Mathematics vocabulary word wall cards provide a display of mathematics content words and associated visual cues to assist in vocabulary development. The cards should be used as an instructional tool for teachers and then as a reference for all students.

### Table of Contents

#### Expressions and Operations
- **Real Numbers**
- **Complex Numbers**
- **Complex Number (examples)**
- **Absolute Value**
- **Order of Operations**
- **Expression**
- **Variable**
- **Coefficient**
- **Term**
- **Scientific Notation**
- **Exponential Form**
- **Negative Exponent**
- **Zero Exponent**
- **Product of Powers Property**
- **Power of a Power Property**
- **Power of a Product Property**
- **Power of a Quotient Property**
- **Polynomial**
- **Degree of Polynomial**
- **Leading Coefficient**
- **Add Polynomials (group like terms)**
- **Add Polynomials (align like terms)**
- **Subtract Polynomials (group like terms)**
- **Subtract Polynomials (align like terms)**
- **Multiply Binomials**
- **Multiply Binomials (model)**
- **Multiply Binomials (graphic organizer)**
- **Multiply Binomials (squaring a binomial)**
- **Multiply Binomials (sum and difference)**
- **Factors of a Monomial**
- **Factoring (greatest common factor)**
- **Factoring (perfect square trinomials)**
- **Factoring (difference of squares)**

#### Difference of Squares (model)
- **Factoring (sum and difference of cubes)**
- **Factor by Grouping**
- **Divide Polynomials (monomial divisor)**
- **Divide Polynomials (binomial divisor)**
- **Prime Polynomial**
- **Square Root**
- **Cube Root**
- **n\textsuperscript{th} Root**
- **Simplify Radical Expressions**
- **Add and Subtract Radical Expressions**
- **Product Property of Radicals**
- **Quotient Property of Radicals**

#### Equations and Inequalities
- **Zero Product Property**
- **Solutions or Roots**
- **Zeros**
- **x-Intercepts**
- **Coordinate Plane**
- **Literal Equation**
- **Vertical Line**
- **Horizontal Line**
- **Quadratic Equation (solve by factoring and graphing)**
- **Quadratic Equation (number of solutions)**
- **Inequality**
- **Graph of an Inequality**
- **Transitive Property for Inequality**
- **Addition/Subtraction Property of Inequality**
- **Multiplication Property of Inequality**
- **Division Property of Inequality**
- **Absolute Value Inequalities**
- **Linear Equation (standard form)**
- **Linear Equation (slope intercept form)**
- **Linear Equation (point-slope form)**
Equivalent Forms of a Linear Equation
Slope
Slope Formula
Slopes of Lines
Perpendicular Lines
Parallel Lines
Mathematical Notation
System of Linear Equations (graphing)
System of Linear Equations (substitution)
System of Linear Equations (elimination)
System of Linear Equations (number of solutions)
System of Equations (linear-quadratic)
Graphing Linear Inequalities
System of Linear Inequalities
Dependent and Independent Variable
Dependent and Independent Variable (application)
Graph of a Quadratic Equation
Vertex of a Quadratic Function
Quadratic Formula

Relations and Functions
Relations (definition and examples)
Functions (definition)
Function (example)
Domain
Range
Increasing/Decreasing
Extrema
End Behavior
Function Notation
Parent Functions
  - Linear, Quadratic
  - Absolute Value, Square Root
  - Cubic, Cube Root
  - Rational
  - Exponential, Logarithmic
Transformations of Parent Functions
  - Translation
  - Reflection
  - Dilation
Linear Function (transformational graphing)
  - Translation
  - Dilation (m>0)
  - Dilation/reflection (m<0)
Quadratic Function (transformational graphing)
  - Vertical translation
  - Dilation (a>0)
  - Dilation/reflection (a<0)
  - Horizontal translation
Multiple Representations of Functions
Inverse of a Function
Continuity
Discontinuity (asymptotes)
Discontinuity (removable or point)
Discontinuity (removable or point)
Arithmetic Sequence
Geometric Sequence

Statistics
Direct Variation
Inverse Variation
Joint Variation
Fundamental Counting Principle
Permutation
Permutation (formula)
Combination
Combination (formula)
Statistics Notation
Mean
Median
Mode
Summation
Variance
Standard Deviation (definition)
Standard Deviation (graphic)
z-Score (definition)
z-Score (graphic)
Empirical Rule
Elements within One Standard Deviation of the Mean (graphic)
Scatterplot
Positive Linear Relationship (Correlation)
Negative Linear Relationship (Correlation)
No Correlation
Curve of Best Fit (linear)
Curve of Best Fit (quadratic)
Curve of Best Fit (exponential)
Outlier Data (graphic)
# Real Numbers

The set of all rational and irrational numbers

- **Rational Numbers**
  - **Integers**
  - **Whole Numbers**
  - **Natural Numbers**
- **Irrational Numbers**

### Table

<table>
<thead>
<tr>
<th>Natural Numbers</th>
<th>{1, 2, 3, 4 \ldots}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Whole Numbers</td>
<td>{0, 1, 2, 3, 4 \ldots}</td>
</tr>
<tr>
<td>Integers</td>
<td>{\ldots -3, -2, -1, 0, 1, 2, 3 \ldots}</td>
</tr>
<tr>
<td>Rational Numbers</td>
<td>the set of all numbers that can be written as the ratio of two integers with a non-zero denominator (e.g., $2\frac{3}{5}$, -5, 0.3, $\sqrt{16}$, $\frac{13}{7}$)</td>
</tr>
<tr>
<td>Irrational Numbers</td>
<td>the set of all nonrepeating, nonterminating decimals (e.g, $\sqrt{7}$, $\pi$, \0.2322322232223\ldots)</td>
</tr>
</tbody>
</table>
Complex Numbers

The set of all real and imaginary numbers
Complex Number (Examples)

\[ a \pm bi \]

\( a \) and \( b \) are real numbers and \( i = \sqrt{-1} \)

A complex number consists of both real (\( a \)) and imaginary (\( bi \)) but either part can be 0

