

Florida Tutorials are designed specifically for the New Florida Standards for Math and English Language Arts and the Next Generation Sunshine State Standards (NGSSS) for science and social studies to prepare students for the Florida Standards Assessments and the NGSSS End-of-Course (EOC) exams.

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. REAL NUMBER SYSTEM

### • LAWS OF EXPONENTS

- **MAFS.912.A-SSE.1.2** Use the structure of an expression to identify ways to rewrite it.
- **MAFS.912.N-RN.1.1** 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.
- **MAFS.912.A-APR.4.6** 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.
- **MAFS.912.A-REI.1.1** 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.
- **MAFS.912.F-IF.3.8.b** Use the properties of exponents to interpret expressions for exponential functions.
- **MAFS.912.N-RN.1.2** Rewrite expressions involving radicals and rational exponents using the properties of exponents.
- **MAFS.912.A-REI.2.4.b** 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  $b$ .

### • MONITORING PRECISION AND ACCURACY

- **MAFS.912.N-Q.1.1** Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
- **MAFS.912.N-Q.1.2** Define appropriate quantities for the purpose of descriptive modeling.
- **MAFS.912.N-Q.1.3** Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.

## 2. EQUATIONS AND INEQUALITIES

### • ONE-STEP EQUATIONS AND INEQUALITIES

- **MAFS.912.A-CED.1.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- **MAFS.912.A-CED.1.1** Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational, absolute, and exponential functions.

- **MAFS.912.A-REI.2.3** Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.
- **MAFS.912.A-CED.1.3** 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.
- **MAFS.912.A-REI.1.1** 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.
- **MAFS.912.F-BF.1.1.a** Determine an explicit expression, a recursive process, or steps for calculation from a context.
- **MAFS.912.A-REI.1.2** Solve simple rational and radical equations in one variable, and give examples showing how extraneous solutions may arise.

### ● MULTI-STEP EQUATIONS AND INEQUALITIES

- **MAFS.912.A-CED.1.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- **MAFS.912.A-CED.1.3** 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.
- **MAFS.912.A-CED.1.1** Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational, absolute, and exponential functions.
- **MAFS.912.A-REI.1.1** 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.
- **MAFS.912.A-REI.2.3** Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.

### ● LITERAL EQUATIONS

- **MAFS.912.A-REI.2.3** Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.
- **MAFS.912.A-CED.1.4** Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations.
- **MAFS.912.A-CED.1.1** Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational, absolute, and exponential functions.

### ● AXIOMS OF EQUALITY

- **MAFS.912.A-SSE.1.2** Use the structure of an expression to identify ways to rewrite it.
- **MAFS.912.A-SSE.1.1.b** Interpret complicated expressions by viewing one or more of their parts as a single entity.
- **MAFS.912.A-REI.1.1** 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.

## 3. WRITING EQUATIONS AND INEQUALITIES

### ● FORMULATING AND SOLVING EQUATIONS FROM WORD PROBLEMS

- **MAFS.912.F-LE.1.2** 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).
- **MAFS.912.F-LE.1.1.b** Recognize situations in which one quantity changes at a constant rate per unit interval relative to another.
- **MAFS.912.F-BF.1.1.a** Determine an explicit expression, a recursive process, or steps for calculation from a context.
- **MAFS.912.A-CED.1.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- **MAFS.912.A-CED.1.1** Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational, absolute, and exponential functions.
- **MAFS.912.A-REI.2.3** Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.
- **MAFS.912.F-IF.2.4** 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.

- **MAFS.912.A-SSE.1.1.a** Interpret parts of an expression, such as terms, factors, and coefficients.

- **FORMULATING AND SOLVING INEQUALITIES FROM WORD PROBLEMS**

- **MAFS.912.A-REI.2.3** Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.
- **MAFS.912.A-CED.1.3** 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.
- **MAFS.912.A-CED.1.1** Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational, absolute, and exponential functions.
- **MAFS.912.A-SSE.1.1.a** Interpret parts of an expression, such as terms, factors, and coefficients.
- **MAFS.912.A-REI.4.12** Graph the solutions to a linear inequality in two variables as a half-plane (excluding the boundary in the case of a strict inequality), and graph the solution set to a system of linear inequalities in two variables as the intersection of the corresponding half-planes.

## 4. SEQUENCES

- **SEQUENCES**

- **MAFS.912.F-IF.1.3** Recognize that sequences are functions, sometimes defined recursively, whose domain is a subset of the integers.
- **MAFS.912.F-BF.1.2** Write arithmetic and geometric sequences both recursively and with an explicit formula, use them to model situations, and translate between the two forms.
- **MAFS.912.F-BF.1.1.a** Determine an explicit expression, a recursive process, or steps for calculation from a context.
- **MAFS.912.F-LE.1.2** 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).

