

Patterns, Functions and Algebra

Grades K-2

Ohio Benchmarks Grades K-2	Grade-Level Indicators Kindergarten	Grade-Level Indicators Grade 1	Grade-Level Indicators Grade 2
<p>A. Sort, classify, and order objects by size, number, and other properties, and describe the attributes used.</p>	<p>1. Sort, classify and order objects by size, number and other properties. For example:</p> <ul style="list-style-type: none"> a. Identify how objects are alike and different. b. Order three events or objects according to a given attribute, such as time or size. c. Recognize and explain how objects can be classified in more than one way. d. Identify what attribute was used to sort groups of objects that have already been sorted. 	<p>1. Sort, classify and order objects by two or more attributes, such as color and shape, and explain how objects were sorted.</p>	

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<p>B. Extend sequences of sounds and shapes or simple number patterns, and create and record similar patterns.</p>	<p>2. Identify, create, extend and copy sequences of sounds (such as musical notes), shapes (such as buttons, leaves or blocks), motions (such as hops or skips), and numbers from 1 to 10.</p>	<p>2. Extend sequences of sounds, shapes or simple number patterns, and create and record similar patterns. For example:</p> <ul style="list-style-type: none"> a. Analyze and describe patterns with multiple attributes using numbers and shapes; e.g., AA, B, aa, b, AA, B, aa, b,... b. Continue repeating and growing patterns with materials, pictures and geometric items; e.g., XO, XOO, XOOO, XOOOO. 	<p>1. Extend simple number patterns (both repeating and growing patterns), and create similar patterns using different objects, such as using physical materials or shapes to represent numerical patterns.</p>

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C. Create and extend patterns and describe the rule in words.	3. Describe orally the pattern of a given sequence.	3. Describe orally the basic unit or general plan of a repeating or growing pattern.	2. Use patterns to make generalizations and predictions; e.g., determine a missing element in a pattern. 3. Create new patterns with consistent rules or plans, and describe the rule or general plan of existing patterns.
D. Model problem situations using objects, pictures, tables, numbers, letters, and other symbols.	4. Model a problem situation using physical materials.	5. Describe orally and model a problem situation using words, objects or number phrase or sentence.	4. Use objects, pictures, numbers and other symbols to represent a problem situation.

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E. Solve open sentences and explain strategies.		4. Solve open sentences by representing an expression in more than one way using the commutative property; e.g., $4 + 5 = 5 + 4$ or the number of blue balls plus red balls is the same as the number of red balls plus blue balls ($R+B=B+R$).	5. Understand equivalence and extend the concept to situations involving symbols; e.g., $4 + 5 = 9$ and $9 = 4 + 5$ and $4 + 5 = 3 + 6 = \Delta + \Delta \dots$
F. Represent an unknown quantity as a variable using a symbol, such as \square , Δ , O .			6. Use symbols to represent unknown quantities and identify values for symbols in an expression or equation using addition and subtraction; e.g., $\Delta + O = 10$, $\Delta - 2 = 4$.

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G. Describe and compare qualitative and quantitative change.				7. Describe qualitative and quantitative changes, especially those involving addition and subtraction; e.g., a student growing taller versus a student growing two inches in one year.	
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Grades 3-4

Ohio Benchmarks Grades 3-4	Grade-Level Indicators Grade 3	Grade-Level Indicators Grade 4
A. Analyze and extend patterns, and describe the rule in words.	1. Extend multiplicative and growing patterns, and describe the pattern or rule in words. 2. Analyze and replicate arithmetic sequences with and without a calculator.	2. Represent and analyze patterns and functions using words, tables and graphs.
B. Use patterns to make predictions, identify relationships, and solve problems.	3. Use patterns to make predictions, identify relationships, and solve problems.	1. Use models and words to describe, extend and make generalizations of patterns and relationships occurring in computation, numerical patterns, geometry, graphs and other applications.
C. Write and solve open sentences and explain strategies.	5. Write, solve and explain simple mathematical statements, such as $7 + \Delta > 8$ or $\Delta + 8 = 10$. 6. Express mathematical relationships as equations and inequalities.	5. Represent mathematical relationships with equations or inequalities.

