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| **N-Q** | **Quantities**<br>Reason quantitatively and use units to solve problems. | |
| N-Q.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. | Organizing Data Into Matrices<br>Multiplication Matrix<br>Identity and Inverse Matrices<br>Determinants<br>Geometric Transformations with Matrices<br>Solving Systems with Matrix Equations<br>Ellipses<br>Hyperbolas<br>Probability<br>Multiplying Probabilities<br>The Sine Function<br>The Cosine Function<br>Circular Functions<br>Area and The Law of Sines |
| N-Q.2 | Define appropriate quantities for the purpose of descriptive modeling. | |
| N-Q.3 | Choose a level of accuracy appropriate to limitations on measurement when reporting quantities. | |
| **N-CN** | **The Complex Number System**<br>Perform arithmetic operations with complex numbers. | |
| N-CN.1 | Know there is a complex number i such that $i^2 = -1$, and every complex number has the form a + bi with a and b real. | Complex Numbers |
| N-CN.2 | Use the relation $i^2 = -1$ and the commutative, associative, and distributive properties to add, subtract, and multiply complex numbers. | Complex Numbers |
| N-CN.3 | Find the conjugate of a complex number; use conjugates to find moduli and quotients of complex numbers. | Complex Numbers |

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| | Represent complex numbers and their operations on the complex plane. | |
| N-CN.4 | Represent complex numbers on the complex plane in rectangular and polar form (including real and imaginary numbers), and explain why the rectangular and polar forms of a given complex number represent the same number. | Complex Numbers<br>Polar Coordinates |
| N-CN.5 | Represent addition, subtraction, multiplication, and conjugation of complex numbers geometrically on the complex plane; use properties of this representation for computation. | Complex Numbers<br>Polar Coordinates |
| N-CN.6 | Calculate the distance between numbers in the complex plane as the modulus of the difference, and the midpoint of a segment as the average of the numbers at its endpoints. | Complex Numbers<br>Polar Coordinates |
| | Use complex numbers in polynomial identities and equations. | |
| N-CN.7 | Solve quadratic equations with real coefficients that have complex solutions. | Solving Quadratic Equations Algebraically<br>Complex Numbers |
| N-CN.8 | Extend polynomial identities to the complex numbers. | Complex Numbers |
| N-CN.9 | Know the Fundamental Theorem of Algebra; show that it is true for quadratic polynomials. | |
| **N-VM** | **Vector and Matrix Quantities** | |
| | Represent and model with vector quantities. | |
| N-VM.1 | Recognize vector quantities as having both magnitude and direction. Represent vector quantities by directed line segments, and use appropriate symbols for vectors and their magnitudes (e.g., v, \|v\|, \|\|v\|\|, v). | Geometric Vectors<br>Algebraic Vectors<br>Vectors in Geometry |
| N-VM.2 | Find the components of a vector by subtracting the coordinates of an initial point from the coordinates of a terminal point. | Geometric Vectors<br>Algebraic Vectors<br>Vectors in Geometry |
| N-VM.3 | Solve problems involving velocity and other quantities that can be represented by vectors. | Geometric Vectors<br>Algebraic Vectors |

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| | Perform operations on vectors. | |
| N-VM.4 | Add and subtract vectors. | |
| N-VM.4.a | Add vectors end-to-end, component-wise, and by the parallelogram rule. Understand that the magnitude of a sum of two vectors is typically not the sum of the magnitudes. | Geometric Vectors<br>Algebraic Vectors<br>Vectors in Geometry |
| N-VM.4.b | Given two vectors in magnitude and direction form, determine the magnitude and direction of their sum. | Geometric Vectors<br>Algebraic Vectors<br>Vectors in Geometry |
| N-VM.4.c | Understand vector subtraction v - w as v + (-w), where -w is the additive inverse of w, with the same magnitude as w and pointing in the opposite direction. Represent vector subtraction graphically by connecting the tips in the appropriate order, and perform vector subtraction component-wise. | Geometric Vectors<br>Algebraic Vectors<br>Vectors in Geometry |
| N-VM.5 | Multiply a vector by a scalar. | |
| N-VM.5.a | Represent scalar multiplication graphically by scaling vectors and possibly reversing their direction; perform scalar multiplication component-wise, e.g., as c(v subscript x, v subscript y) = (cv subscript x, cv subscript y). | Geometric Vectors<br>Algebraic Vectors<br>Dot Products of Vectors |
| N-VM.5.b | Compute the magnitude of a scalar multiple cv using \|\|cv\|\| = \|c\|v. Compute the direction of cv knowing that when \|c\|v is not equal to 0, the direction of cv is either along v (for c > 0) or against v (for c < 0). | Geometric Vectors<br>Algebraic Vectors<br>Vectors in Geometry |
| | Perform operations on matrices and use matrices in applications. | |
| N-VM.6 | Use matrices to represent and manipulate data, e.g., to represent payoffs or incidence relationships in a network. | Organizing Data Into Matrices<br>Matrices<br>Modeling Motion with Matrices<br>Networks |