- **ARITHMETIC AND GEOMETRIC SEQUENCES**

- **MAFS.912.F-BF.1.2** Write arithmetic and geometric sequences both recursively and with an explicit formula, use them to model situations, and translate between the two forms.
- **MAFS.912.F-BF.1.1.a** Determine an explicit expression, a recursive process, or steps for calculation from a context.
- **MAFS.912.F-LE.1.2** 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).
- **MAFS.912.F-IF.1.3** Recognize that sequences are functions, sometimes defined recursively, whose domain is a subset of the integers.

- **SUMS OF GEOMETRIC SEQUENCES**

- **MAFS.912.A-SSE.2.4** 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.

## 5. FUNCTIONS

- **FUNCTIONS AND RELATIONS**

- **MAFS.912.F-IF.1.1** 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  $y = f(x)$ .
- **MAFS.912.F-IF.1.2** Use function notation, evaluate functions for inputs in their domains, and interpret statements that use function notation in terms of a context.
- **MAFS.912.F-IF.2.4** 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.
- **MAFS.912.F-LE.1.2** 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).
- **MAFS.912.F-IF.3.7.b** Graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions.
- **MAFS.912.A-CED.1.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.

- **DOMAIN AND RANGE**

- **MAFS.912.F-IF.1.1** 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  $y = f(x)$ .
- **MAFS.912.F-IF.2.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.
- **MAFS.912.F-LE.1.2** 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).

- **INVERSE FUNCTIONS**

- **MAFS.912.F-BF.2.4.c** Read values of an inverse function from a graph or a table, given that the function has an inverse.
- **MAFS.912.F-BF.2.4.a** 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.
- **MAFS.912.F-BF.2.4.d** Produce an invertible function from a non-invertible function by restricting the domain.

## 6. LINEAR FUNCTIONS, EQUATIONS, AND INEQUALITIES

- **SLOPE**

- **MAFS.912.F-IF.2.6** 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.
- **MAFS.912.F-IF.1.1** 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  $y = f(x)$ .
- **MAFS.912.F-IF.2.4** 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.
- **MAFS.912.S-ID.3.7** Interpret the slope (rate of change) and the intercept (constant term) of a linear model in the context of the data.
- **MAFS.912.G-GPE.2.5** 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**

- **MAFS.912.F-IF.1.1** 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  $y = f(x)$ .
- **MAFS.912.F-LE.1.2** 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).
- **MAFS.912.F-IF.2.6** 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.
- **MAFS.912.F-IF.2.4** 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.
- **MAFS.912.F-IF.2.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.
- **MAFS.912.F-IF.1.2** Use function notation, evaluate functions for inputs in their domains, and interpret statements that use function notation in terms of a context.
- **MAFS.912.F-IF.3.7.a** Graph linear and quadratic functions and show intercepts, maxima, and minima.
- **MAFS.912.S-ID.3.7** Interpret the slope (rate of change) and the intercept (constant term) of a linear model in the context of the data.

- **GRAPHING AND MANIPULATING  $Y = MX + B$**

- **MAFS.912.A-CED.1.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- **MAFS.912.F-IF.1.1** 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  $y = f(x)$ .

- **MAFS.912.F-IF.2.4** 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.
- **MAFS.912.F-IF.2.6** 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.
- **MAFS.912.F-IF.3.9** Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions).
- **MAFS.912.F-LE.1.2** 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).
- **MAFS.912.F-IF.3.7.a** Graph linear and quadratic functions and show intercepts, maxima, and minima.
- **MAFS.912.S-ID.3.7** Interpret the slope (rate of change) and the intercept (constant term) of a linear model in the context of the data.
- **MAFS.912.F-LE.1.1.b** Recognize situations in which one quantity changes at a constant rate per unit interval relative to another.
- **MAFS.912.A-CED.1.3** 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.
- **MAFS.912.F-LE.2.5** Interpret the parameters in a linear or exponential function in terms of a context.

### ● **GRAPHS OF LINEAR INEQUALITIES**

- **MAFS.912.A-REI.4.12** Graph the solutions to a linear inequality in two variables as a half-plane (excluding the boundary in the case of a strict inequality), and graph the solution set to a system of linear inequalities in two variables as the intersection of the corresponding half-planes.
- **MAFS.912.A-REI.2.3** Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.
- **MAFS.912.A-CED.1.3** 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.

## 7. SYSTEMS OF EQUATIONS

### ● **SOLVING SYSTEMS OF LINEAR EQUATIONS: GRAPHING**

- **MAFS.912.A-CED.1.3** 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.
- **MAFS.912.A-CED.1.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- **MAFS.912.A-REI.3.6** Solve systems of linear equations exactly and approximately (e.g., with graphs), focusing on pairs of linear equations in two variables.
- **MAFS.912.A-REI.4.11** 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.
- **MAFS.912.A-REI.4.10** Understand that the graph of an equation in two variables is the set of all its solutions plotted in the coordinate plane, often forming a curve (which could be a line).
- **MAFS.912.A-REI.3.5** 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.