<table>
<thead>
<tr>
<th>Case</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a = 0 )</td>
<td>-i, 0.01i, ( \frac{2i}{5} )</td>
</tr>
<tr>
<td>( b = 0 )</td>
<td>( \sqrt{5}, 4, -12.8 )</td>
</tr>
<tr>
<td>( a \neq 0, b \neq 0 )</td>
<td>39 – 6i, -2 + ( \pi i )</td>
</tr>
</tbody>
</table>
Absolute Value

\[ |5| = 5 \quad |\text{-}5| = 5 \]

The distance between a number and zero

5 units

5 units
# Order of Operations

<table>
<thead>
<tr>
<th>Grouping Symbols</th>
<th>( )  \sqrt{}  { }</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Exponents</td>
<td>$a^n$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Multiplication</td>
<td>Left to Right</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Division</td>
<td>Left to Right</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Addition</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Subtraction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Expression

A representation of a quantity that may contain numbers, variables or operation symbols

\[ x \]

\[-\frac{4}{\sqrt{54}}\]

\[ \frac{1}{3^2 + 2m} \]

\[ 3(y + 3.9)^4 - \frac{8}{9} \]
Variable

$2^y + 3$

$9 + \log(x) = 2.08$

$d = 7c - 5$

$A = \pi r^2$
Coefficient

\((-4) + 2 \log x\)

\(-7y^3\)

\(\frac{2}{3}ab - \frac{1}{2}\)

\(\pi r^2\)
Term

\[ 3 \log x + 2y - 8 \]

3 terms

\[-5x^2 - x\]

2 terms

\[ \left( \frac{2}{3} \right)^a \]

1 term
Scientific Notation

\[ a \times 10^n \]

1 ≤ |a| < 10 and \( n \) is an integer

<table>
<thead>
<tr>
<th>Standard Notation</th>
<th>Scientific Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>17,500,000</td>
<td>1.75 \times 10^7</td>
</tr>
<tr>
<td>-84,623</td>
<td>-8.4623 \times 10^4</td>
</tr>
<tr>
<td>0.0000026</td>
<td>2.6 \times 10^{-6}</td>
</tr>
<tr>
<td>-0.080029</td>
<td>-8.0029 \times 10^{-2}</td>
</tr>
<tr>
<td>( (4.3 \times 10^5) ) ( (2 \times 10^{-2}) )</td>
<td>( (4.3 \times 2) ) ( (10^5 \times 10^{-2}) ) = ( 8.6 \times 10^{5+(-2)} ) = ( 8.6 \times 10^3 )</td>
</tr>
<tr>
<td>( \frac{6.6 \times 10^6}{2 \times 10^3} )</td>
<td>( \frac{6.6}{2} \times \frac{10^6}{10^3} = 3.3 \times 10^{6-3} = 3.3 \times 10^3 )</td>
</tr>
</tbody>
</table>
Exponential Form

\[ a^n = a \cdot a \cdot a \cdot a \ldots, \quad a \neq 0 \]

Examples:

\[
\begin{array}{|c|}
\hline
2 \cdot 2 \cdot 2 = 2^3 = 8 \\
\hline
n \cdot n \cdot n \cdot n = n^4 \\
\hline
3 \cdot 3 \cdot 3 \cdot x \cdot x = 3^3 x^2 = 27x^2 \\
\hline
\end{array}
\]
Negative Exponent

\[ a^{-n} = \frac{1}{a^n}, \quad a \neq 0 \]

Examples:

\[
4^{-2} = \frac{1}{4^2} = \frac{1}{16}
\]

\[
\frac{x^4}{y^{-2}} = \frac{x^4}{\frac{1}{y^2}} = \frac{x^4}{1} \cdot \frac{y^2}{1} = x^4y^2
\]

\[
(2 - a)^{-2} = \frac{1}{(2 - a)^2}, \quad a \neq 2
\]
Zero Exponent

$$a^0 = 1, \ a \neq 0$$

**Examples:**

<table>
<thead>
<tr>
<th>Expression</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>$(-5)^0$</td>
<td>$1$</td>
</tr>
<tr>
<td>$(3x + 2)^0$</td>
<td>$1$</td>
</tr>
<tr>
<td>$(x^2y^{-5}z^8)^0$</td>
<td>$1$</td>
</tr>
<tr>
<td>$4m^0$</td>
<td>$4 \cdot 1 = 4$</td>
</tr>
<tr>
<td>$\left(\frac{2}{3}\right)^0$</td>
<td>$1$</td>
</tr>
</tbody>
</table>
### Product of Powers Property

\[ a^m \cdot a^n = a^{m+n} \]

**Examples:**

<table>
<thead>
<tr>
<th>( x^4 \cdot x^2 )</th>
<th>( x^4 \cdot x^2 = x^{4+2} = x^6 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a^3 \cdot a )</td>
<td>( a^3 \cdot a = a^{3+1} = a^4 )</td>
</tr>
<tr>
<td>( w^{\frac{1}{3}} \cdot w^{\frac{1}{4}} )</td>
<td>( w^{\frac{1}{3}+\frac{1}{4}} = w^{\frac{7}{12}} )</td>
</tr>
</tbody>
</table>
Power of a Power Property

\[(a^m)^n = a^{m \cdot n}\]

Examples:

\[\left(\frac{1}{y^4}\right)^8 = y^{4 \cdot 1} = y^2\]

\[(g^2)^{-3} = g^{2 \cdot (-3)} = g^{-6} = \frac{1}{g^6}\]
Power of a Product Property

\[(ab)^m = a^m \cdot b^m\]

Examples:

\[
\frac{1}{2} \left(9a^4 b^6\right)^\frac{1}{2} = \left(9\right)^\frac{1}{2} \cdot \left(a^4\right)^\frac{1}{2} \left(b^6\right)^\frac{1}{2} = 3a^2 b^3
\]

\[
\frac{-1}{(2x)^3} = \frac{-1}{2^3 x^3} = \frac{-1}{8x^3}
\]
Quotient of Powers Property

\[ \frac{a^m}{a^n} = a^{m-n}, \quad a \neq 0 \]

Examples:

1. \[ \frac{3}{5} \cdot \frac{3}{5} = \frac{3 - 1}{5} = \frac{2}{5} \]

2. \[ y^{-3} = y^{-3 - (-5)} = y^2 \]

3. \[ a^4 = a^{4-4} = a^0 = 1 \]
Power of Quotient Property

\[
\left(\frac{a}{b}\right)^m = \frac{a^m}{b^m}, \quad b \neq 0
\]

