNCTIONS, AND INEQUALITIES

### EXPONENTIAL FUNCTIONS

- **CCSS.Math.Content.HSA-SSE.A.1a** Interpret parts of an expression, such as terms, factors, and coefficients.
- **CCSS.Math.Content.HSA-SSE.A.1b** Interpret complicated expressions by viewing one or more of their parts as a single entity.
- **CCSS.Math.Content.HSF-IF.B.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.
- **CCSS.Math.Content.HSF-IF.C.8b** Use the properties of exponents to interpret expressions for exponential functions.
- **CCSS.Math.Content.HSF-LE.A.1a** Prove that linear functions grow by equal differences over equal intervals, and that exponential functions grow by equal factors over equal intervals.
- **CCSS.Math.Content.HSF-LE.A.2** Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table).
- **CCSS.Math.Content.HSF-IF.B.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.
- **CCSS.Math.Content.HSF-LE.A.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.
- **CCSS.Math.Content.HSF-IF.A.1** Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If  $f$  is a function and  $x$  is an element of its

domain, then  $f(x)$  denotes the output of  $f$  corresponding to the input  $x$ . The graph of  $f$  is the graph of the equation  $y = f(x)$ .

- **CCSS.Math.Content.HSF-IF.B.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.
- **CCSS.Math.Content.HSF-IF.C.7e** Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude.
- **CCSS.Math.Content.HSA-CED.A.1** Create equations and inequalities in one variable and use them to solve problems.
- **CCSS.Math.Content.HSA-CED.A.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- **CCSS.Math.Content.HSA-REI.B.3** Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.
- **CCSS.Math.Content.HSA-SSE.B.3c** Use the properties of exponents to transform expressions for exponential functions.
- **CCSS.Math.Content.HSF-BF.A.1a** Determine an explicit expression, a recursive process, or steps for calculation from a context.
- **CCSS.Math.Content.HSF-LE.B.5** Interpret the parameters in a linear or exponential function in terms of a context.
- **CCSS.Math.Content.HSF-LE.A.1c** Recognize situations in which a quantity grows or decays by a constant percent rate per unit interval relative to another.

## ● EXPONENTIAL GROWTH AND DECAY

- **CCSS.Math.Content.HSA-SSE.A.1a** Interpret parts of an expression, such as terms, factors, and coefficients.
- **CCSS.Math.Content.HSA-SSE.A.1b** Interpret complicated expressions by viewing one or more of their parts as a single entity.
- **CCSS.Math.Content.HSF-LE.A.2** Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table).
- **CCSS.Math.Content.HSF-IF.C.8b** Use the properties of exponents to interpret expressions for exponential functions.
- **CCSS.Math.Content.HSF-LE.A.1a** Prove that linear functions grow by equal differences over equal intervals, and that exponential functions grow by equal factors over equal intervals.
- **CCSS.Math.Content.HSF-LE.B.5** Interpret the parameters in a linear or exponential function in terms of a context.
- **CCSS.Math.Content.HSF-LE.A.1c** Recognize situations in which a quantity grows or decays by a constant percent rate per unit interval relative to another.
- **CCSS.Math.Content.HSA-CED.A.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- **CCSS.Math.Content.HSF-LE.A.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.
- **CCSS.Math.Content.HSF-LE.A.1b** Recognize situations in which one quantity changes at a constant rate per unit interval relative to another.

## ● SOLVING EXPONENTIAL EQUATIONS

- **CCSS.Math.Content.HSA-SSE.B.3c** Use the properties of exponents to transform expressions for exponential functions.
- **CCSS.Math.Content.HSF-LE.A.4** For exponential models, express as a logarithm the solution to  $ab^{ct} = d$  where  $a$ ,  $c$ , and  $d$  are numbers and the base  $b$  is 2, 10, or  $e$ ; evaluate the logarithm using technology.
- **CCSS.Math.Content.HSF-IF.C.8b** Use the properties of exponents to interpret expressions for exponential functions.
- **CCSS.Math.Content.HSF-BF.B.4a** Solve an equation of the form  $f(x) = c$  for a simple function  $f$  that has an inverse and write an expression for the inverse.
- **CCSS.Math.Content.HSF-IF.B.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.
- **CCSS.Math.Content.HSF-LE.A.2** Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table).
- **CCSS.Math.Content.HSF-IF.C.7e** Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude.

## ● SOLVING EXPONENTIAL INEQUALITIES

- **CCSS.Math.Content.HSF-LE.A.2** Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table).

- **CCSS.Math.Content.HSA-CED.A.1** Create equations and inequalities in one variable and use them to solve problems.
- **CCSS.Math.Content.HSA-CED.A.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- **CCSS.Math.Content.HSA-CED.A.3** Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or non-viable options in a modeling context.
- **CCSS.Math.Content.HSA-SSE.A.1b** Interpret complicated expressions by viewing one or more of their parts as a single entity.
- **CCSS.Math.Content.HSF-LE.A.1c** Recognize situations in which a quantity grows or decays by a constant percent rate per unit interval relative to another.