### ● **SOLVING SYSTEMS OF LINEAR EQUATIONS: SUBSTITUTION**

- **MAFS.912.A-CED.1.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- **MAFS.912.A-REI.3.6** Solve systems of linear equations exactly and approximately (e.g., with graphs), focusing on pairs of linear equations in two variables.
- **MAFS.912.A-CED.1.3** 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.
- **MAFS.912.A-REI.3.5** 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.
- **MAFS.912.A-REI.3.7** Solve a simple system consisting of a linear equation and a quadratic equation in two variables algebraically and graphically.

## ● SOLVING SYSTEMS OF LINEAR EQUATIONS: ELIMINATION

- **MAFS.912.A-CED.1.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- **MAFS.912.A-REI.3.6** Solve systems of linear equations exactly and approximately (e.g., with graphs), focusing on pairs of linear equations in two variables.
- **MAFS.912.A-CED.1.3** 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.
- **MAFS.912.A-REI.3.5** 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.

## ● SOLVING SYSTEMS OF LINEAR INEQUALITIES

- **MAFS.912.A-CED.1.3** 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.
- **MAFS.912.A-REI.4.12** Graph the solutions to a linear inequality in two variables as a half-plane (excluding the boundary in the case of a strict inequality), and graph the solution set to a system of linear inequalities in two variables as the intersection of the corresponding half-planes.

# 8. EXPONENTIAL EQUATIONS, FUNCTIONS, AND INEQUALITIES

## ● EXPONENTIAL FUNCTIONS

- **MAFS.912.F-IF.2.4** 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.
- **MAFS.912.F-LE.1.1.a** Prove that linear functions grow by equal differences over equal intervals, and that exponential functions grow by equal factors over equal intervals.
- **MAFS.912.A-SSE.1.1.a** Interpret parts of an expression, such as terms, factors, and coefficients.
- **MAFS.912.A-SSE.1.1.b** Interpret complicated expressions by viewing one or more of their parts as a single entity.
- **MAFS.912.F-IF.3.8.b** Use the properties of exponents to interpret expressions for exponential functions.
- **MAFS.912.F-IF.2.6** 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.
- **MAFS.912.F-LE.1.2** 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).
- **MAFS.912.F-LE.1.3** Observe using graphs and tables that a quantity increasing exponentially eventually exceeds a quantity increasing linearly, quadratically, or (more generally) as a polynomial function.
- **MAFS.912.F-IF.1.1** 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  $y = f(x)$ .
- **MAFS.912.F-IF.2.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.
- **MAFS.912.F-IF.3.7.e** Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude, and using phase shift.
- **MAFS.912.A-CED.1.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- **MAFS.912.F-LE.2.5** Interpret the parameters in a linear or exponential function in terms of a context.
- **MAFS.912.A-SSE.2.3.c** Use the properties of exponents to transform expressions for exponential functions.
- **MAFS.912.F-BF.1.1.a** Determine an explicit expression, a recursive process, or steps for calculation from a context.
- **MAFS.912.F-LE.1.1.c** Recognize situations in which a quantity grows or decays by a constant percent rate per unit interval relative to another.
- **MAFS.912.A-CED.1.1** Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational, absolute, and exponential functions.

## ● EXPONENTIAL GROWTH AND DECAY

- **MAFS.912.F-LE.1.2** 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).
- **MAFS.912.F-LE.1.1.a** Prove that linear functions grow by equal differences over equal intervals, and that exponential functions grow by equal factors over equal intervals.

- **MAFS.912.F-LE.1.1.b** Recognize situations in which one quantity changes at a constant rate per unit interval relative to another.
- **MAFS.912.F-LE.1.3** Observe using graphs and tables that a quantity increasing exponentially eventually exceeds a quantity increasing linearly, quadratically, or (more generally) as a polynomial function.
- **MAFS.912.F-LE.2.5** Interpret the parameters in a linear or exponential function in terms of a context.
- **MAFS.912.A-SSE.1.1.a** Interpret parts of an expression, such as terms, factors, and coefficients.
- **MAFS.912.A-SSE.1.1.b** Interpret complicated expressions by viewing one or more of their parts as a single entity.
- **MAFS.912.A-SSE.2.3.c** Use the properties of exponents to transform expressions for exponential functions.
- **MAFS.912.F-IF.3.8.b** Use the properties of exponents to interpret expressions for exponential functions.
- **MAFS.912.F-LE.1.1.c** Recognize situations in which a quantity grows or decays by a constant percent rate per unit interval relative to another.
- **MAFS.912.F-IF.3.9** Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions).
- **MAFS.912.A-CED.1.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- **MAFS.912.F-BF.1.1.a** Determine an explicit expression, a recursive process, or steps for calculation from a context.
- **MAFS.912.A-CED.1.1** Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational, absolute, and exponential functions.
- **MAFS.912.F-IF.3.7.e** Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude, and using phase shift.