Examples:

\[
\left(\frac{y}{3}\right)^4 = \frac{y^4}{3^4} = \frac{y}{81}
\]

\[
\left(\frac{5}{t}\right)^{-3} = \frac{5^{-3}}{t^{-3}} = \frac{1}{5^3} = \frac{1}{t^3} = \frac{1}{5^3} \cdot \frac{t^3}{1} = \frac{t^3}{5^3} = \frac{t^3}{125}
\]
# Polynomial

<table>
<thead>
<tr>
<th>Example</th>
<th>Name</th>
<th>Terms</th>
</tr>
</thead>
<tbody>
<tr>
<td>$7 + 6x$</td>
<td>monomial</td>
<td>1 term</td>
</tr>
<tr>
<td>$3t - 1$</td>
<td>binomial</td>
<td>2 terms</td>
</tr>
<tr>
<td>$12xy^3 + 5x^4y$</td>
<td>binomial</td>
<td>2 terms</td>
</tr>
<tr>
<td>$2x^2 + 3x - 7$</td>
<td>trinomial</td>
<td>3 terms</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nonexample</th>
<th>Reason</th>
</tr>
</thead>
<tbody>
<tr>
<td>$5m^n - 8$</td>
<td>variable exponent</td>
</tr>
<tr>
<td>$n^{-3} + 9$</td>
<td>negative exponent</td>
</tr>
</tbody>
</table>
# Degree of a Polynomial

The largest exponent or the largest sum of exponents of a term within a polynomial

<table>
<thead>
<tr>
<th>Polynomial</th>
<th>Degree of Each Term</th>
<th>Degree of Polynomial</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-7m^3n^5$</td>
<td>$-7m^3n^5 \rightarrow \text{degree 8}$</td>
<td>8</td>
</tr>
</tbody>
</table>
| $2x + 3$            | $2x \rightarrow \text{degree 1}$  
|                    | $3 \rightarrow \text{degree 0}$    | 1                    |
| $6a^3 + 3a^2b^3 - 21$ | $6a^3 \rightarrow \text{degree 3}$  
|                    | $3a^2b^3 \rightarrow \text{degree 5}$  
|                    | -21 $\rightarrow \text{degree 0}$    | 5                    |
Leading Coefficient

The coefficient of the first term of a polynomial written in descending order of exponents

<table>
<thead>
<tr>
<th>Examples:</th>
</tr>
</thead>
<tbody>
<tr>
<td>$7a^3 - 2a^2 + 8a - 1$</td>
</tr>
<tr>
<td>$-3n^3 + 7n^2 - 4n + 10$</td>
</tr>
<tr>
<td>$16t - 1$</td>
</tr>
</tbody>
</table>
Add Polynomials

(Group Like Terms – Horizontal Method)

Example:

\[ h(g) = 2g^2 + 6g - 4; \quad k(g) = g^2 - g \]

\[ h(g) + k(g) = (2g^2 + 6g - 4) + (g^2 - g) \]

\[ = 2g^2 + 6g - 4 + g^2 - g \]

(Positive like terms and add)

\[ = (2g^2 + g^2) + (6g - g) - 4 \]

\[ h(g) + k(g) = 3g^2 + 5g - 4 \]
Add Polynomials

(Align Like Terms – Vertical Method)

Example:

\[ h(g) = 2g^3 + 6g^2 - 4; \quad k(g) = g^3 - g - 3 \]

\[ h(g) + k(g) = (2g^3 + 6g^2 - 4) + (g^3 - g - 3) \]

(Align like terms and add)

\[
\begin{align*}
2g^3 + 6g^2 & \quad - 4 \\
+ & \quad g^3 \\
\underline{-} & \quad g - 3
\end{align*}
\]

\[ h(g) + k(g) = 3g^3 + 6g^2 - g - 7 \]
Subtract Polynomials
(Group Like Terms - Horizontal Method)

Example:

\[ f(x) = 4x^2 + 5; \ g(x) = -2x^2 + 4x - 7 \]

\[ f(x) - g(x) = (4x^2 + 5) - (-2x^2 + 4x - 7) \]

(Add the inverse)

\[ = (4x^2 + 5) + (2x^2 - 4x + 7) \]

\[ = 4x^2 + 5 + 2x^2 - 4x + 7 \]

(Add the inverse)

\[ = (4x^2 + 2x^2) - 4x + (5 + 7) \]

\[ f(x) - g(x) = 6x^2 - 4x + 12 \]
Subtract Polynomials
(Align Like Terms - Vertical Method)

Example:

\[ f(x) = 4x^2 + 5; \quad g(x) = -2x^2 + 4x - 7 \]

\[ f(x) - g(x) = (4x^2 + 5) - (-2x^2 + 4x - 7) \]

(Align like terms then add the inverse and add the like terms.)

\[ 4x^2 + 5 \quad \rightarrow \quad 4x^2 + 5 \]

\[ -(-2x^2 + 4x - 7) \quad \rightarrow \quad +2x^2 - 4x + 7 \]

\[ f(x) - g(x) = 6x^2 - 4x + 12 \]
Multiply Binomials

Apply the distributive property.

\[(a + b)(c + d) =\]
\[a(c + d) + b(c + d) =\]
\[ac + ad + bc + bd\]

Example: \((x + 3)(x + 2)\)

\[= (x + 3)(x + 2)\]
\[= x(x + 2) + 3(x + 2)\]
\[= x^2 + 2x + 3x + 6\]
\[= x^2 + 5x + 6\]
Multiply Polynomials

Apply the distributive property.

\[(a + b)(d + e + f)\]

\[= a(d + e + f) + b(d + e + f)\]

\[= ad + ae + af + bd + be + bf\]
Multiply Binomials
(Model)

Apply the distributive property.

Example: \((x + 3)(x + 2)\)

\[ x^2 + 2x + 3x + 6 = x^2 + 5x + 6 \]
Multiply Binomials
(Graphic Organizer)

Apply the distributive property.