## 5. LOGARITHMIC EXPRESSIONS, EQUATIONS, AND FUNCTIONS

### ● LOGARITHMIC FUNCTIONS

- **CCSS.Math.Content.HSF-IF.B.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.
- **CCSS.Math.Content.HSF-LE.A.4** For exponential models, express as a logarithm the solution to  $ab = c$  to the  $ct$  power = where  $a$ ,  $c$ , and  $d$  are numbers and the base  $b$  is 2, 10, or  $e$ ; evaluate the logarithm using technology.
- **CCSS.Math.Content.HSF-BF.B.4a** Solve an equation of the form  $f(x) = c$  for a simple function  $f$  that has an inverse and write an expression for the inverse.
- **CCSS.Math.Content.HSF-BF.B.4c** Read values of an inverse function from a graph or a table, given that the function has an inverse.
- **CCSS.Math.Content.HSF-BF.B.5** Understand the inverse relationship between exponents and logarithms and use this relationship to solve problems involving logarithms and exponents.
- **CCSS.Math.Content.HSF-IF.A.1** Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If  $f$  is a function and  $x$  is an element of its domain, then  $f(x)$  denotes the output of  $f$  corresponding to the input  $x$ . The graph of  $f$  is the graph of the equation  $y = f(x)$ .
- **CCSS.Math.Content.HSF-IF.B.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.
- **CCSS.Math.Content.HSF-IF.C.7e** Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude.

### ● EVALUATING LOGARITHMIC EXPRESSIONS

- **CCSS.Math.Content.HSA-SSE.A.2** Use the structure of an expression to identify ways to rewrite it.
- **CCSS.Math.Content.HSA-SSE.A.1a** Interpret parts of an expression, such as terms, factors, and coefficients.
- **CCSS.Math.Content.HSA-SSE.A.1b** Interpret complicated expressions by viewing one or more of their parts as a single entity.
- **CCSS.Math.Content.HSF-LE.A.4** For exponential models, express as a logarithm the solution to  $ab = c$  to the  $ct$  power = where  $a$ ,  $c$ , and  $d$  are numbers and the base  $b$  is 2, 10, or  $e$ ; evaluate the logarithm using technology.

### ● SOLVING LOGARITHMIC EQUATIONS

- **CCSS.Math.Content.HSF-LE.A.4** For exponential models, express as a logarithm the solution to  $ab = c$  to the  $ct$  power = where  $a$ ,  $c$ , and  $d$  are numbers and the base  $b$  is 2, 10, or  $e$ ; evaluate the logarithm using technology.
- **CCSS.Math.Content.HSF-BF.B.4a** Solve an equation of the form  $f(x) = c$  for a simple function  $f$  that has an inverse and write an expression for the inverse.
- **CCSS.Math.Content.HSF-IF.A.1** Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If  $f$  is a function and  $x$  is an element of its domain, then  $f(x)$  denotes the output of  $f$  corresponding to the input  $x$ . The graph of  $f$  is the graph of the equation  $y = f(x)$ .
- **CCSS.Math.Content.HSF-IF.B.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.
- **CCSS.Math.Content.HSA-REI.A.1** Explain each step in solving a simple equation as following from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution. Construct a viable argument to justify a solution method.

## 6. SIMPLIFYING, ADDING, AND SUBTRACTING POLYNOMIAL EXPRESSIONS

### • POLYNOMIAL BASICS

- **CCSS.Math.Content.HSA-SSE.A.1a** Interpret parts of an expression, such as terms, factors, and coefficients.
- **CCSS.Math.Content.HSA-SSE.A.1b** Interpret complicated expressions by viewing one or more of their parts as a single entity.
- **CCSS.Math.Content.HSA-SSE.A.2** Use the structure of an expression to identify ways to rewrite it.
- **CCSS.Math.Content.HSA-APR.A.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.

### • ADDITION AND SUBTRACTION OF POLYNOMIALS

- **CCSS.Math.Content.HSA-SSE.A.2** Use the structure of an expression to identify ways to rewrite it.
- **CCSS.Math.Content.HSA-APR.A.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.

## 7. MULTIPLYING AND DIVIDING POLYNOMIAL EXPRESSIONS AND COMPOSING FUNCTIONS

### • MULTIPLICATION OF POLYNOMIALS

- **CCSS.Math.Content.HSA-SSE.A.2** Use the structure of an expression to identify ways to rewrite it.
- **CCSS.Math.Content.HSA-APR.A.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.