### ● SOLVING EXPONENTIAL EQUATIONS

- **MAFS.912.F-LE.1.4** For exponential models, express as a logarithm the solution to  $ab$  to the  $ct$  power =  $d$  where  $a$ ,  $c$ , and  $d$  are numbers and the base  $b$  is 2, 10, or  $e$ ; evaluate the logarithm using technology.
- **MAFS.912.A-SSE.2.3.c** Use the properties of exponents to transform expressions for exponential functions.
- **MAFS.912.F-IF.3.8.b** Use the properties of exponents to interpret expressions for exponential functions.
- **MAFS.912.F-BF.2.4.a** 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.
- **MAFS.912.F-IF.3.7.e** Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude, and using phase shift.
- **MAFS.912.F-LE.1.2** 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).
- **MAFS.912.F-IF.2.4** 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.

## 9. LOGARITHMIC EXPRESSIONS, EQUATIONS, AND FUNCTIONS

### ● LOGARITHMIC FUNCTIONS

- **MAFS.912.F-IF.2.4** 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.
- **MAFS.912.F-BF.2.5** Understand the inverse relationship between exponents and logarithms and use this relationship to solve problems involving logarithms and exponents.
- **MAFS.912.F-LE.1.4** For exponential models, express as a logarithm the solution to  $ab$  to the  $ct$  power =  $d$  where  $a$ ,  $c$ , and  $d$  are numbers and the base  $b$  is 2, 10, or  $e$ ; evaluate the logarithm using technology.
- **MAFS.912.F-IF.3.8.b** Use the properties of exponents to interpret expressions for exponential functions.
- **MAFS.912.F-BF.2.4.a** 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.
- **MAFS.912.F-BF.2.4.c** Read values of an inverse function from a graph or a table, given that the function has an inverse.
- **MAFS.912.F-IF.1.1** 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  $y = f(x)$ .
- **MAFS.912.F-IF.2.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.
- **MAFS.912.F-IF.3.7.e** Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude, and using phase shift.

## ● EVALUATING LOGARITHMIC EXPRESSIONS

- **MAFS.912.A-SSE.1.2** Use the structure of an expression to identify ways to rewrite it.
- **MAFS.912.A-SSE.1.1.a** Interpret parts of an expression, such as terms, factors, and coefficients.
- **MAFS.912.A-SSE.1.1.b** Interpret complicated expressions by viewing one or more of their parts as a single entity.
- **MAFS.912.F-LE.1.4** For exponential models, express as a logarithm the solution to  $ab$  to the  $ct$  power  $= d$  where  $a$ ,  $c$ , and  $d$  are numbers and the base  $b$  is 2, 10, or  $e$ ; evaluate the logarithm using technology.
- **MAFS.912.F-BF.2.a** Use the change of base formula.

## ● SOLVING LOGARITHMIC EQUATIONS

- **MAFS.912.F-LE.1.4** For exponential models, express as a logarithm the solution to  $ab$  to the  $ct$  power  $= d$  where  $a$ ,  $c$ , and  $d$  are numbers and the base  $b$  is 2, 10, or  $e$ ; evaluate the logarithm using technology.
- **MAFS.912.F-BF.2.4.a** 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.
- **MAFS.912.F-IF.1.1** 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  $y = f(x)$ .
- **MAFS.912.F-IF.2.4** 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.
- **MAFS.912.A-REI.1.1** 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.

## 10. POLYNOMIALS

### ● ADDITION AND SUBTRACTION OF POLYNOMIALS

- **MAFS.912.A-SSE.1.2** Use the structure of an expression to identify ways to rewrite it.
- **MAFS.912.A-APR.1.1** 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.

### ● MULTIPLICATION OF POLYNOMIALS

- **MAFS.912.A-APR.1.1** 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.
- **MAFS.912.A-SSE.1.1.b** Interpret complicated expressions by viewing one or more of their parts as a single entity.

### ● DIVISION OF POLYNOMIALS

- **MAFS.912.A-APR.2.2** 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  $p(x)$ .
- **MAFS.912.A-APR.4.6** 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.
- **MAFS.912.A-SSE.1.2** Use the structure of an expression to identify ways to rewrite it.
- **MAFS.912.A-APR.1.1** 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.
- **MAFS.912.A-SSE.1.1.a** Interpret parts of an expression, such as terms, factors, and coefficients.
- **MAFS.912.A-SSE.1.1.b** Interpret complicated expressions by viewing one or more of their parts as a single entity.

### ● ARITHMETIC OPERATIONS ON FUNCTIONS

- **MAFS.912.F-BF.1.1.b** Combine standard function types using arithmetic operations.
- **MAFS.912.A-APR.1.1** 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.