Patterns, Functions and Algebra

Grades 3-4

Ohio Benchmarks Grades 3-4	Grade-Level Indicators Grade 3	Grade-Level Indicators Grade 4
D. Represent an unknown quantity as a variable using a symbol, including letters.		1. Represent and analyze patterns and functions using words, tables and graphs.
E. Use variables to create and solve equations representing problem situations.	4. Model problem situations using objects, pictures, tables, numbers, letters and other symbols.	4. Use rules and variables to describe patterns and other relationships.
F. Construct and use a table of values to solve problems associated with mathematical relationships.	7. Create tables to record, organize and analyze data to discover patterns and rules.	3. Construct a table of values to solve problems associated with a mathematical relationship.
G. Describe how a change in one variable affects the value of a related variable.	8. Identify and describe quantitative changes, especially those involving addition and subtraction; e.g., the height of water in a glass becoming 1 centimeter lower each week due to evaporation.	6. Describe how a change in one variable affects the value of a related variable; e.g., as one increases the other increases or as one increases the other decreases.
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Grades 5-7

Ohio Benchmarks Grades 5-7	Grade-Level Indicators Grade 5	Grade-Level Indicators Grade 6	Grade-Level Indicators Grade 7
<p>A. Describe, extend and determine the rule for patterns and relationships occurring in numeric patterns, computation, geometry, graphs and other applications.</p>	<ol style="list-style-type: none"> 1. Justify a general rule for a pattern or a function by using physical materials, visual representations, words, tables or graphs. 2. Use calculators or computers to develop patterns, and generalize them using tables and graphs. 	<ol style="list-style-type: none"> 1. Represent and analyze patterns, rules and functions, using physical materials, tables and graphs. 2. Use words and symbols to describe numerical and geometric patterns, rules and functions. 	
<p>B. Represent, analyze and generalize a variety of patterns and functions with tables, graphs, words and symbolic rules.</p>	<ol style="list-style-type: none"> 3. Use variables as unknown quantities in general rules when describing patterns and other relationships. 		<ol style="list-style-type: none"> 1. Represent and analyze patterns, rules and functions with words, tables, graphs and simple variable expressions. 2. Generalize patterns by describing in words how to find the next term.

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Grades 5-7

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<p>C. Use variables to create and solve equations and inequalities representing problem situations.</p>	<p>4. Create and interpret the meaning of equations and inequalities representing problem situations.</p>	<p>5. Produce and interpret graphs that represent the relationship between two variables.</p> <p>6. Evaluate simple expressions by replacing variables with given values, and use formulas in problem-solving situations.</p>	
<p>D. Use symbolic algebra to represent and explain mathematical relationships.</p>		<p>3. Recognize and generate equivalent forms of algebraic expressions, and explain how the commutative, associative and distributive properties can be used to generate equivalent forms; e.g., perimeter as $2(1 + w)$ or $21 + 2w$.</p>	<p>9. Recognize a variety of uses for variables; e.g., placeholder for an unknown quantity in an equation, generalization for a pattern, formula.</p>

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E. Use rules and variables to describe patterns, functions and other relationships.	3. Use variables as unknown quantities in general rules when describing patterns and other relationships.	2. Use words and symbols to describe numerical and geometric patterns, rules and functions.	3. Recognize and explain when numerical patterns are linear or nonlinear progressions; e.g., 1,3,5,7... is linear and 1,3,4,8,16... is nonlinear.
F. Use representations, such as tables, graphs and equations, to model situations and to solve problems, especially those that involve linear relationships.	5. Model problems with physical materials and visual representations, and use models, graphs and tables to draw conclusions and make predictions.		5. Represent linear equations by plotting points in the coordinate plane. 6. Represent inequalities on a number line or a coordinate plane.

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Ohio Benchmarks Grades 5-7	Grade-Level Indicators Grade 5	Grade-Level Indicators Grade 6	Grade-Level Indicators Grade 7
<p>G. Write, simplify and evaluate algebraic expressions.</p>	<p>3. Use variables as unknown quantities in general rules when describing patterns and other relationships.</p>	<p>6. Evaluate simple expressions by replacing variables with given values, and use formulas in problem-solving situations.</p>	<p>1. Represent and analyze patterns, rules and functions with words, tables, graphs and simple variable expressions.</p> <p>7. Justify that two forms of an algebraic expression are equivalent, and recognize when an expression is simplified; e.g., $4m = m + m + m + m$ or $a \cdot 5 + 4 = 5a + 4$.</p>
<p>H. Solve linear equations and inequalities symbolically, graphically and numerically.</p>		<p>4. Solve simple linear equations and inequalities using physical models, paper and pencil, tables and graphs.</p>	<p>4. Create visual representations of equation-solving processes that model the use of inverse operations.</p>
<p>I. Explain how inverse operations are used to solve linear equations.</p>	<p>8. <i>Identify and use relationships between operations to solve problems. Number, Number Sense and Operations</i></p>		<p>4. Create visual representations of equation-solving processes that model the use of inverse operations.</p>