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| N-VM.7 | Multiply matrices by scalars to produce new matrices, e.g., as when all of the payoffs in a game are doubled. | Multiplication Matrix<br>Matrices |
| N-VM.8 | Add, subtract, and multiply matrices of appropriate dimensions. | Adding and Subtracting Matrices<br>Multiplication Matrix<br>Geometric Transformations with Matrices<br>Matrices |
| N-VM.9 | Understand that, unlike multiplication of numbers, matrix multiplication for square matrices is not a commutative operation, but still satisfies the associative and distributive properties. | Multiplication Matrix<br>Matrices |
| N-VM.10 | Understand that the zero and identity matrices play a role in matrix addition and multiplication similar to the role of 0 and 1 in the real numbers. The determinant of a square matrix is nonzero if and only if the matrix has a multiplicative inverse. | Adding and Subtracting Matrices<br>Identity and Inverse Matrices<br>Determinants<br>Matrices |
| N-VM.11 | Multiply a vector (regarded as a matrix with one column) by a matrix of suitable dimensions to produce another vector. Work with matrices as transformations of vectors. | Matrices<br>Modeling Motion with Matrices<br>Algebraic Vectors |
| N-VM.12 | Work with 2 × 2 matrices as transformations of the plane, and interpret the absolute value of the determinant in terms of area. | Determinants<br>Geometric Transformations with Matrices<br>Matrices<br>Modeling Motion with Matrices |

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| **A-SSE** | **Seeing Structure in Expressions** | |
| | Interpret the structure of expressions | |
| A-SSE.1 | Interpret expressions that represent a quantity in terms of its context. | |
| A-SSE.1.a | Interpret parts of an expression, such as terms, factors, and coefficients. | |
| | | Applications of Equations |
| | | Fundamental Polynomial Connections |
| | | Locating Zeros of Polynomial Function |
| A-SSE.1.b | Interpret complicated expressions by viewing one or more of their parts as a single entity. | |
| | | Complex Numbers |
| | | Exponential and Logistic Functions |
| | | Trigonometric Inverses and Their Graphs |
| A-SSE.2 | Use the structure of an expression to identify ways to rewrite it. | |
| | | Writing Equations of Parallel and Perpendicular Lines |
| | | Solving Quadratic Equations Algebraically |
| | | Logarithmic Functions and Their Graphs |
| | Write expressions in equivalent forms to solve problems | |
| A-SSE.3 | Choose and produce an equivalent form of an expression to reveal and explain properties of the quantity represented by the expression. | |
| A-SSE.3.a | Factor a quadratic expression to reveal the zeros of the function it defines. | |
| | | Solving Quadratic Equations Algebraically |
| | | Fundamental Polynomial Connections |
| A-SSE.3.b | Complete the square in a quadratic expression to reveal the maximum or minimum value of the function it defines. | |
| | | Solving Quadratic Equations Algebraically |
| A-SSE.3.c | Use the properties of exponents to transform expressions for exponential functions. | |
| | | Twelve Basic Functions |
| | | Families of Graphs |
| | | Exponential and Logistic Functions |
| | | The Number e |
| | | Logarithmic Functions and Their Graphs |
| A-SSE.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. | |

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| A-APR | Arithmetic with Polynomials and Rational Expressions | |
| | Perform arithmetic operations on polynomials | |
| A-APR.1 | Understand that polynomials form a system analogous to the integers, namely, they are closed under the operations of addition, subtraction, and multiplication; add, subtract, and multiply polynomials. | |
| | | Fundamental Polynomial Connections |
| | | Locating Zeros of Polynomial Function |
| | Understand the relationship between zeros and factors of polynomials | |
| A-APR.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). | |
| | | Fundamental Polynomial Connections |
| A-APR.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. | |
| | | Graphing Linear Equations |
| | | Solving Equations Graphically |
| | | Fundamental Polynomial Connections |
| | | Locating Zeros of Polynomial Function |
| | Use polynomial identities to solve problems | |
| A-APR.4 | Prove polynomial identities and use them to describe numerical relationships. | |
| | | Fundamental Polynomial Connections |
| A-APR.5 | Know and apply the Binomial Theorem for the expansion of (x + y) to the n power 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. | |