## 11. GRAPHS AND REPRESENTATIONS OF QUADRATIC FUNCTIONS



## ● ANALYZING GRAPHS OF QUADRATIC FUNCTIONS

- **MAFS.912.A-SSE.1.2** Use the structure of an expression to identify ways to rewrite it.
- **MAFS.912.F-IF.3.9** Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions).
- **MAFS.912.F-IF.1.1** 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  $y = f(x)$ .
- **MAFS.912.F-IF.2.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.
- **MAFS.912.F-IF.2.4** 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.
- **MAFS.912.F-BF.2.3** 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.
- **MAFS.912.F-IF.3.7.a** Graph linear and quadratic functions and show intercepts, maxima, and minima.
- **MAFS.912.A-REI.4.10** Understand that the graph of an equation in two variables is the set of all its solutions plotted in the coordinate plane, often forming a curve (which could be a line).
- **MAFS.912.A-APR.2.3** 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.
- **MAFS.912.F-IF.3.8.a** 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

- **MAFS.912.A-SSE.1.2** Use the structure of an expression to identify ways to rewrite it.
- **MAFS.912.A-REI.2.4.b** 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  $b$ .
- **MAFS.912.A-CED.1.3** 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.
- **MAFS.912.A-SSE.2.3.a** Factor a quadratic expression to reveal the zeros of the function it defines.
- **MAFS.912.A-REI.2.4.a** 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.
- **MAFS.912.F-IF.3.8.a** 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.
- **MAFS.912.A-CED.1.1** Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational, absolute, and exponential functions.
- **MAFS.912.A-CED.1.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- **MAFS.912.F-IF.1.1** 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  $y = f(x)$ .
- **MAFS.912.F-IF.2.4** 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.
- **MAFS.912.F-IF.3.9** Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions).
- **MAFS.912.A-APR.2.3** 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.
- **MAFS.912.F-BF.1.1.a** Determine an explicit expression, a recursive process, or steps for calculation from a context.
- **MAFS.912.F-IF.3.7.c** Graph polynomial functions, identifying zeros when suitable factorizations are available, and showing end behavior.

## ● PARABOLAS

- **MAFS.912.G-GMD.2.4** Identify the shapes of two-dimensional cross-sections of three-dimensional objects, and identify three-dimensional objects generated by rotations of two-dimensional objects.
- **MAFS.912.G-GPE.1.2** Derive the equation of a parabola given a focus and directrix.
- **MAFS.912.A-CED.1.2** Create equations in two or more variables to represent relationships between quantities; graph

equations on coordinate axes with labels and scales.

## ● MULTIPLE REPRESENTATIONS OF FUNCTIONS

- **MAFS.912.A-CED.1.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- **MAFS.912.F-IF.2.4** 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.
- **MAFS.912.F-IF.3.9** Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions).
- **MAFS.912.F-LE.1.2** 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).
- **MAFS.912.F-LE.1.1.a** Prove that linear functions grow by equal differences over equal intervals, and that exponential functions grow by equal factors over equal intervals.

## 12. SOLVING QUADRATIC EQUATIONS

### ● SOLVING QUADRATIC FUNCTIONS WITH FACTORING

- **MAFS.912.A-CED.1.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- **MAFS.912.A-REI.2.4.b** 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  $b$ .
- **MAFS.912.A-APR.2.3** 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.
- **MAFS.912.A-SSE.2.3.a** Factor a quadratic expression to reveal the zeros of the function it defines.
- **MAFS.912.F-IF.3.8.a** 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.
- **MAFS.912.A-APR.3.4** Prove polynomial identities and use them to describe numerical relationships.
- **MAFS.912.F-IF.1.1** 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  $y = f(x)$ .
- **MAFS.912.F-IF.3.7.a** Graph linear and quadratic functions and show intercepts, maxima, and minima.
- **MAFS.912.A-APR.1.1** 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.
- **MAFS.912.F-BF.1.1.a** Determine an explicit expression, a recursive process, or steps for calculation from a context.

### ● COMPLETING THE SQUARE

- **MAFS.912.A-REI.2.4.b** 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  $b$ .
- **MAFS.912.A-SSE.2.3.b** Complete the square in a quadratic expression to reveal the maximum or minimum value of the function it defines.
- **MAFS.912.A-REI.2.4.a** 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.
- **MAFS.912.F-IF.3.7.a** Graph linear and quadratic functions and show intercepts, maxima, and minima.
- **MAFS.912.F-IF.3.8.a** 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.
- **MAFS.912.A-SSE.1.2** Use the structure of an expression to identify ways to rewrite it.

### ● QUADRATIC FORMULA

- **MAFS.912.A-REI.2.4.b** 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  $b$ .
- **MAFS.912.A-SSE.1.1.a** Interpret parts of an expression, such as terms, factors, and coefficients.
- **MAFS.912.A-SSE.1.1.b** Interpret complicated expressions by viewing one or more of their parts as a single entity.

- **MAFS.912.N-CN.3.7** Solve quadratic equations with real coefficients that have complex solutions.
- **MAFS.912.F-IF.1.1** 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  $y = f(x)$ .
- **MAFS.912.F-IF.2.4** 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.
- **MAFS.912.A-REI.2.4.a** 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.
- **MAFS.912.F-BF.1.1.a** Determine an explicit expression, a recursive process, or steps for calculation from a context.

#### ● **COMPLEX NUMBERS AND QUADRATIC FUNCTIONS**

- **MAFS.912.A-REI.2.4.b** 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  $b$ .
- **MAFS.912.N-CN.3.7** Solve quadratic equations with real coefficients that have complex solutions.
- **MAFS.912.N-CN.1.1** 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.
- **MAFS.912.N-CN.1.2** Use the relation  $i^2 = -1$  and the commutative, associative, and distributive properties to add, subtract, and multiply complex numbers.