### • DIVISION OF POLYNOMIALS

- **CCSS.Math.Content.HSA-APR.B.2** Know and apply the Remainder Theorem: For a polynomial  $p(x)$  and a number  $a$ , the remainder on division by  $x - a$  is  $p(a)$ , so  $p(a) = 0$  if and only if  $(x - a)$  is a factor of  $p(x)$ .
- **CCSS.Math.Content.HSA-SSE.A.2** Use the structure of an expression to identify ways to rewrite it.
- **CCSS.Math.Content.HSA-SSE.A.1a** Interpret parts of an expression, such as terms, factors, and coefficients.
- **CCSS.Math.Content.HSA-SSE.A.1b** Interpret complicated expressions by viewing one or more of their parts as a single entity.
- **CCSS.Math.Content.HSA-APR.D.6** Rewrite simple rational expressions in different forms; write  $a(x)/b(x)$  in the form  $(x) + r(x)/b(x)$ , where  $a(x)$ ,  $b(x)$ ,  $q(x)$ , and  $r(x)$  are polynomials with the degree of  $r(x)$  less than the degree of  $b(x)$ , using inspection, long division, or, for the more complicated examples, a computer algebra system.

### • ARITHMETIC OPERATIONS ON FUNCTIONS

- **CCSS.Math.Content.HSF-BF.A.1b** Combine standard function types using arithmetic operations.

## 8. GRAPHS AND REPRESENTATIONS OF QUADRATIC FUNCTIONS

### • ANALYZING GRAPHS OF QUADRATIC FUNCTIONS

- **CCSS.Math.Content.HSA-SSE.A.2** Use the structure of an expression to identify ways to rewrite it.
- **CCSS.Math.Content.HSF-IF.C.9** Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions).
- **CCSS.Math.Content.HSF-IF.A.1** Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If  $f$  is a function and  $x$  is an element of its domain, then  $f(x)$  denotes the output of  $f$  corresponding to the input  $x$ . The graph of  $f$  is the graph of the equation  $y = f(x)$ .
- **CCSS.Math.Content.HSF-IF.B.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.
- **CCSS.Math.Content.HSF-IF.B.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.
- **CCSS.Math.Content.HSF-BF.B.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.

- **CCSS.Math.Content.HSF-IF.C.7a** Graph linear and quadratic functions and show intercepts, maxima, and minima.
- **CCSS.Math.Content.HSA-APR.B.3** Identify zeros of polynomials when suitable factorizations are available, and use the zeros to construct a rough graph of the function defined by the polynomial.
- **CCSS.Math.Content.HSA-REI.B.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  $b$ .
- **CCSS.Math.Content.HSF-IF.C.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.

#### ● REPRESENTATIONS OF QUADRATIC FUNCTIONS

- **CCSS.Math.Content.HSA-SSE.A.2** Use the structure of an expression to identify ways to rewrite it.
- **CCSS.Math.Content.HSA-REI.B.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.
- **CCSS.Math.Content.HSF-IF.C.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.
- **CCSS.Math.Content.HSF-IF.A.1** Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If  $f$  is a function and  $x$  is an element of its domain, then  $f(x)$  denotes the output of  $f$  corresponding to the input  $x$ . The graph of  $f$  is the graph of the equation  $y = f(x)$ .
- **CCSS.Math.Content.HSF-IF.B.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.
- **CCSS.Math.Content.HSF-IF.C.9** Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions).
- **CCSS.Math.Content.HSF-BF.A.1a** Determine an explicit expression, a recursive process, or steps for calculation from a context.
- **CCSS.Math.Content.HSA-APR.B.3** Identify zeros of polynomials when suitable factorizations are available, and use the zeros to construct a rough graph of the function defined by the polynomial.
- **CCSS.Math.Content.HSF-IF.C.7c** Graph polynomial functions, identifying zeros when suitable factorizations are available, and showing end behavior.
- **CCSS.Math.Content.HSA-SSE.B.3a** Factor a quadratic expression to reveal the zeros of the function it defines.
- **CCSS.Math.Content.HSA-CED.A.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- **CCSS.Math.Content.HSA-CED.A.3** Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or non-viable options in a modeling context.
- **CCSS.Math.Content.HSF-BF.B.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.

#### ● MULTIPLE REPRESENTATIONS OF FUNCTIONS

- **CCSS.Math.Content.HSF-IF.B.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.
- **CCSS.Math.Content.HSF-IF.C.9** Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions).
- **CCSS.Math.Content.HSF-LE.A.2** Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table).
- **CCSS.Math.Content.HSA-CED.A.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- **CCSS.Math.Content.HSF-LE.A.1a** Prove that linear functions grow by equal differences over equal intervals, and that exponential functions grow by equal factors over equal intervals.

## 9. SOLVING QUADRATIC EQUATIONS

#### ● SOLVING QUADRATIC EQUATIONS BY FACTORING

- **CCSS.Math.Content.HSA-REI.B.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  $b$ .

- **CCSS.Math.Content.HSF-IF.C.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.
- **CCSS.Math.Content.HSA-SSE.B.3a** Factor a quadratic expression to reveal the zeros of the function it defines.
- **CCSS.Math.Content.HSA-APR.B.3** Identify zeros of polynomials when suitable factorizations are available, and use the zeros to construct a rough graph of the function defined by the polynomial.
- **CCSS.Math.Content.HSA-APR.C.4** Prove polynomial identities and use them to describe numerical relationships.
- **CCSS.Math.Content.HSF-IF.A.1** Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If  $f$  is a function and  $x$  is an element of its domain, then  $f(x)$  denotes the output of  $f$  corresponding to the input  $x$ . The graph of  $f$  is the graph of the equation  $y = f(x)$ .
- **CCSS.Math.Content.HSF-IF.C.7a** Graph linear and quadratic functions and show intercepts, maxima, and minima.
- **CCSS.Math.Content.HSA-CED.A.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- **CCSS.Math.Content.HSF-BF.A.1a** Determine an explicit expression, a recursive process, or steps for calculation from a context.