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Ohio Benchmarks Grades 5-7	Grade-Level Indicators Grade 5	Grade-Level Indicators Grade 6	Grade-Level Indicators Grade 7
<p>J. Use formulas in problem-solving situations.</p>	<p>6. Use strategies to develop formulas for determining perimeter and area of triangles, rectangles and parallelograms, and volume of rectangular prisms. Measurement</p>	<p>2. Use strategies to develop formulas for finding circumference and area of circles, and to determine the area of sectors; e.g., $\frac{1}{2}$ circle, $\frac{2}{3}$ circle, $\frac{1}{3}$ circle, $\frac{1}{4}$ circle. Measurement</p> <p>6. Evaluate simple expressions by replacing variables with given values, and use formulas in problem-solving situations.</p>	<p>8. Use formulas in problem-solving situations.</p> <p>6. Use strategies to develop formulas for finding area of trapezoids and volume of cylinders and prisms. Measurement</p> <p>3. Use and demonstrate understanding of the properties of triangles. For example: a. Use Pythagorean Theorem to solve problems involving right triangles. b. Use triangle angle sum relationships to solve problems. Geometry and Spatial Sense</p>

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Grades 5-7

Ohio Benchmarks Grades 5-7	Grade-Level Indicators Grade 5	Grade-Level Indicators Grade 6	Grade-Level Indicators Grade 7		
K. Graph linear equations and inequalities.	5. Model problems with physical materials and visual representations, and use models, graphs and tables to draw conclusions and make predictions.	4. Solve simple linear equations and inequalities using physical models, paper and pencil, tables and graphs. 5. Produce and interpret graphs that represent the relationship between two variables.	5. Represent linear equations by plotting points in the coordinate plane. 6. Represent inequalities on a number line or a coordinate plane.		
L. Analyze functional relationships, and explain how a change in one quantity results in a change in the other.	6. Describe how the quantitative change in a variable affects the value of a related variable; e.g., describe how the rate of growth varies over time, based upon data in a table or graph.	7. Identify and describe situations with constant or varying rates of change, and compare them.	10. Analyze linear and simple nonlinear relationships to explain how a change in one variable results in the change of another.		
M. Approximate and interpret rates of change from graphical and numerical data.		8. Use technology to analyze change; e.g., use computer applications or graphing calculators to display and interpret rate of change.	11. Use graphing calculators or computers to analyze change; e.g., distance-time relationships.		
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Patterns, Functions and Algebra

Grades 8-10

Ohio Benchmarks Grades 8-10	Grade-Level Indicators Grade 8	Grade-Level Indicators Grade 9	Grade-Level Indicators Grade 10
<p>A. Generalize and explain patterns and sequences in order to find the next term and the nth term.</p>	<p>2. Generalize patterns and sequences by describing how to find the nth term.</p>	<p>2. Generalize patterns using functions or relationships (linear, quadratic and exponential), and freely translate among tabular, graphical and symbolic representations.</p>	
<p>B. Identify and classify functions as linear or nonlinear, and contrast their properties using tables, graphs or equations.</p>	<p>3. Identify functions as linear or nonlinear based on information given in a table, graph or equation.</p>	<p>1. Define function with ordered pairs in which each domain element is assigned exactly one range element.</p> <p>3. Describe problem situations (linear, quadratic and exponential) by using tabular, graphical and symbolic representations.</p>	<p>1. Define function formally and with $f(x)$ notation.</p> <p>2. Describe and compare characteristics of the following families of functions: square root, cubic, absolute value and basic trigonometric functions; e.g., general shape, possible number of roots, domain and range.</p>