### 13. FACTORING POLYNOMIALS AND THE FACTOR THEOREM

#### ● **FACTORING SPECIAL CASES**

- **MAFS.912.A-SSE.1.2** Use the structure of an expression to identify ways to rewrite it.
- **MAFS.912.A-APR.3.4** Prove polynomial identities and use them to describe numerical relationships.
- **MAFS.912.A-SSE.1.1.a** Interpret parts of an expression, such as terms, factors, and coefficients.
- **MAFS.912.A-SSE.1.1.b** Interpret complicated expressions by viewing one or more of their parts as a single entity.
- **MAFS.912.A-REI.2.4.b** 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  $b$ .
- **MAFS.912.A-APR.2.3** 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.
- **MAFS.912.F-IF.3.8.a** 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.

#### ● **FACTORING CUBIC POLYNOMIALS**

- **MAFS.912.A-SSE.1.2** Use the structure of an expression to identify ways to rewrite it.
- **MAFS.912.A-APR.3.4** Prove polynomial identities and use them to describe numerical relationships.
- **MAFS.912.A-APR.2.3** 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**

- **MAFS.912.A-APR.2.3** 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.
- **MAFS.912.A-SSE.1.1.a** Interpret parts of an expression, such as terms, factors, and coefficients.
- **MAFS.912.A-SSE.1.1.b** Interpret complicated expressions by viewing one or more of their parts as a single entity.
- **MAFS.912.A-SSE.1.2** Use the structure of an expression to identify ways to rewrite it.
- **MAFS.912.A-APR.3.4** Prove polynomial identities and use them to describe numerical relationships.

#### ● **FACTOR THEOREM AND REMAINDER THEOREM**

- **MAFS.912.A-APR.2.2** 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  $p(x)$ .
- **MAFS.912.A-APR.4.6** 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.

- **MAFS.912.F-IF.1.2** Use function notation, evaluate functions for inputs in their domains, and interpret statements that use function notation in terms of a context.

## 14. POLYNOMIAL FUNCTIONS AND POLYNOMIAL IDENTITIES

### ● GRAPHS OF POLYNOMIAL FUNCTIONS

- **MAFS.912.F-IF.2.4** 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.
- **MAFS.912.A-APR.2.3** 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.
- **MAFS.912.F-BF.2.3** 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.
- **MAFS.912.F-IF.3.7.c** Graph polynomial functions, identifying zeros when suitable factorizations are available, and showing end behavior.

### ● COMPLEX NUMBERS

- **MAFS.912.N-CN.1.1** 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.
- **MAFS.912.N-CN.1.2** Use the relation  $i^2 = -1$  and the commutative, associative, and distributive properties to add, subtract, and multiply complex numbers.

### ● POLYNOMIAL IDENTITIES

- **MAFS.912.A-SSE.1.2** Use the structure of an expression to identify ways to rewrite it.
- **MAFS.912.A-APR.3.4** Prove polynomial identities and use them to describe numerical relationships.
- **MAFS.912.A-REI.2.4.b** 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  $b$ .
- **MAFS.912.A-REI.2.4.a** 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.
- **MAFS.912.A-APR.3.5** 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

- **MAFS.912.A-SSE.1.2** Use the structure of an expression to identify ways to rewrite it.
- **MAFS.912.N-CN.3.8** Extend polynomial identities to the complex numbers.
- **MAFS.912.A-APR.3.4** Prove polynomial identities and use them to describe numerical relationships.
- **MAFS.912.A-SSE.1.1.a** Interpret parts of an expression, such as terms, factors, and coefficients.
- **MAFS.912.A-SSE.1.1.b** Interpret complicated expressions by viewing one or more of their parts as a single entity.
- **MAFS.912.A-REI.2.4.b** 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  $b$ .
- **MAFS.912.N-CN.1.1** 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.
- **MAFS.912.N-CN.3.7** Solve quadratic equations with real coefficients that have complex solutions.
- **MAFS.912.N-CN.3.9** Know the Fundamental Theorem of Algebra; show that it is true for quadratic polynomials.

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

### ● ANALYZING GRAPHS OF SQUARE ROOT FUNCTIONS

- **MAFS.912.G-CO.2.6** 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.

- **MAFS.912.F-BF.2.3** 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.
- **MAFS.912.F-IF.3.7.b** Graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions.
- **MAFS.912.F-BF.2.4.a** 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.
- **MAFS.912.F-BF.2.4.c** Read values of an inverse function from a graph or a table, given that the function has an inverse.
- **MAFS.912.F-IF.1.1** 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  $y = f(x)$ .
- **MAFS.912.F-IF.2.4** 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.
- **MAFS.912.F-IF.2.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.