## ● QUADRATIC FORMULA

- **CCSS.Math.Content.HSA-SSE.A.1a** Interpret parts of an expression, such as terms, factors, and coefficients.
- **CCSS.Math.Content.HSA-SSE.A.1b** Interpret complicated expressions by viewing one or more of their parts as a single entity.
- **CCSS.Math.Content.HSA-REI.B.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  $b$ .
- **CCSS.Math.Content.HSA-REI.B.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.
- **CCSS.Math.Content.HSN-CN.C.7** Solve quadratic equations with real coefficients that have complex solutions.
- **CCSS.Math.Content.HSF-IF.A.1** Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If  $f$  is a function and  $x$  is an element of its domain, then  $f(x)$  denotes the output of  $f$  corresponding to the input  $x$ . The graph of  $f$  is the graph of the equation  $y = f(x)$ .
- **CCSS.Math.Content.HSF-IF.B.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.
- **CCSS.Math.Content.HSF-BF.A.1a** Determine an explicit expression, a recursive process, or steps for calculation from a context.

## ● COMPLETING THE SQUARE

- **CCSS.Math.Content.HSA-SSE.B.3b** Complete the square in a quadratic expression to reveal the maximum or minimum value of the function it defines.
- **CCSS.Math.Content.HSA-REI.B.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.
- **CCSS.Math.Content.HSA-REI.B.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  $b$ .
- **CCSS.Math.Content.HSF-IF.C.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.
- **CCSS.Math.Content.HSA-SSE.A.2** Use the structure of an expression to identify ways to rewrite it.
- **CCSS.Math.Content.HSF-IF.C.7a** Graph linear and quadratic functions and show intercepts, maxima, and minima.

## ● COMPLEX NUMBERS AND QUADRATIC FUNCTIONS

- **CCSS.Math.Content.HSN-CN.C.7** Solve quadratic equations with real coefficients that have complex solutions.
- **CCSS.Math.Content.HSA-REI.B.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  $b$ .

- **CCSS.Math.Content.HSN-CN.A.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.
- **CCSS.Math.Content.HSN-CN.A.2** Use the relation  $i^2 = -1$  and the commutative, associative, and distributive properties to add, subtract, and multiply complex numbers.

## 10. FACTORING POLYNOMIALS AND THE FACTOR THEOREM

### • FACTORING SPECIAL CASES

- **CCSS.Math.Content.HSA-SSE.A.2** Use the structure of an expression to identify ways to rewrite it.
- **CCSS.Math.Content.HSA-APR.C.4** Prove polynomial identities and use them to describe numerical relationships.
- **CCSS.Math.Content.HSA-SSE.A.1a** Interpret parts of an expression, such as terms, factors, and coefficients.
- **CCSS.Math.Content.HSA-SSE.A.1b** Interpret complicated expressions by viewing one or more of their parts as a single entity.
- **CCSS.Math.Content.HSA-APR.B.3** Identify zeros of polynomials when suitable factorizations are available, and use the zeros to construct a rough graph of the function defined by the polynomial.

### • FACTORING CUBIC POLYNOMIALS

- **CCSS.Math.Content.HSA-SSE.A.2** Use the structure of an expression to identify ways to rewrite it.
- **CCSS.Math.Content.HSA-APR.C.4** Prove polynomial identities and use them to describe numerical relationships.
- **CCSS.Math.Content.HSA-SSE.A.1b** Interpret complicated expressions by viewing one or more of their parts as a single entity.
- **CCSS.Math.Content.HSA-APR.B.3** Identify zeros of polynomials when suitable factorizations are available, and use the zeros to construct a rough graph of the function defined by the polynomial.

### • FACTORING HIGHER-ORDER POLYNOMIALS

- **CCSS.Math.Content.HSA-APR.B.3** Identify zeros of polynomials when suitable factorizations are available, and use the zeros to construct a rough graph of the function defined by the polynomial.
- **CCSS.Math.Content.HSA-SSE.A.1a** Interpret parts of an expression, such as terms, factors, and coefficients.
- **CCSS.Math.Content.HSA-SSE.A.1b** Interpret complicated expressions by viewing one or more of their parts as a single entity.
- **CCSS.Math.Content.HSA-SSE.A.2** Use the structure of an expression to identify ways to rewrite it.
- **CCSS.Math.Content.HSA-APR.C.4** Prove polynomial identities and use them to describe numerical relationships.