Example: \((x + 8)(2x - 3)\)

\[= (x + 8)(2x + -3)\]

\[2x + -3\]

\[
\begin{array}{c|c|c}
  x & 2x^2 & -3x \\
+ & 16x & -24 \\
8 & & \\
\end{array}
\]

\[2x^2 + 16x + -3x + -24 = 2x^2 + 13x - 24\]
Multiply Binomials  
(Squaring a Binomial)

\[(a + b)^2 = a^2 + 2ab + b^2\]

\[(a - b)^2 = a^2 - 2ab + b^2\]

Examples:

\[(3m + n)^2 = 9m^2 + 2(3m)(n) + n^2\]
\[= 9m^2 + 6mn + n^2\]

\[(y - 5)^2 = y^2 - 2(5)(y) + 25\]
\[= y^2 - 10y + 25\]
Multiply Binomials
(Sum and Difference)

\[(a + b)(a - b) = a^2 - b^2\]

Examples:

\[(2b + 5)(2b - 5) = 4b^2 - 25\]

\[(7 - w)(7 + w) = 49 - w^2\]
Factors of a Monomial

The number(s) and/or variable(s) that are multiplied together to form a monomial

<table>
<thead>
<tr>
<th>Examples:</th>
<th>Factors</th>
<th>Expanded Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>$5b^2$</td>
<td>$5 \cdot b^2$</td>
<td>$5 \cdot b \cdot b$</td>
</tr>
<tr>
<td>$6x^2y$</td>
<td>$6 \cdot x^2 \cdot y$</td>
<td>$2 \cdot 3 \cdot x \cdot x \cdot y$</td>
</tr>
<tr>
<td>$\frac{-5p^2q^3}{2}$</td>
<td>$\frac{-5}{2} \cdot p^2 \cdot q^3$</td>
<td>$\frac{1}{2} \cdot (-5) \cdot p \cdot p \cdot q \cdot q \cdot q$</td>
</tr>
</tbody>
</table>
Factoring
(Greatest Common Factor)

Find the greatest common factor (GCF) of all terms of the polynomial and then apply the distributive property.

Example: $20a^4 + 8a$

$$2 \cdot 2 \cdot 5 \cdot a \cdot a \cdot a + 2 \cdot 2 \cdot 2 \cdot a$$

common factors

GCF = $2 \cdot 2 \cdot a = 4a$

$$20a^4 + 8a = 4a(5a^3 + 2)$$
Factoring
(Perfect Square Trinomials)

\[ a^2 + 2ab + b^2 = (a + b)^2 \]
\[ a^2 - 2ab + b^2 = (a - b)^2 \]

Examples:

\[
\begin{array}{c}
x^2 + 6x + 9 = x^2 + 2 \cdot 3 \cdot x + 3^2 \\
= (x + 3)^2
\end{array}
\]

\[
\begin{array}{c}
4x^2 - 20x + 25 = (2x)^2 - 2 \cdot 2x \cdot 5 + 5^2 \\
= (2x - 5)^2
\end{array}
\]
Factoring
(Difference of Squares)

\[ a^2 - b^2 = (a + b)(a - b) \]

Examples:

\[
\begin{align*}
x^2 - 49 &= x^2 - 7^2 = (x + 7)(x - 7) \\
4 - n^2 &= 2^2 - n^2 = (2 - n)(2 + n) \\
9x^2 - 25y^2 &= (3x)^2 - (5y)^2 \\
&= (3x + 5y)(3x - 5y)
\end{align*}
\]
Difference of Squares
(Model)

\[ a^2 - b^2 = (a + b)(a - b) \]
Factoring
(Sum and Difference of Cubes)

\[ a^3 + b^3 = (a + b)(a^2 - ab + b^2) \]
\[ a^3 - b^3 = (a - b)(a^2 + ab + b^2) \]

Examples:

\[
27y^3 + 1 = (3y)^3 + (1)^3
= (3y + 1)(9y^2 - 3y + 1)
\]

\[
x^3 - 64 = x^3 - 4^3 = (x - 4)(x^2 + 4x + 16)
\]
Factoring (By Grouping)

For trinomials of the form \( ax^2 + bx + c \)

Example: \( 3x^2 + 8x + 4 \)

\[
\begin{align*}
ac &= 3 \cdot 4 = 12 \\
\text{Find factors of } ac \text{ that add to equal } b \\
12 &= 2 \cdot 6 \rightarrow 2 + 6 = 8
\end{align*}
\]

\[
3x^2 + 2x + 6x + 4 \\
(3x^2 + 2x) + (6x + 4) \\
x(3x + 2) + 2(3x + 2) \\
(3x + 2)(x + 2)
\]
Divide Polynomials (Monomial Divisor)

Divide each term of the dividend by the monomial divisor

Example:

\[ f(x) = 12x^3 - 36x^2 + 16x; \quad g(x) = 4x \]

\[
\frac{f(x)}{g(x)} = \frac{(12x^3 - 36x^2 + 16x)}{4x}
\]

\[
= \frac{12x^3}{4x} - \frac{36x^2}{4x} + \frac{16x}{4x}
\]

\[
= 3x^2 - 9x + 4
\]
Divide Polynomials
(Binomial Divisor)

Factor and simplify

Example:

\[
f(w) = 7w^2 + 3w - 4; \quad g(w) = w + 1
\]

\[
\frac{f(w)}{g(w)} = (7w^2 + 3w - 4) \div (w + 1)
\]

\[
= \frac{7w^2 + 3w - 4}{w + 1}
\]

\[
= \frac{(7w - 4)(w + 1)}{w + 1}
\]

\[
\frac{f(w)}{g(w)} = 7w - 4
\]
Prime Polynomial

Cannot be factored into a product of lesser degree polynomial factors

<table>
<thead>
<tr>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>$r$</td>
</tr>
<tr>
<td>$3t + 9$</td>
</tr>
<tr>
<td>$x^2 + 1$</td>
</tr>
<tr>
<td>$5y^2 - 4y + 3$</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Nonexample</th>
<th>Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x^2 - 4$</td>
<td>$(x + 2)(x - 2)$</td>
</tr>
<tr>
<td>$3x^2 - 3x - 6$</td>
<td>$3(x + 1)(x - 2)$</td>
</tr>
<tr>
<td>$x^3$</td>
<td>$x \cdot x^2$</td>
</tr>
</tbody>
</table>
Square Root

$\sqrt{x^2}$

radical symbol

radicand or argument

Simplify square root expressions.