### ● SOLVING SQUARE ROOT EQUATIONS

- **MAFS.912.A-REI.1.2** Solve simple rational and radical equations in one variable, and give examples showing how extraneous solutions may arise.
- **MAFS.912.A-REI.1.1** 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.
- **MAFS.912.F-BF.1.1.a** Determine an explicit expression, a recursive process, or steps for calculation from a context.

## 16. RATIONAL EXPRESSIONS, EQUATIONS, AND FUNCTIONS

### ● ANALYZING GRAPHS OF RATIONAL FUNCTIONS

- **MAFS.912.F-BF.2.3** 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.
- **MAFS.912.F-IF.3.7.d** Graph rational functions, identifying zeros and asymptotes when suitable factorizations are available, and showing end behavior.
- **MAFS.912.F-IF.2.4** 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.
- **MAFS.912.F-IF.1.1** 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  $y = f(x)$ .
- **MAFS.912.F-IF.2.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.

### ● SOLVING RATIONAL EQUATIONS

- **MAFS.912.A-REI.1.1** 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.
- **MAFS.912.F-IF.1.1** 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  $y = f(x)$ .
- **MAFS.912.A-REI.1.2** Solve simple rational and radical equations in one variable, and give examples showing how extraneous solutions may arise.
- **MAFS.912.F-IF.3.7.d** Graph rational functions, identifying zeros and asymptotes when suitable factorizations are available, and showing end behavior.
- **MAFS.912.A-CED.1.1** Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational, absolute, and exponential functions.

### ● MODELING SITUATIONS WITH RATIONAL FUNCTIONS

- **MAFS.912.A-REI.1.2** Solve simple rational and radical equations in one variable, and give examples showing how

extraneous solutions may arise.

- **MAFS.912.A-SSE.1.1.a** Interpret parts of an expression, such as terms, factors, and coefficients.
- **MAFS.912.A-SSE.1.1.b** Interpret complicated expressions by viewing one or more of their parts as a single entity.
- **MAFS.912.A-CED.1.2** Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales.
- **MAFS.912.A-CED.1.3** 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.
- **MAFS.912.F-BF.1.1.a** Determine an explicit expression, a recursive process, or steps for calculation from a context.

## 17. NONLINEAR FUNCTIONS

### ● LINEAR VERSUS NONLINEAR FUNCTIONS

- **MAFS.912.F-IF.2.6** 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.
- **MAFS.912.F-LE.1.2** 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).
- **MAFS.912.F-LE.1.1.a** Prove that linear functions grow by equal differences over equal intervals, and that exponential functions grow by equal factors over equal intervals.
- **MAFS.912.F-LE.1.1.b** Recognize situations in which one quantity changes at a constant rate per unit interval relative to another.
- **MAFS.912.F-LE.1.1.c** Recognize situations in which a quantity grows or decays by a constant percent rate per unit interval relative to another.
- **MAFS.912.F-IF.2.4** 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.
- **MAFS.912.F-IF.3.9** Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions).
- **MAFS.912.F-IF.3.7.b** Graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions.

### ● ABSOLUTE VALUE FUNCTIONS

- **MAFS.912.F-IF.1.1** 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  $y = f(x)$ .
- **MAFS.912.F-IF.2.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.
- **MAFS.912.F-IF.3.7.b** Graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions.
- **MAFS.912.A-CED.1.1** Create equations and inequalities in one variable and use them to solve problems. Include equations arising from linear and quadratic functions, and simple rational, absolute, and exponential functions.
- **MAFS.912.F-IF.2.4** 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.
- **MAFS.912.F-BF.2.3** 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.

### ● RADIANS AND THE UNIT CIRCLE

- **MAFS.912.F-TF.1.1** Understand radian measure of an angle as the length of the arc on the unit circle subtended by the angle; Convert between degrees and radians.
- **MAFS.912.F-TF.1.2** 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.
- **MAFS.912.G-C.2.5** 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.
- **MAFS.912.F-TF.1.3** 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.

- **MAFS.912.F-TF.1.4** Use the unit circle to explain symmetry (odd and even) and periodicity of trigonometric functions.
- **MAFS.912.G-SRT.3.8** Use trigonometric ratios and the Pythagorean Theorem to solve right triangles in applied problems.

### ● TRIGONOMETRIC FUNCTIONS

- **MAFS.912.F-TF.1.2** 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.
- **MAFS.912.F-TF.2.5** Choose trigonometric functions to model periodic phenomena with specified amplitude, frequency, and midline.
- **MAFS.912.F-IF.3.7.e** Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude, and using phase shift.
- **MAFS.912.F-TF.3.8** Prove the Pythagorean identity  $\sin^2(\theta) + \cos^2(\theta) = 1$  and use it to calculate trigonometric ratios.

### ● SYSTEMS OF NONLINEAR EQUATIONS

- **MAFS.912.A-REI.3.6** Solve systems of linear equations exactly and approximately (e.g., with graphs), focusing on pairs of linear equations in two variables.
- **MAFS.912.A-REI.4.11** 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.
- **MAFS.912.A-REI.3.7** Solve a simple system consisting of a linear equation and a quadratic equation in two variables algebraically and graphically.
- **MAFS.912.A-REI.3.5** 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.
- **MAFS.912.F-LE.1.2** 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).