### • FACTOR THEOREM AND REMAINDER THEOREM

- **CCSS.Math.Content.HSA-APR.B.2** Know and apply the Remainder Theorem: For a polynomial  $p(x)$  and a number  $a$ , the remainder on division by  $x - a$  is  $p(a)$ , so  $p(a) = 0$  if and only if  $(x - a)$  is a factor of  $p(x)$ .
- **CCSS.Math.Content.HSA-APR.D.6** Rewrite simple rational expressions in different forms; write  $a(x)/b(x)$  in the form  $(x) + r(x)/b(x)$ , where  $a(x)$ ,  $b(x)$ ,  $q(x)$ , and  $r(x)$  are polynomials with the degree of  $r(x)$  less than the degree of  $b(x)$ , using inspection, long division, or, for the more complicated examples, a computer algebra system.
- **CCSS.Math.Content.HSF-IF.A.2** Use function notation, evaluate functions for inputs in their domains, and interpret statements that use function notation in terms of a context.

## 11. POLYNOMIAL FUNCTIONS AND POLYNOMIAL IDENTITIES

### • GRAPHS OF POLYNOMIAL FUNCTIONS

- **CCSS.Math.Content.HSA-APR.B.3** Identify zeros of polynomials when suitable factorizations are available, and use the zeros to construct a rough graph of the function defined by the polynomial.
- **CCSS.Math.Content.HSF-IF.B.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.
- **CCSS.Math.Content.HSF-BF.B.3** Identify the effect on the graph of replacing  $f(x)$  by  $f(x) + k$ ,  $k f(x)$ ,  $f(kx)$ , and  $(x + k)$  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.
- **CCSS.Math.Content.HSF-IF.C.7c** Graph polynomial functions, identifying zeros when suitable factorizations are

available, and showing end behavior.

### ● COMPLEX NUMBERS

- **CCSS.Math.Content.HSN-CN.A.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.
- **CCSS.Math.Content.HSN-CN.A.2** Use the relation  $i^2 = -1$  and the commutative, associative, and distributive properties to add, subtract, and multiply complex numbers.

### ● POLYNOMIAL IDENTITIES

- **CCSS.Math.Content.HSA-SSE.A.2** Use the structure of an expression to identify ways to rewrite it.
- **CCSS.Math.Content.HSA-APR.C.4** Prove polynomial identities and use them to describe numerical relationships.
- **CCSS.Math.Content.HSA-REI.B.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.
- **CCSS.Math.Content.HSA-REI.B.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  $b$ .
- **CCSS.Math.Content.HSA-APR.C.5** Know and apply the Binomial Theorem for the expansion of  $(x + y)^n$  in powers of  $x$  and  $y$  for a positive integer  $n$ , where  $x$  and  $y$  are any numbers, with coefficients determined for example by Pascal's Triangle.

### ● POLYNOMIAL IDENTITIES AND COMPLEX NUMBERS

- **CCSS.Math.Content.HSN-CN.C.8** Extend polynomial identities to the complex numbers.
- **CCSS.Math.Content.HSA-SSE.A.2** Use the structure of an expression to identify ways to rewrite it.
- **CCSS.Math.Content.HSA-APR.C.4** Prove polynomial identities and use them to describe numerical relationships.
- **CCSS.Math.Content.HSA-SSE.A.1a** Interpret parts of an expression, such as terms, factors, and coefficients.
- **CCSS.Math.Content.HSA-SSE.A.1b** Interpret complicated expressions by viewing one or more of their parts as a single entity.
- **CCSS.Math.Content.HSN-CN.A.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.
- **CCSS.Math.Content.HSN-CN.C.7** Solve quadratic equations with real coefficients that have complex solutions.
- **CCSS.Math.Content.HSA-REI.B.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  $b$ .
- **CCSS.Math.Content.HSN-CN.C.9** Know the Fundamental Theorem of Algebra; show that it is true for quadratic polynomials.

## 12. RADICAL AND RATIONAL EXPRESSIONS, EQUATIONS, AND FUNCTIONS

### ● ANALYZING GRAPHS OF SQUARE ROOT FUNCTIONS

- **CCSS.Math.Content.HSF-BF.B.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.
- **CCSS.Math.Content.HSG-CO.B.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.
- **CCSS.Math.Content.HSF-IF.B.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.
- **CCSS.Math.Content.HSF-IF.C.7b** Graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions.
- **CCSS.Math.Content.HSF-BF.B.4a** Solve an equation of the form  $f(x) = c$  for a simple function  $f$  that has an inverse and write an expression for the inverse.
- **CCSS.Math.Content.HSF-BF.B.4c** Read values of an inverse function from a graph or a table, given that the function has an inverse.
- **CCSS.Math.Content.HSF-IF.A.1** Understand that a function from one set (called the domain) to another set (called the

range) assigns to each element of the domain exactly one element of the range. If  $f$  is a function and  $x$  is an element of its domain, then  $f(x)$  denotes the output of  $f$  corresponding to the input  $x$ . The graph of  $f$  is the graph of the equation  $y = f(x)$ .

- **CCSS.Math.Content.HSF-IF.B.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.