Examples:

\[
\sqrt{9x^2} = \sqrt{3^2 \cdot x^2} = \sqrt{(3x)^2} = 3x
\]

\[
-\sqrt{(x - 3)^2} = -(x - 3) = -x + 3
\]

Squaring a number and taking a square root are inverse operations.
Cube Root

Simplify cube root expressions.

Examples:

\[
\sqrt[3]{64} = \sqrt[3]{4^3} = 4
\]

\[
\sqrt[3]{-27} = \sqrt[3]{(-3)^3} = -3
\]

\[
\sqrt[3]{x^3} = x
\]

Cubing a number and taking a cube root are inverse operations.
$n^{th}$ Root

\[ \sqrt[n]{x^m} = x^{\frac{m}{n}} \]

Examples:

\[
\frac{5}{5}\sqrt{64} = \frac{5}{5}\sqrt{4^3} = 4^{\frac{3}{5}}
\]

\[
\sqrt[6]{729x^9y^6} = 3x^{\frac{3}{2}}y
\]
Simplify Radical Expressions

Simplify radicals and combine like terms where possible.

Examples:

\[
\frac{1}{2} + 3\sqrt{-32} - \frac{11}{2} - \sqrt{8} = \frac{10}{2} - 2\sqrt{4} - 2\sqrt{2} = -5 - 2\sqrt{4} - 2\sqrt{2}
\]

\[
\sqrt{18} - 2\sqrt[3]{27} = 2\sqrt{3} - 2(3) = 2\sqrt{3} - 6
\]
Add and Subtract Radical Expressions

Add or subtract the numerical factors of the like radicals.

Examples:

\[2\sqrt{a} + 5\sqrt{a} = (2 + 5)\sqrt{a} = 7\sqrt{a}\]

\[6^3\sqrt{xy} - 4^3\sqrt{xy} - 3\sqrt{xy} = (6 - 4 - 1)^3\sqrt{xy} = ^3\sqrt{xy}\]

\[2^4\sqrt{c} + 7\sqrt{2} - 2^4\sqrt{c} = (2 - 2)^4\sqrt{c} + 7\sqrt{2} = 7\sqrt{2}\]
Product Property of Radicals

The nth root of a product equals the product of the nth roots.

\[ \sqrt[n]{ab} = \sqrt[n]{a} \cdot \sqrt[n]{b} \]

\(a \geq 0\) and \(b \geq 0\)

### Examples:

<table>
<thead>
<tr>
<th>(\sqrt{4x})</th>
<th>(\sqrt{4} \cdot \sqrt{x} = 2\sqrt{x})</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\sqrt{5a^3})</td>
<td>(\sqrt{5} \cdot \sqrt{a^3} = a\sqrt{5a})</td>
</tr>
<tr>
<td>(\sqrt[3]{16})</td>
<td>(\sqrt[3]{8 \cdot 2} = \sqrt[3]{8} \cdot \sqrt[3]{2} = 2\sqrt[3]{2})</td>
</tr>
</tbody>
</table>
Quotient Property of Radicals

The $n$th root of a quotient equals the quotient of the $n$th roots of the numerator and denominator.

$$\sqrt[n]{\frac{a}{b}} = \frac{\sqrt[n]{a}}{\sqrt[n]{b}}$$

$a \geq 0$ and $b > 0$

Examples:

$$\sqrt{\frac{5}{y^2}} = \frac{\sqrt{5}}{\sqrt{y^2}} = \frac{\sqrt{5}}{y}, \ y \neq 0$$

$$\frac{\sqrt{25}}{\sqrt{3}} = \frac{5}{\sqrt{3}} \cdot \frac{\sqrt{3}}{\sqrt{3}} = \frac{5\sqrt{3}}{3}$$
Zero Product Property

If \( ab = 0 \), then \( a = 0 \) or \( b = 0 \).

Example:

\[
(x + 3)(x - 4) = 0
\]

\[
(x + 3) = 0 \text{ or } (x - 4) = 0
\]

\[
x = -3 \text{ or } x = 4
\]

The solutions or roots of the polynomial equation are -3 and 4.
Solutions or Roots

\[ x^2 + 2x = 3 \]

Solve using the zero product property.

\[ x^2 + 2x - 3 = 0 \]
\[ (x + 3)(x - 1) = 0 \]
\[ x + 3 = 0 \quad \text{or} \quad x - 1 = 0 \]
\[ x = -3 \quad \text{or} \quad x = 1 \]

The solutions or roots of the polynomial equation are -3 and 1.
Zeros

The zeros of a function $f(x)$ are the values of $x$ where the function is equal to zero.

$$f(x) = x^2 + 2x - 3$$

Find $f(x) = 0$.

$$0 = x^2 + 2x - 3$$
$$0 = (x + 3)(x - 1)$$
$$x = -3 \text{ or } x = 1$$

The zeros of the function $f(x) = x^2 + 2x - 3$ are $-3$ and $1$ and are located at the $x$-intercepts $(-3,0)$ and $(1,0)$.

The zeros of a function are also the solutions or roots of the related equation.
**x-Intercepts**

The *x*-intercepts of a graph are located where the graph crosses the *x*-axis and where $f(x) = 0$.

$$f(x) = x^2 + 2x - 3$$

$$0 = (x + 3)(x - 1)$$

$$0 = x + 3 \text{ or } 0 = x - 1$$

$$x = -3 \text{ or } x = 1$$

The zeros are -3 and 1.