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| **A-CED** | **Creating Equations** | |
| | Create equations that describe numbers or relationships | |
| A-CED.1 | Create equations and inequalities in one variable and use them to solve problems. | |
| | | Adding and Subtracting Matrices |
| | | Hyperbolas |
| | | The Cosine Function |
| | | Graphing Linear Equations |
| | | Writing Linear Equations |
| | | Writing Equations of Parallel and Perpendicular Lines |
| | | Applications of Equations |
| | | Inequalities |
| | | Graphing Linear Inequalities |
| | | Solving Systems of Equations in Two Variables |
| | | Graphs of Rational Functions |
| | | Direct, Inverse, and Joint Variation |
| | | The Number e |
| | | Circles and Parabolas |

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| A-CED.2 | Create equations in two or more variables to represent relationships between quantities; graph equations on coordinate axes with labels and scales. | Hyperbolas<br>The Cosine Function<br>Graphing Linear Equations<br>Writing Linear Equations<br>Writing Equations of Parallel and Perpendicular Lines<br>Solving Equations Graphically<br>Inequalities<br>Solving Systems of Equations in Two Variables<br>Twelve Basic Functions<br>Piecewise Functions<br>Graphs and Transformations<br>Families of Graphs<br>Graphs of Nonlinear Inequalities<br>Graphs of Rational Functions<br>Direct, Inverse, and Joint Variation<br>The Number e<br>Circles and Parabolas<br>Ellipses |

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| A-CED.3 | Represent constraints by equations or inequalities, and by systems of equations and/or inequalities, and interpret solutions as viable or nonviable options in a modeling context. | Hyperbolas<br>The Cosine Function<br>Graphing Linear Equations<br>Writing Linear Equations<br>Writing Equations of Parallel and Perpendicular Lines<br>Solving Equations Graphically<br>Solving Quadratic Equations Algebraically<br>Applications of Equations<br>Inequalities<br>Graphing Linear Inequalities<br>Solving Systems of Equations in Two Variables<br>Solving Systems of Equations in Three Variables<br>Matrices<br>Solving Systems of Linear Inequalities<br>Linear Programming<br>Graphs of Rational Functions<br>Direct, Inverse, and Joint Variation<br>The Number e<br>Circles and Parabolas<br>Ellipses |
| A-CED.4 | Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. | Applications of Equations<br>Inequalities |
| **A-REI** | **Reasoning with Equations and Inequalities**<br>Understand solving equations as a process of reasoning and explain the reasoning | |
| A-REI.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. | Solving Equations Graphically<br>Applications of Equations |

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| A-REI.2 | Solve simple rational and radical equations in one variable, and give examples showing how extraneous solutions may arise. | Graphing Linear Equations<br>Solving Equations Graphically<br>Applications of Equations<br>Inequalities<br>Graphing Linear Inequalities |
| | Solve equations and inequalities in one variable | |
| A-REI.3 | Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters. | Graphing Linear Equations<br>Solving Equations Graphically<br>Applications of Equations<br>Inequalities<br>Graphing Linear Inequalities |
| A-REI.4 | Solve quadratic equations in one variable. | |
| A-REI.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. | Solving Quadratic Equations Algebraically |
| A-REI.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 ± bi for real numbers a and b. | Solving Equations Graphically<br>Solving Quadratic Equations Algebraically<br>Applications of Equations<br>Inequalities<br>Complex Numbers |
| | Solve systems of equations | |
| A-REI.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 Equations in Two Variables<br>Solving Systems of Equations in Three Variables |