### ● SOLVING SQUARE ROOT EQUATIONS

- **CCSS.Math.Content.HSA-REI.A.2** Solve simple rational and radical equations in one variable, and give examples showing how extraneous solutions may arise.
- **CCSS.Math.Content.HSA-REI.A.1** Explain each step in solving a simple equation as following from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution. Construct a viable argument to justify a solution method.
- **CCSS.Math.Content.HSF-BF.A.1a** Determine an explicit expression, a recursive process, or steps for calculation from a context.

## 13. RATIONAL EXPRESSIONS, EQUATIONS, AND FUNCTIONS

### ● OPERATIONS WITH RATIONAL EXPRESSIONS

- **CCSS.Math.Content.HSA-APR.D.7** Understand that rational expressions form a system analogous to the rational numbers, closed under addition, subtraction, multiplication, and division by a nonzero rational expression; add, subtract, multiply, and divide rational expressions.
- **CCSS.Math.Content.HSA-SSE.A.1a** Interpret parts of an expression, such as terms, factors, and coefficients.
- **CCSS.Math.Content.HSA-SSE.A.1b** Interpret complicated expressions by viewing one or more of their parts as a single entity.
- **CCSS.Math.Content.HSA-SSE.A.2** Use the structure of an expression to identify ways to rewrite it.
- **CCSS.Math.Content.HSA-APR.D.6** Rewrite simple rational expressions in different forms; write  $a(x)/b(x)$  in the form  $q(x) + r(x)/b(x)$ , where  $a(x)$ ,  $b(x)$ ,  $q(x)$ , and  $r(x)$  are polynomials with the degree of  $r(x)$  less than the degree of  $b(x)$ , using inspection, long division, or, for the more complicated examples, a computer algebra system.

### ● ANALYZING GRAPHS OF RATIONAL FUNCTIONS

- **CCSS.Math.Content.HSF-IF.C.7d** Graph rational functions, identifying zeros and asymptotes when suitable factorizations are available, and showing end behavior.
- **CCSS.Math.Content.HSF-BF.B.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.
- **CCSS.Math.Content.HSF-IF.B.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.
- **CCSS.Math.Content.HSF-IF.A.1** Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If  $f$  is a function and  $x$  is an element of its domain, then  $f(x)$  denotes the output of  $f$  corresponding to the input  $x$ . The graph of  $f$  is the graph of the equation  $y = f(x)$ .
- **CCSS.Math.Content.HSF-IF.B.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.

### ● SOLVING RATIONAL EQUATIONS

- **CCSS.Math.Content.HSA-REI.A.1** Explain each step in solving a simple equation as following from the equality of numbers asserted at the previous step, starting from the assumption that the original equation has a solution. Construct a viable argument to justify a solution method.
- **CCSS.Math.Content.HSA-REI.A.2** Solve simple rational and radical equations in one variable, and give examples showing how extraneous solutions may arise.
- **CCSS.Math.Content.HSF-IF.A.1** Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If  $f$  is a function and  $x$  is an element of its domain, then  $f(x)$  denotes the output of  $f$  corresponding to the input  $x$ . The graph of  $f$  is the graph of the equation  $y = f(x)$ .
- **CCSS.Math.Content.HSF-IF.C.7d** Graph rational functions, identifying zeros and asymptotes when suitable factorizations

are available, and showing end behavior.

- **MODELING SITUATIONS WITH RATIONAL FUNCTIONS**

- **CCSS.Math.Content.HSA-SSE.A.1a** Interpret parts of an expression, such as terms, factors, and coefficients.
- **CCSS.Math.Content.HSA-SSE.A.1b** Interpret complicated expressions by viewing one or more of their parts as a single entity.
- **CCSS.Math.Content.HSA-CED.A.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- **CCSS.Math.Content.HSA-CED.A.3** Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or non-viable options in a modeling context.
- **CCSS.Math.Content.HSA-REI.A.2** Solve simple rational and radical equations in one variable, and give examples showing how extraneous solutions may arise.
- **CCSS.Math.Content.HSF-BF.A.1a** Determine an explicit expression, a recursive process, or steps for calculation from a context.

## 14. NONLINEAR FUNCTIONS

- **LINEAR VERSUS NONLINEAR FUNCTIONS**

- **CCSS.Math.Content.HSF-IF.C.9** Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions).
- **CCSS.Math.Content.HSF-LE.A.2** Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table).
- **CCSS.Math.Content.HSF-LE.A.1a** Prove that linear functions grow by equal differences over equal intervals, and that exponential functions grow by equal factors over equal intervals.
- **CCSS.Math.Content.HSF-IF.B.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.
- **CCSS.Math.Content.HSF-LE.A.1c** Recognize situations in which a quantity grows or decays by a constant percent rate per unit interval relative to another.
- **CCSS.Math.Content.HSF-LE.A.1b** Recognize situations in which one quantity changes at a constant rate per unit interval relative to another.
- **CCSS.Math.Content.HSF-IF.B.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.