The *x*-intercepts are:

• -3 or (-3,0)
• 1 or (1,0)
Coordinate Plane

ordered pair \((x, y)\)
Literal Equation

A formula or equation that consists primarily of variables

Examples:

\[ Ax + By = C \]

\[ A = \frac{1}{2}bh \]

\[ V = lwh \]

\[ F = \frac{9}{5}C + 32 \]

\[ A = \pi r^2 \]
Vertical Line

\[ x = a \]

(where \( a \) can be any real number)

Example: \[ x = -4 \]

Vertical lines have undefined slope.
Horizontal Line

\[ y = c \]

(where \( c \) can be any real number)

Example: \( y = 6 \)

Horizontal lines have a slope of 0.
# Quadratic Equation

\[ a x^2 + bx + c = 0 \]

\[ a \neq 0 \]

**Example:** \( x^2 - 6x + 8 = 0 \)

<table>
<thead>
<tr>
<th>Solve by factoring</th>
<th>Solve by graphing</th>
</tr>
</thead>
<tbody>
<tr>
<td>( x^2 - 6x + 8 = 0 )</td>
<td>Graph the related function ( f(x) = x^2 - 6x + 8 ).</td>
</tr>
<tr>
<td>( (x - 2)(x - 4) = 0 )</td>
<td></td>
</tr>
<tr>
<td>( (x - 2) = 0 ) or ( (x - 4) = 0 )</td>
<td></td>
</tr>
<tr>
<td>( x = 2 ) or ( x = 4 )</td>
<td></td>
</tr>
</tbody>
</table>

Solutions (roots) to the equation are 2 and 4; the x-coordinates where the function crosses the x-axis.
# Quadratic Equation

(Number/Type of Solutions)

\[ ax^2 + bx + c = 0, \quad a \neq 0 \]

<table>
<thead>
<tr>
<th>Examples</th>
<th>Graph of the related function</th>
<th>Number and Type of Solutions/Roots</th>
</tr>
</thead>
<tbody>
<tr>
<td>( x^2 - x = 3 )</td>
<td><img src="image1" alt="Graph" /></td>
<td>2 distinct Real roots (crosses ( x )-axis twice)</td>
</tr>
<tr>
<td>( x^2 + 16 = 8x )</td>
<td><img src="image2" alt="Graph" /></td>
<td>1 distinct Real root with a multiplicity of two (double root) (touches ( x )-axis but does not cross)</td>
</tr>
<tr>
<td>( \frac{1}{2}x^2 - 2x + 3 = 0 )</td>
<td><img src="image3" alt="Graph" /></td>
<td>0 Real roots; 2 Complex roots</td>
</tr>
</tbody>
</table>
Inequality

An algebraic sentence comparing two quantities

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Meaning</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;</td>
<td>less than</td>
</tr>
<tr>
<td>≤</td>
<td>less than or equal to</td>
</tr>
<tr>
<td>&gt;</td>
<td>greater than</td>
</tr>
<tr>
<td>≥</td>
<td>greater than or equal to</td>
</tr>
<tr>
<td>≠</td>
<td>not equal to</td>
</tr>
</tbody>
</table>

Examples:

-10.5 > -9.9 – 1.2
8 > 3t + 2
x – 5y ≥ -12
r ≠ 3
Graph of an Inequality

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Examples</th>
<th>Graph</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; ; &gt;</td>
<td>$x &lt; 3$</td>
<td>![Graph of $x &lt; 3$]</td>
</tr>
<tr>
<td>≤ ; ≥</td>
<td>$-3 \geq y$</td>
<td>![Graph of $-3 \geq y$]</td>
</tr>
<tr>
<td>≠</td>
<td>$t \neq -2$</td>
<td>![Graph of $t \neq -2$]</td>
</tr>
</tbody>
</table>
Transitive Property of Inequality

<table>
<thead>
<tr>
<th>If</th>
<th>Then</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a &lt; b ) and ( b &lt; c )</td>
<td>( a &lt; c )</td>
</tr>
<tr>
<td>( a &gt; b ) and ( b &gt; c )</td>
<td>( a &gt; c )</td>
</tr>
</tbody>
</table>

Examples:

If \( 4x < 2y \) and \( 2y < 16 \), then \( 4x < 16 \).

If \( x > y - 1 \) and \( y - 1 > 3 \), then \( x > 3 \).
Addition/Subtraction Property of Inequality

<table>
<thead>
<tr>
<th>If</th>
<th>Then</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a &gt; b$</td>
<td>$a + c &gt; b + c$</td>
</tr>
<tr>
<td>$a \geq b$</td>
<td>$a + c \geq b + c$</td>
</tr>
<tr>
<td>$a &lt; b$</td>
<td>$a + c &lt; b + c$</td>
</tr>
<tr>
<td>$a \leq b$</td>
<td>$a + c \leq b + c$</td>
</tr>
</tbody>
</table>

Example:

\[
d - 1.9 \geq -8.7 \\
d - 1.9 + 1.9 \geq -8.7 + 1.9 \\
d \geq -6.8
\]
## Multiplication Property of Inequality

<table>
<thead>
<tr>
<th>If</th>
<th>Case</th>
<th>Then</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a &lt; b$</td>
<td>$c &gt; 0$, positive</td>
<td>$ac &lt; bc$</td>
</tr>
<tr>
<td>$a &gt; b$</td>
<td>$c &gt; 0$, positive</td>
<td>$ac &gt; bc$</td>
</tr>
<tr>
<td>$a &lt; b$</td>
<td>$c &lt; 0$, negative</td>
<td>$ac &gt; bc$</td>
</tr>
<tr>
<td>$a &gt; b$</td>
<td>$c &lt; 0$, negative</td>
<td>$ac &lt; bc$</td>
</tr>
</tbody>
</table>

**Example:** If $c = -2$

\[
\begin{align*}
5 & > -3 \\
5(-2) & \leq -3(-2) \\
-10 & < 6
\end{align*}
\]
## Division Property of Inequality

<table>
<thead>
<tr>
<th>If</th>
<th>Case</th>
<th>Then</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a &lt; b$</td>
<td>$c &gt; 0$, positive</td>
<td>$\frac{a}{c} &lt; \frac{b}{c}$</td>
</tr>
<tr>
<td>$a &gt; b$</td>
<td>$c &gt; 0$, positive</td>
<td>$\frac{a}{c} &gt; \frac{b}{c}$</td>
</tr>
<tr>
<td>$a &lt; b$</td>
<td>$c &lt; 0$, negative</td>
<td>$\frac{a}{c} &gt; \frac{b}{c}$</td>
</tr>
<tr>
<td>$a &gt; b$</td>
<td>$c &lt; 0$, negative</td>
<td>$\frac{a}{c} &lt; \frac{b}{c}$</td>
</tr>
</tbody>
</table>

### Example: If $c = -4$

\[
\begin{align*}
-90 & \geq -4t \\
\frac{-90}{-4} & \leq \frac{-4t}{-4} \\
22.5 & \leq t
\end{align*}
\]
# Absolute Value Inequalities