## 18. PARENT FUNCTIONS AND TRANSFORMATIONS

### ● PARENT FUNCTIONS

- **MAFS.912.F-IF.2.4** 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.
- **MAFS.912.F-BF.2.3** 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.
- **MAFS.912.F-IF.3.7.b** Graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions.
- **MAFS.912.F-IF.3.7.c** Graph polynomial functions, identifying zeros when suitable factorizations are available, and showing end behavior.
- **MAFS.912.F-IF.1.1** 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  $y = f(x)$ .
- **MAFS.912.F-IF.2.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.
- **MAFS.912.F-LE.1.2** 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).
- **MAFS.912.F-IF.3.7.e** Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude, and using phase shift.

### ● TRANSFORMATIONS OF PARENT FUNCTIONS

- **MAFS.912.G-CO.1.2** 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).
- **MAFS.912.F-BF.2.3** 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.

- **MAFS.912.F-IF.3.7.b** Graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions.
- **MAFS.912.F-IF.3.7.c** Graph polynomial functions, identifying zeros when suitable factorizations are available, and showing end behavior.
- **MAFS.912.G-CO.2.6** 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.
- **MAFS.912.F-IF.2.4** 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.
- **MAFS.912.F-IF.3.7.e** Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude, and using phase shift.
- **MAFS.912.F-IF.1.1** 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 T TRANSFORMATIONS OF PARENT FUNCTIONS**

- **MAFS.912.G-CO.1.2** 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).
- **MAFS.912.G-CO.1.5** 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.
- **MAFS.912.G-CO.2.6** 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.
- **MAFS.912.F-BF.2.3** 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.
- **MAFS.912.F-IF.3.7.b** Graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions.
- **MAFS.912.F-IF.3.7.c** Graph polynomial functions, identifying zeros when suitable factorizations are available, and showing end behavior.
- **MAFS.912.F-IF.2.4** 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.
- **MAFS.912.F-IF.2.5** Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes.
- **MAFS.912.F-IF.3.7.e** Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude, and using phase shift.

## 19. SAMPLES, EXPERIMENTS, AND OBSERVATIONAL STUDIES

#### ● **ANALYZING STATISTICAL SAMPLES**

- **MAFS.912.S-IC.1.1** Understand statistics as a process for making inferences about population parameters based on a random sample from that population.
- **MAFS.912.S-IC.2.4** 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.
- **MAFS.912.S-IC.1.2** Decide if a specified model is consistent with results from a given data-generating process, e.g., using simulation.

#### ● **EXPERIMENTAL AND OBSERVATIONAL DESIGN**

- **MAFS.912.S-IC.2.3** Recognize the purposes of and differences among sample surveys, experiments, and observational studies; explain how randomization relates to each.

#### ● **CONCLUSIONS IN DATA**

- **MAFS.912.S-IC.2.5** Use data from a randomized experiment to compare two treatments; use simulations to decide if differences between parameters are significant.



- **NORMAL DISTRIBUTION**

- **MAFS.912.S-ID.1.3** Interpret differences in shape, center, and spread in the context of the data sets, accounting for possible effects of extreme data points (outliers).
- **MAFS.912.S-ID.1.4** 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.

## 20. PROBABILITY

- **INTRODUCTION TO PROBABILITY**

- **MAFS.912.S-CP.1.2** 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.
- **MAFS.912.S-CP.2.8** Apply the general Multiplication Rule in a uniform probability model,  $P(A \text{ and } B) = P(A)P(B|A) = (B)P(A|B)$ , and interpret the answer in terms of the model.
- **MAFS.912.S-CP.1.1** 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”).
- **MAFS.912.S-CP.1.5** Recognize and explain the concepts of conditional probability and independence in everyday language and everyday situations.
- **MAFS.912.S-CP.2.7** 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.

- **CONDITIONAL PROBABILITY**

- **MAFS.912.S-CP.1.3** 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  $B$ .
- **MAFS.912.S-CP.1.5** Recognize and explain the concepts of conditional probability and independence in everyday language and everyday situations.
- **MAFS.912.S-CP.2.6** 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.
- **MAFS.912.S-CP.1.2** 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.
- **MAFS.912.S-ID.2.5** Summarize categorical data for two categories in two-way frequency tables. Interpret relative frequencies in the context of the data (including joint, marginal, and conditional relative frequencies). Recognize possible associations and trends in the data.
- **MAFS.912.S-CP.1.4** 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.

- **GEOMETRIC PROBABILITIES**

- **MAFS.912.G-MG.1.3** Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios).
- **MAFS.912.S-MD.2.7** Analyze decisions and strategies using probability concepts (e.g., product testing, medical testing, pulling a hockey goalie at the end of a game).
- **MAFS.912.S-CP.1.1** 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”).
- **MAFS.912.S-CP.2.7** 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.