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Grades 8-10

Ohio Benchmarks Grades 8-10	Grade-Level Indicators Grade 8	Grade-Level Indicators Grade 9	Grade-Level Indicators Grade 10
<p>C. Translate information from one representation (words, table, graph or equation) to another representation of a relation or function.</p>	<p>1. Relate the various representations of a relationship; i.e., relate a table to graph, description and symbolic form.</p>	<p>2. Generalize patterns using functions or relationships (linear, quadratic and exponential), and freely translate among tabular, graphical and symbolic representations.</p>	

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Grades 8-10

Ohio Benchmarks Grades 8-10	Grade-Level Indicators Grade 8	Grade-Level Indicators Grade 9	Grade-Level Indicators Grade 10
<p>D. Use algebraic representations, such as tables, graphs, expressions, functions and inequalities, to model and solve problem situations.</p>	<p>4. Extend the uses of variables to include covariants where y depends on x.</p> <p>5. Use physical models to add and subtract monomials and polynomials, and to multiply a polynomial by a monomial.</p> <p>7. Use symbolic algebra (equations and inequalities), graphs and tables to represent situations and solve problems.</p> <p>8. Write, simplify and evaluate algebraic expressions (including formulas) to generalize situations and solve problems.</p>	<p>7. Use formulas to solve problems involving exponential growth and decay.</p> <p>11. Add, subtract, multiply and divide monomials and polynomials (division of polynomials by monomials only).</p> <p>12. Simplify rational expressions by eliminating common factors and applying properties of integer exponents.</p>	<p>3. Solve equations and formulas for a specified variable; e.g., express the base of a triangle in terms of the area and height.</p> <p>4. Use algebraic representations and functions to describe and generalize geometric properties and relationships.</p> <p>5. Solve simple linear and nonlinear equations and inequalities having square roots as coefficients and solutions.</p> <p>6. Solve equations and inequalities having rational expressions as coefficients and solutions.</p>

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Ohio Benchmarks Grades 8-10	Grade-Level Indicators Grade 8	Grade-Level Indicators Grade 9	Grade-Level Indicators Grade 10
<p>E. Analyze and compare functions and their graphs using attributes, such as rates of change, intercepts and zeros.</p>	<p>6. Describe the relationship between the graph of a line and its equation, including being able to explain the meaning of slope as a constant rate of change and y-intercept in real-world problems.</p>	<p>4. Demonstrate the relationship among zeros of a function, roots of equations, and solutions of equations graphically and in words.</p> <p>5. Describe and compare characteristics of the following families of functions: linear, quadratic and exponential functions; e.g., general shape, number of roots, domain, range, rate of change, maximum or minimum.</p>	

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Ohio Benchmarks Grades 8-10	Grade-Level Indicators Grade 8	Grade-Level Indicators Grade 9	Grade-Level Indicators Grade 10
<p>F. Solve and graph linear equations and inequalities.</p>	<p>7. Use symbolic algebra (equations and inequalities), graphs and tables to represent situations and solve problems.</p> <p>9. Solve linear equations and inequalities graphically, symbolically and using technology.</p>	<p>6. Write and use equivalent forms of equations and inequalities in problem situations; e.g., changing a linear equation to the slope-intercept form.</p> <p>8. Find linear equations that represent lines that pass through a given set of ordered pairs, and find linear equations that represent lines parallel or perpendicular to a given line through a specific point.</p>	<p>10. Solve real-world problems that can be modeled using linear, quadratic, exponential or square root functions.</p>
<p>G. Solve quadratic equations with real roots by graphing, formula and factoring.</p>	<p>12. Solve simple quadratic equations graphically; e.g., $y = x^2 - 16$.</p>	<p>10. Solve quadratic equations with real roots by factoring, graphing, using the quadratic formula and with technology.</p>	<p>8. Graph the quadratic relationship that defines circles.</p> <p>10. Solve real-world problems that can be modeled using linear, quadratic, exponential or square root functions.</p>

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Ohio Benchmarks Grades 8-10	Grade-Level Indicators Grade 8	Grade-Level Indicators Grade 9	Grade-Level Indicators Grade 10
<p>H. Solve systems of linear equations involving two variables graphically and symbolically.</p>	<p>10. Solve 2 by 2 systems of linear equations graphically and by simple substitution.</p> <p>11. Interpret the meaning of the solution of a 2 by 2 system of equations; i.e., point, line, no solution.</p>	<p>9. Solve and interpret the meaning of 2 by 2 systems of linear equations graphically, by substitution and by elimination, with and without technology.</p>	<p>7. Solve systems of linear inequalities.</p> <p>11. Solve real-world problems that can be modeled, using systems of linear equations and inequalities.</p>
<p>I. Model and solve problem situations involving direct and inverse variation.</p>	<p>14. Differentiate and explain types of changes in mathematical relationships, such as linear vs. nonlinear, continuous vs. noncontinuous, direct variation vs. inverse variation.</p>	<p>13. Model and solve problems involving direct and inverse variation using proportional reasoning.</p> <p>14. Describe the relationship between slope and the graph of a direct variation and inverse variation.</p>	