<table>
<thead>
<tr>
<th>Absolute Value Inequality</th>
<th>Equivalent Compound Inequality</th>
</tr>
</thead>
<tbody>
<tr>
<td>$</td>
<td>x</td>
</tr>
<tr>
<td>$</td>
<td>x</td>
</tr>
</tbody>
</table>

Example:

$$|2x - 5| \geq 8$$

$$2x - 5 \leq -8 \text{ or } 2x - 5 \geq 8$$

$$2x \leq -3 \text{ or } 2x \geq 13$$

$$x \leq -\frac{3}{2} \text{ or } x \geq \frac{13}{2}$$
Linear Equation
(Standard Form)

\[ Ax + By = C \]

(A, B and C are integers; A and B cannot both equal zero)

Example:

-2x + y = -3

The graph of the linear equation is a straight line and represents all solutions \((x, y)\) of the equation.
Linear Equation
(Slope-Intercept Form)

\[ y = mx + b \]

(slope is \( m \) and \( y \)-intercept is \( b \))

Example: \( y = \frac{-4}{3}x + 5 \)

\( m = \frac{-4}{3} \)

\( b = 5 \)
Linear Equation
(Point-Slope Form)

\[ y - y_1 = m(x - x_1) \]
where \( m \) is the slope and \((x_1, y_1)\) is the point

Example:
Write an equation for the line that passes through the point \((-4,1)\) and has a slope of 2.

\[
\begin{align*}
y - 1 &= 2(x - -4) \\
y - 1 &= 2(x + 4) \\
y &= 2x + 9
\end{align*}
\]
# Equivalent Forms of a Linear Equation

<table>
<thead>
<tr>
<th>Forms of a Linear Equation</th>
<th>$3y = 6 - 4x$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slope-Intercept</td>
<td>$y = -\frac{4}{3}x + 2$</td>
</tr>
<tr>
<td>Point-Slope</td>
<td>$y - (-2) = -\frac{4}{3}(x - 3)$</td>
</tr>
<tr>
<td>Standard</td>
<td>$4x + 3y = 6$</td>
</tr>
</tbody>
</table>
Slope

A number that represents the rate of change in \( y \) for a unit change in \( x \)

The slope indicates the steepness of a line.

\[
\text{Slope} = \frac{2}{3}
\]
Slope Formula

The ratio of vertical change to horizontal change

\[ \text{slope} = m = \frac{\text{change in } y}{\text{change in } x} = \frac{y_2 - y_1}{x_2 - x_1} \]
Slopes of Lines

Line $p$ has a **positive** slope.

Line $n$ has a **negative** slope.

Vertical line $s$ has an **undefined** slope.

Horizontal line $t$ has a **zero** slope.
Perpendicular Lines

Lines that intersect to form a right angle

Perpendicular lines (not parallel to either of the axes) have slopes whose product is -1.

Example:
The slope of line $n = -2$. The slope of line $p = \frac{1}{2}$.

$-2 \cdot \frac{1}{2} = -1$, therefore, $n$ is perpendicular to $p$. 
Parallel Lines

Lines in the same plane that do not intersect are parallel.

Parallel lines have the same slopes.

Example:

The slope of line $a = -2$.
The slope of line $b = -2$.

$-2 = -2$, therefore, $a$ is parallel to $b$. 
## Mathematical Notation

<table>
<thead>
<tr>
<th>Equation or Inequality</th>
<th>Set Notation</th>
<th>Interval Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 &lt; x ≤ 3</td>
<td>{x</td>
<td>0 &lt; x ≤ 3}</td>
</tr>
<tr>
<td>y ≥ -5</td>
<td>{y: y ≥ -5}</td>
<td>[-5, +∞)</td>
</tr>
<tr>
<td>z &lt; -1 or z ≥ 3</td>
<td>{z</td>
<td>z &lt; -1 or z ≥ 3}</td>
</tr>
<tr>
<td>x &lt; 5 or x &gt; 5</td>
<td>{x: x ≠ 5}</td>
<td>(-∞, 5) U (5, +∞)</td>
</tr>
<tr>
<td>Empty (null) set (∅)</td>
<td>{}</td>
<td>(∅)</td>
</tr>
<tr>
<td>All Real Numbers (\mathbb{R})</td>
<td>({x : x \in \mathbb{R}})</td>
<td>(−∞, ∞)</td>
</tr>
</tbody>
</table>
System of Linear Equations
(Graphing)

\[
\begin{align*}
-x + 2y &= 3 \\
2x + y &= 4
\end{align*}
\]

The solution, \((1, 2)\), is the only ordered pair that satisfies both equations (the point of intersection).
System of Linear Equations (Substitution)

\[
\begin{align*}
    x + 4y &= 17 \\
    y &= x - 2
\end{align*}
\]

Substitute \(x - 2\) for \(y\) in the first equation.

\[
x + 4(x - 2) = 17
\]

\[
x = 5
\]

Now substitute 5 for \(x\) in the second equation.

\[
y = 5 - 2
\]

\[
y = 3
\]

The solution to the linear system is (5, 3), the ordered pair that satisfies both equations.
System of Linear Equations
(Elimination)

\[
\begin{align*}
-5x - 6y &= 8 \\
5x + 2y &= 4
\end{align*}
\]

Add or subtract the equations to eliminate one variable.

\[
\begin{align*}
-5x - 6y &= 8 \\
+ 5x + 2y &= 4 \\
\hline
-4y &= 12 \\
y &= -3
\end{align*}
\]

Now substitute -3 for \(y\) in either original equation to find the value of \(x\), the eliminated variable.

\[
\begin{align*}
-5x - 6(-3) &= 8 \\
-5x + 18 &= 8 \\
-5x &= -10 \\
x &= 2
\end{align*}
\]

The solution to the linear system is \((2,-3)\), the ordered pair that satisfies both equations.
# System of Linear Equations

(Number of Solutions)

<table>
<thead>
<tr>
<th>Number of Solutions</th>
<th>Slopes and y-intercepts</th>
<th>Graph</th>
</tr>
</thead>
<tbody>
<tr>
<td>One solution</td>
<td>Different slopes</td>
<td><img src="image1.png" alt="Graph" /></td>
</tr>
<tr>
<td>No solution</td>
<td>Same slope and different - intercepts</td>
<td><img src="image2.png" alt="Graph" /></td>
</tr>
<tr>
<td>Infinitely many solutions</td>
<td>Same slope and same y-intercepts</td>
<td><img src="image3.png" alt="Graph" /></td>
</tr>
</tbody>
</table>
System of Equations (Linear – Quadratic)

\[
\begin{align*}
y &= x + 1 \\
y &= x^2 - 1
\end{align*}
\]