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| A-REI.6 | Solve systems of linear equations exactly and approximately (e.g., with graphs), focusing on pairs of linear equations in two variables. | |
| | | Solving Systems with Matrix Equations |
| | | Solving Systems of Equations in Two Variables |
| | | Solving Systems of Equations in Three Variables |
| | | Matrices |
| A-REI.7 | Solve a simple system consisting of a linear equation and a quadratic equation in two variables algebraically and graphically. | |
| | | Solving Systems of Equations in Two Variables |
| A-REI.8 | Represent a system of linear equations as a single matrix equation in a vector variable. | |
| | | Solving Systems with Matrix Equations |
| | | Solving Systems of Equations in Two Variables |
| | | Solving Systems of Equations in Three Variables |
| | | Matrices |
| A-REI.9 | Find the inverse of a matrix if it exists and use it to solve systems of linear equations (using technology for matrices of dimension 3 × 3 or greater). | |
| | | Identity and Inverse Matrices |
| | | Solving Systems with Matrix Equations |
| | Represent and solve equations and inequalities graphically | |
| A-REI.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). | |
| | | Ellipses |
| | | Hyperbolas |
| | | Graphing Linear Equations |
| | | Solving Equations Graphically |
| | | Solving Systems of Equations in Two Variables |
| | | Twelve Basic Functions |
| | | Piecewise Functions |
| | | Graphs and Transformations |
| | | Families of Graphs |
| A-REI.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. | |
| | | Solving Equations Graphically |
| | | Solving Systems of Equations in Two Variables |

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| A-REI.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. | Inequalities<br>Graphing Linear Inequalities<br>Solving Systems of Linear Inequalities<br>Linear Programming |
| **F-IF** | **Interpreting Functions**<br>Understand the concept of a function and use function notation | |
| F-IF.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). | Graphing Linear Equations<br>Operations with Functions<br>Twelve Basic Functions<br>Inverse Functions and Relations |
| F-IF.2 | Use function notation, evaluate functions for inputs in their domains, and interpret statements that use function notation in terms of a context. | Graphing Linear Equations<br>Operations with Functions<br>Twelve Basic Functions<br>Inverse Functions and Relations |
| F-IF.3 | Recognize that sequences are functions, sometimes defined recursively, whose domain is a subset of the integers. | |

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| | Interpret functions that arise in applications in terms of the context | |
| F-IF.4 | For a function that models a relationship between two quantities, interpret key features of graphs and tables in terms of the quantities, and sketch graphs showing key features given a verbal description of the relationship. | |
| | | Hyperbolas<br>The Cosine Function<br>Graphing Linear Equations<br>Solving Equations Graphically<br>Solving Systems of Equations in Two Variables<br>Twelve Basic Functions<br>Piecewise Functions<br>Graphs and Transformations<br>Families of Graphs<br>Direct, Inverse, and Joint Variation<br>Fundamental Polynomial Connections<br>Locating Zeros of Polynomial Function<br>Exponential and Logistic Functions<br>Ellipses |
| F-IF.5 | Relate the domain of a function to its graph and, where applicable, to the quantitative relationship it describes. | |
| | | Operations with Functions<br>Twelve Basic Functions<br>Piecewise Functions<br>Inverse Functions and Relations<br>Exponential and Logistic Functions |
| F-IF.6 | Calculate and interpret the average rate of change of a function (presented symbolically or as a table) over a specified interval. Estimate the rate of change from a graph. | |
| | | Graphing Linear Equations<br>Writing Linear Equations |

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| | Analyze functions using different representations | |
| F-IF.7 | Graph functions expressed symbolically and show key features of the graph, by hand in simple cases and using technology for more complicated cases. | |
| F-IF.7.a | Graph linear and quadratic functions and show intercepts, maxima, and minima. | |
| | | Graphing Linear Equations |
| | | Solving Equations Graphically |
| | | Solving Quadratic Equations Algebraically |
| | | Solving Systems of Equations in Two Variables |
| | | Twelve Basic Functions |
| | | Graphs and Transformations |
| | | Families of Graphs |
| | | Graphs of Nonlinear Inequalities |
| | | Circles and Parabolas |
| F-IF.7.b | Graph square root, cube root, and piecewise-defined functions, including step functions and absolute value functions. | |
| | | Twelve Basic Functions |
| | | Piecewise Functions |
| | | Graphs and Transformations |
| | | Families of Graphs |
| | | Graphs of Nonlinear Inequalities |
| F-IF.7.c | Graph polynomial functions, identifying zeros when suitable factorizations are available, and showing end behavior. | |
| | | Twelve Basic Functions |
| | | Graphs and Transformations |
| | | Families of Graphs |
| | | Fundamental Polynomial Connections |
| | | Locating Zeros of Polynomial Function |
| F-IF.7.d | Graph rational functions, identifying zeros and asymptotes when suitable factorizations are available, and showing end behavior. | |
| | | Twelve Basic Functions |
| | | Graphs and Transformations |
| | | Families of Graphs |
| | | Graphs of Rational Functions |