- **ABSOLUTE VALUE FUNCTIONS**

- **CCSS.Math.Content.HSF-IF.A.1** Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If  $f$  is a function and  $x$  is an element of its domain, then  $f(x)$  denotes the output of  $f$  corresponding to the input  $x$ . The graph of  $f$  is the graph of the equation  $y = f(x)$ .
- **CCSS.Math.Content.HSF-IF.B.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.
- **CCSS.Math.Content.HSF-BF.B.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.
- **CCSS.Math.Content.HSF-IF.B.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.
- **CCSS.Math.Content.HSF-IF.C.7b** Graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions.

- **RADIANS AND THE UNIT CIRCLE**

- **CCSS.Math.Content.HSF-TF.A.1** Understand radian measure of an angle as the length of the arc on the unit circle subtended by the angle.
- **CCSS.Math.Content.HSF-TF.A.2** Explain how the unit circle in the coordinate plane enables the extension of trigonometric functions to all real numbers, interpreted as radian measures of angles traversed counterclockwise around the unit circle.

- **CCSS.Math.Content.HSG-C.B.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.
- **CCSS.Math.Content.HSF-TF.A.3** Use special triangles to determine geometrically the values of sine, cosine, tangent for  $\pi/3$ ,  $\pi/4$  and  $\pi/6$ , and use the unit circle to express the values of sine, cosine, and tangent for  $\pi-x$ ,  $\pi+x$ , and  $2\pi-x$  in terms of their values for  $x$ , where  $x$  is any real number.
- **CCSS.Math.Content.HSF-TF.A.4** Use the unit circle to explain symmetry (odd and even) and periodicity of trigonometric functions.
- **CCSS.Math.Content.HSG-SRT.C.8** Use trigonometric ratios and the Pythagorean Theorem to solve right triangles in applied problems.

## ● TRIGONOMETRIC FUNCTIONS

- **CCSS.Math.Content.HSF-TF.A.2** Explain how the unit circle in the coordinate plane enables the extension of trigonometric functions to all real numbers, interpreted as radian measures of angles traversed counterclockwise around the unit circle.
- **CCSS.Math.Content.HSF-TF.B.5** Choose trigonometric functions to model periodic phenomena with specified amplitude, frequency, and midline.
- **CCSS.Math.Content.HSF-IF.C.7e** Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude.
- **CCSS.Math.Content.HSF-TF.C.8** Prove the Pythagorean identity  $\sin^2(\theta) + \cos^2(\theta) = 1$  and use it to find  $\sin(\theta)$ ,  $\cos(\theta)$ , or  $\tan(\theta)$  given  $\sin(\theta)$ ,  $\cos(\theta)$ , or  $\tan(\theta)$  and the quadrant of the angle.

## 15. PARENT FUNCTIONS AND TRANSFORMATIONS

### ● PARENT FUNCTIONS

- **CCSS.Math.Content.HSF-IF.B.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.
- **CCSS.Math.Content.HSF-IF.C.7b** Graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions.
- **CCSS.Math.Content.HSF-IF.A.1** Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If  $f$  is a function and  $x$  is an element of its domain, then  $f(x)$  denotes the output of  $f$  corresponding to the input  $x$ . The graph of  $f$  is the graph of the equation  $y = f(x)$ .
- **CCSS.Math.Content.HSF-IF.B.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.
- **CCSS.Math.Content.HSF-BF.B.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.
- **CCSS.Math.Content.HSF-IF.C.7c** Graph polynomial functions, identifying zeros when suitable factorizations are available, and showing end behavior.
- **CCSS.Math.Content.HSF-LE.A.2** Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table).
- **CCSS.Math.Content.HSF-IF.C.7e** Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude.

### ● TRANSFORMATIONS OF PARENT FUNCTIONS

- **CCSS.Math.Content.HSF-BF.B.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.
- **CCSS.Math.Content.HSG-CO.A.2** Represent transformations in the plane using, e.g., transparencies and geometry software; describe transformations as functions that take points in the plane as inputs and give other points as outputs. Compare transformations that preserve distance and angle to those that do not (e.g., translation versus horizontal stretch).
- **CCSS.Math.Content.HSG-CO.B.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.
- **CCSS.Math.Content.HSF-IF.B.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.

- **CCSS.Math.Content.HSF-IF.B.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.
- **CCSS.Math.Content.HSF-IF.C.7b** Graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions.
- **CCSS.Math.Content.HSF-IF.C.7c** Graph polynomial functions, identifying zeros when suitable factorizations are available, and showing end behavior.
- **CCSS.Math.Content.HSF-IF.C.7e** Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude.
- **CCSS.Math.Content.HSF-IF.A.1** Understand that a function from one set (called the domain) to another set (called the range) assigns to each element of the domain exactly one element of the range. If  $f$  is a function and  $x$  is an element of its domain, then  $f(x)$  denotes the output of  $f$  corresponding to the input  $x$ . The graph of  $f$  is the graph of the equation  $y = f(x)$ .