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Grades 8-10

Ohio Benchmarks Grades 8-10	Grade-Level Indicators Grade 8	Grade-Level Indicators Grade 9	Grade-Level Indicators Grade 10		
<p>J. Describe and interpret rates of change from graphical and numerical data.</p>	<p>13. Compute and interpret slope, midpoint and distance given a set of ordered pairs.</p> <p>15. Describe and compare how changes in an equation affects the related graphs; e.g., for a linear equation changing the coefficient of x affects the slope and changing the constant affects the intercepts.</p> <p>16. Use graphing calculators or computers to analyze change; e.g., interest compounded over time as a nonlinear growth pattern.</p>	<p>15. Describe how a change in the value of a constant in a linear or quadratic equation affects the related graphs.</p>	<p>9. Recognize and explain that the slopes of parallel lines are equal and the slopes of perpendicular lines are negative reciprocals.</p> <p>12. Describe the relationship between slope of a line through the origin and the tangent function of the angle created by the line and the positive x-axis.</p>		
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Grades 11-12

Ohio Benchmarks Grades 11-12	Grade-Level Indicators Grade 11	Grade-Level Indicators Grade 12
<p>A. Analyze functions by investigating rates of change, intercepts, zeros, asymptotes, and local and global behavior.</p>	<ol style="list-style-type: none"> 3. Describe and compare the characteristics of the following families of functions: quadratics with complex roots, polynomials of any degree, logarithms, and rational functions; e.g., general shape, number of roots, domain and range, asymptotic behavior. 4. Identify the maximum and minimum points of polynomial, rational and trigonometric functions graphically and with technology. 5. Identify families of functions with graphs that have rotation symmetry or reflection symmetry about the y-axis, x-axis or $y = x$. 6. Represent the inverse of a function symbolically and graphically as a reflection about $y = x$. 10. Describe the characteristics of the graphs of conic sections. 11. Describe how a change in the value of a constant in an exponential, logarithmic or radical equation affects the graph of the equation. 	<ol style="list-style-type: none"> 1. Analyze the behavior of arithmetic and geometric sequences and series as the number of terms increases. 2. Translate between the numeric and symbolic form of a sequence or series. 3. Describe and compare the characteristics of transcendental and periodic functions; e.g., general shape, number of roots, domain and range, asymptotic behavior, extrema, local and global behavior. 4. Represent the inverse of a transcendental function symbolically. 6. Make arguments about mathematical properties using mathematical induction. 7. Make mathematical arguments using the concepts of limit. 9. Translate freely between polar and Cartesian coordinate systems. 10. Use the concept of limit to find instantaneous rate of change for a point on a graph as the slope of a tangent at a point.

Patterns, Functions and Algebra

Grades 11-12

Ohio Benchmarks Grades 11-12	Grade-Level Indicators Grade 11	Grade-Level Indicators Grade 12			
B. Use the quadratic formula to solve quadratic equations that have complex roots.	8. Solve equations involving radical expressions and complex roots.				
C. Use recursive functions to model and solve problems; e.g., home mortgages, annuities.	1. Identify and describe problem situations involving an iterative process that can be represented as a recursive function; e.g., compound interest. 2. Translate a recursive function into a closed form expression or formula for the n th term to solve a problem situation involving an iterative process; e.g., find the value of an annuity after 7 years.	8. Compare estimates of the area under a curve over a bounded interval by partitioning the region with rectangles; e.g., make successive estimates using progressively smaller rectangles.			
D. Apply algebraic methods to represent and generalize problem situations involving vectors and matrices.	7. Model and solve problems with matrices and vectors. 9. Solve 3 by 3 systems of linear equations by elimination and using technology, and interpret graphically what the solution means (a point, line, plane, or no solution).	5. Set up and solve systems of equations using matrices and graphs, with and without technology.			
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