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| F-IF.7.e | Graph exponential and logarithmic functions, showing intercepts and end behavior, and trigonometric functions, showing period, midline, and amplitude. | |
| | | The Sine Function |
| | | The Cosine Function |
| | | Circular Functions |
| | | Twelve Basic Functions |
| | | Graphs and Transformations |
| | | Families of Graphs |
| | | Exponential and Logistic Functions |
| | | The Number e |
| | | Logarithmic Functions and Their Graphs |
| | | Amplitude and Period |
| F-IF.8 | Write a function defined by an expression in different but equivalent forms to reveal and explain different properties of the function. | |
| F-IF.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. | |
| | | Solving Quadratic Equations Algebraically |
| | | Fundamental Polynomial Connections |
| F-IF.8.b | Use the properties of exponents to interpret expressions for exponential functions. | |
| | | Twelve Basic Functions |
| | | Families of Graphs |
| | | Exponential and Logistic Functions |
| | | The Number e |
| | | Logarithmic Functions and Their Graphs |
| F-IF.9 | Compare properties of two functions each represented in a different way (algebraically, graphically, numerically in tables, or by verbal descriptions). | |
| | | Twelve Basic Functions |

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| **F-BF** | **Building Functions** | |
| | Build a function that models a relationship between two quantities | |
| F-BF.1 | Write a function that describes a relationship between two quantities. | |
| F-BF.1.a | Determine an explicit expression, a recursive process, or steps for calculation from a context. | |
| | | Hyperbolas |
| | | The Cosine Function |
| | | Graphing Linear Equations |
| | | Writing Linear Equations |
| | | Writing Equations of Parallel and Perpendicular Lines |
| | | Inequalities |
| | | Solving Systems of Equations in Two Variables |
| | | Graphs of Rational Functions |
| | | Direct, Inverse, and Joint Variation |
| | | The Number e |
| | | Circles and Parabolas |
| | | Ellipses |
| F-BF.1.b | Combine standard function types using arithmetic operations. | |
| | | Operations with Functions |
| | | Twelve Basic Functions |
| | | Graphs and Transformations |
| F-BF.1.c | Compose functions. | |
| | | Operations with Functions |
| | | Twelve Basic Functions |
| | | Graphs and Transformations |
| F-BF.2 | Write arithmetic and geometric sequences both recursively and with an explicit formula, use them to model situations, and translate between the two forms. | |

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| | Build new functions from existing functions | |
| F-BF.3 | Identify the effect on the graph of replacing f(x) by f(x) + k, k f(x), f(kx), and f(x + k) for specific values of k (both positive and negative); find the value of k given the graphs. Experiment with cases and illustrate an explanation of the effects on the graph using technology. | Graphs and Transformations<br>Families of Graphs<br>Graphs of Nonlinear Inequalities<br>Circles and Parabolas<br>Ellipses<br>Amplitude and Period |
| F-BF.4 | Find inverse functions. | |
| F-BF.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. | Inverse Functions and Relations |
| F-BF.4.b | Verify by composition that one function is the inverse of another. | Operations with Functions<br>Twelve Basic Functions<br>Graphs and Transformations<br>Inverse Functions and Relations<br>Trigonometric Inverses and Their Graphs |
| F-BF.4.c | Read values of an inverse function from a graph or a table, given that the function has an inverse. | Graphs and Transformations<br>Inverse Functions and Relations<br>Trigonometric Inverses and Their Graphs |
| F-BF.4.d | Produce an invertible function from a non-invertible function by restricting the domain. | Inverse Functions and Relations<br>Trigonometric Inverses and Their Graphs |
| F-BF.5 | Understand the inverse relationship between exponents and logarithms and use this relationship to solve problems involving logarithms and exponents. | Exponential and Logistic Functions<br>The Number e<br>Logarithmic Functions and Their Graphs |