#### ● **MULTIPLE TRANSFORMATIONS OF PARENT FUNCTIONS**

- **CCSS.Math.Content.HSF-BF.B.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.
- **CCSS.Math.Content.HSG-CO.A.2** Represent transformations in the plane using, e.g., transparencies and geometry software; describe transformations as functions that take points in the plane as inputs and give other points as outputs. Compare transformations that preserve distance and angle to those that do not (e.g., translation versus horizontal stretch).
- **CCSS.Math.Content.HSG-CO.A.5** Given a geometric figure and a rotation, reflection, or translation, draw the transformed figure using, e.g., graph paper, tracing paper, or geometry software. Specify a sequence of transformations that will carry a given figure onto another.
- **CCSS.Math.Content.HSG-CO.B.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.
- **CCSS.Math.Content.HSF-IF.B.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.
- **CCSS.Math.Content.HSF-IF.B.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.
- **CCSS.Math.Content.HSF-IF.C.7b** Graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions.
- **CCSS.Math.Content.HSF-IF.C.7c** Graph polynomial functions, identifying zeros when suitable factorizations are available, and showing end behavior.
- **CCSS.Math.Content.HSF-IF.C.7e** Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude.

## 16. SYSTEMS OF EQUATIONS

#### ● **SOLVING THREE-VARIABLE SYSTEMS OF LINEAR EQUATIONS**

- **CCSS.Math.Content.HSA-CED.A.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- **CCSS.Math.Content.HSA-CED.A.3** Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or non-viable options in a modeling context.
- **CCSS.Math.Content.HSA-REI.C.5** Prove that, given a system of two equations in two variables, replacing one equation by the sum of that equation and a multiple of the other produces a system with the same solutions.

#### ● **SYSTEMS OF NONLINEAR EQUATIONS**

- **CCSS.Math.Content.HSA-REI.C.6** Solve systems of linear equations exactly and approximately (e.g., with graphs), focusing on pairs of linear equations in two variables.
- **CCSS.Math.Content.HSA-REI.C.7** Solve a simple system consisting of a linear equation and a quadratic equation in two variables algebraically and graphically.
- **CCSS.Math.Content.HSA-REI.C.5** Prove that, given a system of two equations in two variables, replacing one equation by the sum of that equation and a multiple of the other produces a system with the same solutions.

- **CCSS.Math.Content.HSA-REI.D.11** Explain why the  $x$ -coordinates of the points where the graphs of the equations  $y = f(x)$  and  $y = g(x)$  intersect are the solutions of the equation  $f(x) = g(x)$ ; find the solutions approximately, e.g., using technology to graph the functions, make tables of values, or find successive approximations. Include cases where  $f(x)$  and/or  $g(x)$  are linear, polynomial, rational, absolute value, exponential, and logarithmic functions.
- **CCSS.Math.Content.HSF-LE.A.2** Construct linear and exponential functions, including arithmetic and geometric sequences, given a graph, a description of a relationship, or two input-output pairs (include reading these from a table).

## 17. STATISTICAL DESIGN AND ANALYSIS

### • ANALYZING STATISTICAL SAMPLES

- **CCSS.Math.Content.HSS-IC.A.1** Understand statistics as a process for making inferences about population parameters based on a random sample from that population.
- **CCSS.Math.Content.HSS-IC.B.4** Use data from a sample survey to estimate a population mean or proportion; develop a margin of error through the use of simulation models for random sampling.
- **CCSS.Math.Content.HSS-IC.A.2** Decide if a specified model is consistent with results from a given data-generating process, e.g., using simulation.

### • EXPERIMENTAL AND OBSERVATIONAL DESIGN

- **CCSS.Math.Content.HSS-IC.B.3** Recognize the purposes of and differences among sample surveys, experiments, and observational studies; explain how randomization relates to each.

### • CONCLUSIONS IN DATA

- **CCSS.Math.Content.HSS-IC.B.5** Use data from a randomized experiment to compare two treatments; use simulations to decide if differences between parameters are significant.
- **CCSS.Math.Content.HSS-IC.B.6** Evaluate reports based on data.

## 18. STATISTICS AND PROBABILITY

### • NORMAL DISTRIBUTION

- **CCSS.Math.Content.HSS-ID.A.3** Interpret differences in shape, center, and spread in the context of the data sets, accounting for possible effects of extreme data points (outliers).
- **CCSS.Math.Content.HSS-ID.A.4** Use the mean and standard deviation of a data set to fit it to a normal distribution and to estimate population percentages. Recognize that there are data sets for which such a procedure is not appropriate. Use calculators, spreadsheets, and tables to estimate areas under the normal curve.
- **CCSS.Math.Content.HSS-IC.B.4** Use data from a sample survey to estimate a population mean or proportion; develop a margin of error through the use of simulation models for random sampling.

### • ANALYZING DECISIONS IN PROBABILITY

- **CCSS.Math.Content.HSS-MD.B.6** Use probabilities to make fair decisions (e.g., drawing by lots, using a random number generator).
- **CCSS.Math.Content.HSS-MD.B.7** Analyze decisions and strategies using probability concepts (e.g., product testing, medical testing, pulling a hockey goalie at the end of a game).