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| **F-LE** | **Linear, Quadratic, and Exponential Models** | |
| | Construct and compare linear, quadratic, and exponential models and solve problems | |
| F-LE.1 | Distinguish between situations that can be modeled with linear functions and with exponential functions. | |
| F-LE.1.a | Prove that linear functions grow by equal differences over equal intervals, and that exponential functions grow by equal factors over equal intervals. | |
| | | Graphing Linear Equations |
| | | Writing Linear Equations |
| | | Writing Equations of Parallel and Perpendicular Lines |
| | | Solving Equations Graphically |
| | | Applications of Equations |
| | | Solving Systems of Equations in Two Variables |
| | | Twelve Basic Functions |
| | | Families of Graphs |
| | | Exponential and Logistic Functions |
| | | The Number e |
| | | Logarithmic Functions and Their Graphs |
| F-LE.1.b | Recognize situations in which one quantity changes at a constant rate per unit interval relative to another. | |
| | | Graphing Linear Equations |
| F-LE.1.c | Recognize situations in which a quantity grows or decays by a constant percent rate per unit interval relative to another. | |
| | | Exponential and Logistic Functions |
| | | The Number e |
| F-LE.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). | |
| | | Graphing Linear Equations |
| | | Writing Linear Equations |
| | | Writing Equations of Parallel and Perpendicular Lines |
| | | Inequalities |
| | | Solving Systems of Equations in Two Variables |
| | | Direct, Inverse, and Joint Variation |
| | | Exponential and Logistic Functions |
| | | The Number e |

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| F-LE.3 | Observe using graphs and tables that a quantity increasing exponentially eventually exceeds a quantity increasing linearly, quadratically, or (more generally) as a polynomial function. | |
| | | Twelve Basic Functions |
| | | Exponential and Logistic Functions |
| | | The Number e |
| F-LE.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. | |
| | | Exponential and Logistic Functions |
| | | The Number e |
| | | Logarithmic Functions and Their Graphs |
| | Interpret expressions for functions in terms of the situation they model | |
| F-LE.5 | Interpret the parameters in a linear or exponential function in terms of a context. | |
| | | Hyperbolas |
| | | Graphing Linear Equations |
| | | Twelve Basic Functions |
| | | Piecewise Functions |
| | | Exponential and Logistic Functions |
| | | The Number e |
| **F-TF** | **Trigonometric Functions** | |
| | Extend the domain of trigonometric functions using the unit circle | |
| F-TF.1 | Understand radian measure of an angle as the length of the arc on the unit circle subtended by the angle. | |
| | | Angles and Radian Measure |
| F-TF.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. | |
| | | Circular Functions |
| | | Angles and Radian Measure |
| F-TF.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 2pi-x in terms of their values for x, where x is any real number. | |
| | | The Sine Function |
| | | The Cosine Function |
| | | Circular Functions |
| | | Twelve Basic Functions |
| | | Applying Trigonometric Functions |
| | | Amplitude and Period |

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|---|---|---|
| F-TF.4 | Use the unit circle to explain symmetry (odd and even) and periodicity of trigonometric functions. | |
| | | The Sine Function |
| | | The Cosine Function |
| | | Circular Functions |
| | | Sum and Difference Identities |
| | | Amplitude and Period |
| | Model periodic phenomena with trigonometric functions | |
| F-TF.5 | Choose trigonometric functions to model periodic phenomena with specified amplitude, frequency, and midline. | |
| | | The Sine Function |
| | | The Cosine Function |
| | | Circular Functions |
| | | Applying Trigonometric Functions |
| | | Trigonometric Inverses and Their Graphs |
| | | Amplitude and Period |
| F-TF.6 | Understand that restricting a trigonometric function to a domain on which it is always increasing or always decreasing allows its inverse to be constructed. | |
| | | Applying Trigonometric Functions |
| | | Trigonometric Inverses and Their Graphs |
| F-TF.7 | Use inverse functions to solve trigonometric equations that arise in modeling contexts; evaluate the solutions using technology, and interpret them in terms of the context. | |
| | | Trigonometric Inverses and Their Graphs |
| | | Inverse Functions |
| | Prove and apply trigonometric identities | |
| F-TF.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. | |
| | | Sum and Difference Identities |
| F-TF.9 | Prove the addition and subtraction formulas for sine, cosine, and tangent and use them to solve problems. | |
| | | Sum and Difference Identities |
| | | Sum and Difference Identities |

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| **G-CO** | **Congruence** | |
| | Experiment with transformations in the plane | |
| G-CO.1 | Know precise definitions of angle, circle, perpendicular line, parallel line, and line segment, based on the undefined notions of point, line, distance along a line, and distance around a circular arc. | |
| G-CO.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). | |
| | | Geometric Transformations with Matrices |
| | | Graphs and Transformations |
| G-CO.3 | Given a rectangle, parallelogram, trapezoid, or regular polygon, describe the rotations and reflections that carry it onto itself. | |
| G-CO.4 | Develop definitions of rotations, reflections, and translations in terms of angles, circles, perpendicular lines, parallel lines, and line segments. | |
| G-CO.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. | |
| | | Modeling Motion with Matrices |
| **G-SRT** | **Similarity, Right Triangles, and Trigonometry** | |
| | Understand similarity in terms of similarity transformations | |
| | Define trigonometric ratios and solve problems involving right triangles | |
| G-SRT.6 | Understand that by similarity, side ratios in right triangles are properties of the angles in the triangle, leading to definitions of trigonometric ratios for acute angles. | |
| G-SRT.7 | Explain and use the relationship between the sine and cosine of complementary angles. | |
| | | The Sine Function |
| | | The Cosine Function |
| | | Circular Functions |
| | | Twelve Basic Functions |
| | | Amplitude and Period |
| G-SRT.8 | Use trigonometric ratios and the Pythagorean Theorem to solve right triangles in applied problems. | |
| | | Circular Functions |
| | | Applying Trigonometric Functions |
| | | Inverse Functions |

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| | Apply trigonometry to general triangles | |
| G-SRT.9 | Derive the formula A = 1/2 ab sin(C) for the area of a triangle by drawing an auxiliary line from a vertex perpendicular to the opposite side. | |
| | | Area and The Law of Sines |
| | | The Law of Sines |
| G-SRT.10 | Prove the Laws of Sines and Cosines and use them to solve problems. | |
| | | Area and The Law of Sines |
| | | The Law of Sines |
| | | The Ambiguous Case for the Law of Sines |
| | | The Law of Cosines |
| G-SRT.11 | Understand and apply the Law of Sines and the Law of Cosines to find unknown measurements in right and non-right triangles (e.g., surveying problems, resultant forces). | |
| | | Area and The Law of Sines |
| | | The Law of Sines |
| | | The Ambiguous Case for the Law of Sines |
| | | The Law of Cosines |
| **G-GPE** | **Expressing Geometric Properties with Equations** | |
| | Translate between the geometric description and the equation for a conic section | |
| G-GPE.1 | Derive the equation of a circle of given center and radius using the Pythagorean Theorem; complete the square to find the center and radius of a circle given by an equation. | |
| | | Circles and Parabolas |
| G-GPE.2 | Derive the equation of a parabola given a focus and directrix. | |
| | | Circles and Parabolas |
| G-GPE.3 | Derive the equations of ellipses and hyperbolas given the foci, using the fact that the sum or difference of distances from the foci is constant. | |
| | | Ellipses |
| | | Hyperbolas |
| | | Ellipses |
| | | Hyperbolas |
| | Use coordinates to prove simple geometric theorems algebraically | |
| G-GPE.4 | Use coordinates to prove simple geometric theorems algebraically. | |
| G-GPE.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). | |
| | | Writing Equations of Parallel and Perpendicular Lines |

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| G-GPE.6 | Find the point on a directed line segment between two given points that partitions the segment in a given ratio. | |
| G-GPE.7 | Use coordinates to compute perimeters of polygons and areas of triangles and rectangles, e.g., using the distance formula. | |
| S-ID | Interpreting Categorical and Quantitative Data | |
| | Summarize, represent, and interpret data on a single count or measurement variable | |
| S-ID.1 | Represent data with plots on the real number line (dot plots, histograms, and box plots). | |
| | | Probability |
| | | Basic Statistics |
| S-ID.2 | Use statistics appropriate to the shape of the data distribution to compare center (median, mean) and spread (interquartile range, standard deviation) of two or more different data sets. | |
| | | Basic Statistics |
| S-ID.3 | Interpret differences in shape, center, and spread in the context of the data sets, accounting for possible effects of extreme data points (outliers). | |
| | | Basic Statistics |
| S-ID.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. | |
| | | Basic Statistics |
| | | Normal Distributions |
| | Summarize, represent, and interpret data on two categorical and quantitative variables | |
| S-ID.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. | |
| | | Basic Statistics |
| | Interpret linear models | |
| S-ID.7 | Interpret the slope (rate of change) and the intercept (constant term) of a linear model in the context of the data. | |
| | | Graphing Linear Equations |
| | | Writing Linear Equations |
| S-ID.8 | Compute (using technology) and interpret the correlation coefficient of a linear fit. | |
| S-ID.9 | Distinguish between correlation and causation. | |

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| **S-IC** | **Making Inferences and Justifying Conclusions** | |
| | Understand and evaluate random processes underlying statistical experiments | |
| S-IC.1 | Understand statistics as a process for making inferences about population parameters based on a random sample from that population. | Basic Statistics |
| S-IC.2 | Decide if a specified model is consistent with results from a given data-generating process, e.g., using simulation. | |
| | Make inferences and justify conclusions from sample surveys, experiments, and observational studies | |
| S-IC.3 | Recognize the purposes of and differences among sample surveys, experiments, and observational studies; explain how randomization relates to each. | Probability |
| S-IC.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. | Basic Statistics |
| S-IC.5 | Use data from a randomized experiment to compare two treatments; use simulations to decide if differences between parameters are significant. | |
| S-IC.6 | Evaluate reports based on data. | |
| S-CP | Conditional Probability and the Rules of Probability | |
| | Understand independence and conditional probability and use them to interpret data | |
| S-CP.1 | Describe events as subsets of a sample space (the set of outcomes) using characteristics (or categories) of the outcomes, or as unions, intersections, or complements of other events ("or," "and," "not"). | Decision Making Using Probability |
| S-CP.2 | Understand that two events A and B are independent if the probability of A and B occurring together is the product of their probabilities, and use this characterization to determine if they are independent. | Multiplying Probabilities |
| S-CP.3 | Understand the conditional probability of A given B as P(A 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. | |
| S-CP.4 | Construct and interpret two-way frequency tables of data when two categories are associated with each object being classified. Use the two-way table as a sample space to decide if events are independent and to approximate conditional probabilities. | Basic Statistics |
| S-CP.5 | Recognize and explain the concepts of conditional probability and independence in everyday language and everyday situations. | |

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| | Use the rules of probability to compute probabilities of compound events in a uniform probability model | |
| S-CP.6 | Find the conditional probability of A given B as the fraction of B's outcomes that also belong to A, and interpret the answer in terms of the model. | |
| S-CP.7 | Apply the Addition Rule, P(A or B) = P(A) + P(B) - P(A and B), and interpret the answer in terms of the model. | |
| S-CP.8 | Apply the general Multiplication Rule in a uniform probability model, P(A and B) = P(A)P(B\|A) = P(B)P(A\|B), and interpret the answer in terms of the model. | |
| | | Multiplying Probabilities |
| | | Probability with Combinations and Permutations |
| S-CP.9 | Use permutations and combinations to compute probabilities of compound events and solve problems. | |
| | | Probability with Combinations and Permutations |
| **S-MD** | **Using Probability to Make Decisions** | |
| | Calculate expected values and use them to solve problems | |
| S-MD.1 | Define a random variable for a quantity of interest by assigning a numerical value to each event in a sample space; graph the corresponding probability distribution using the same graphical displays as for data distributions. | |
| | | Probability |
| | | Basic Statistics |
| | | Normal Distributions |
| S-MD.2 | Calculate the expected value of a random variable; interpret it as the mean of the probability distribution. | |
| | | Probability |
| | | Normal Distributions |
| | | Decision Making Using Probability |
| S-MD.3 | Develop a probability distribution for a random variable defined for a sample space in which theoretical probabilities can be calculated; find the expected value. | |
| | | Probability |
| | | Basic Statistics |
| | | Normal Distributions |
| S-MD.4 | Develop a probability distribution for a random variable defined for a sample space in which probabilities are assigned empirically; find the expected value. | |
| | | Probability |
| | | Basic Statistics |
| | | Normal Distributions |

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| | Use probability to evaluate outcomes of decisions | |
| S-MD.5 | Weigh the possible outcomes of a decision by assigning probabilities to payoff values and finding expected values. | |
| S-MD.5.a | Find the expected payoff for a game of chance. | Basic Statistics<br>Decision Making Using Probability |
| S-MD.5.b | Evaluate and compare strategies on the basis of expected values. | Decision Making Using Probability |
| S-MD.6 | Use probabilities to make fair decisions (e.g., drawing by lots, using a random number generator). | Decision Making Using Probability<br>Probability with Combinations and Permutations |
| S-MD.7 | Analyze decisions and strategies using probability concepts (e.g., product testing, medical testing, pulling a hockey goalie at the end of a game). | Normal Distributions<br>Decision Making Using Probability |