The solutions, \((-1,0)\) and \((2,3)\), are the only ordered pairs that satisfy both equations (the points of intersection).
Graphing Linear Inequalities

<table>
<thead>
<tr>
<th>Example</th>
<th>Graph</th>
</tr>
</thead>
<tbody>
<tr>
<td>$y \leq x + 2$</td>
<td>![Graph of $y \leq x + 2$]</td>
</tr>
<tr>
<td>$y &gt; -x - 1$</td>
<td>![Graph of $y &gt; -x - 1$]</td>
</tr>
</tbody>
</table>

The graph of the solution of a linear inequality is a half-plane bounded by the graph of its related linear equation. Points on the boundary are included unless the inequality contains only $<$ or $>$. 
System of Linear Inequalities

Solve by graphing:

\[ \begin{align*}
  y &> x - 3 \\
  y &\leq -2x + 3
\end{align*} \]

The solution region contains all ordered pairs that are solutions to both inequalities in the system.

(-1,1) is one solution to the system located in the solution region.
Dependent and Independent Variable

\( x, \) independent variable
(input values or domain set)

\( y, \) dependent variable
(output values or range set)

Example:

\[ y = 2x + 7 \]
Dependent and Independent Variable (Application)

Determine the distance a car will travel going 55 mph.

\[ d = 55h \]

<table>
<thead>
<tr>
<th>( h )</th>
<th>( d )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>55</td>
</tr>
<tr>
<td>2</td>
<td>110</td>
</tr>
<tr>
<td>3</td>
<td>165</td>
</tr>
</tbody>
</table>

Independent variable: \( h \)  
Dependent variable: \( d \)
Graph of a Quadratic Equation

\[ y = ax^2 + bx + c \]

\( a \neq 0 \)

Example:

\[ y = x^2 + 2x - 3 \]

The graph of the quadratic equation is a curve (parabola) with one line of symmetry and one vertex.
Vertex of a Quadratic Function

For a given quadratic \( y = ax^2 + bx + c \), the vertex \((h, k)\) is found by computing

\[
h = \frac{-b}{2a}
\]

and then evaluating \( y \) at \( h \) to find \( k \).

Example: \( y = x^2 + 2x - 8 \)

\[
h = \frac{-b}{2a} = \frac{-2}{2(1)} = -1
\]

\[
k = (-1)^2 + 2(-1) - 8
\]

\[
= -9
\]

The vertex is \((-1, -9)\).

Line of symmetry is \( x = h \).

\[
x = -1
\]
Quadratic Formula

Used to find the solutions to any quadratic equation of the form,

\[ f(x) = ax^2 + bx + c \]

\[ x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} \]

Example: \( g(x) = 2x^2 - 4x - 3 \)

\[ x = \frac{-(-4) \pm \sqrt{(-4)^2 - 4(2)(-3)}}{2(2)} \]

\[ x = \frac{2 + \sqrt{10}}{2}, \frac{2 - \sqrt{10}}{2} \]
Relation
A set of ordered pairs

Examples:

<table>
<thead>
<tr>
<th>$x$</th>
<th>$y$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$-3$</td>
<td>$4$</td>
</tr>
<tr>
<td>$0$</td>
<td>$0$</td>
</tr>
<tr>
<td>$1$</td>
<td>$-6$</td>
</tr>
<tr>
<td>$2$</td>
<td>$2$</td>
</tr>
<tr>
<td>$5$</td>
<td>$-1$</td>
</tr>
</tbody>
</table>

Example 1

$\{(0,4), (0,3), (0,2), (0,1)\}$

Example 3
Function
(Definition)
A relationship between two quantities in which every input corresponds to exactly one output.

A relation is a function if and only if each element in the domain is paired with a unique element of the range.
Functions
(Examples)

Example 1

<table>
<thead>
<tr>
<th>$x$</th>
<th>$y$</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>-1</td>
<td>2</td>
</tr>
</tbody>
</table>

Example 2

$\{(3,4), (0,3), (1,2), (4,6)\}$

Example 3

Example 4
Domain

the set of all possible values of the independent variable

Examples:

\[ f(x) = x^2 \]

The domain of \( f(x) \) is all real numbers.

\[ g(x) = \begin{cases} 
\frac{1}{x} & \text{if } x < -1 \\
|x| & \text{if } x \geq -1
\end{cases} \]

The domain of \( g(x) \) is all real numbers.
Range

the set of all possible values of the dependent variable

Examples:

The range of $g(x)$ is all real numbers greater than -1.

The range of $f(x)$ is all real numbers greater than or equal to zero.
Increasing/Decreasing
A function can be described as increasing, decreasing, or constant over a specified interval or the entire domain.

Examples:

- **f(x)** is increasing over \( \{x| -\infty < x < 0\} \) because the values of \( f(x) \) increase as the values of \( x \) increase.
- **f(x)** is decreasing over \( \{x| 0 < x < +\infty\} \) because the values of \( f(x) \) decrease as the values of \( x \) increase.
- **f(x)** is constant over the entire domain because the values of \( f(x) \) remain constant as the values of \( x \) increase.
Extrema

The largest (maximum) and smallest (minimum) value of a function, either within a given open interval (the relative or local extrema) or on the entire domain of a function (the absolute or global extrema)

Example:

- A function, $f$, has an absolute maximum located at $x = a$ if $f(a)$ is the largest value of $f$ over its domain.
- A function, $f$, has a relative maximum located at $x = a$ over some open interval of the domain if $f(a)$ is the largest value of $f$ on the interval.
- A function, $f$, has an absolute minimum located at $x = a$ if $f(a)$ is the smallest value of $f$ over its domain.
- A function, $f$, has a relative minimum located at $x = a$ over some open interval of the domain if $f(a)$ is the smallest value of $f$ on the interval.
End Behavior

The value of a function as x approaches positive or negative infinity

Examples:

As the values of x approach $-\infty$, $f(x)$ approaches $+\infty$.

As the values of x approach $+\infty$, $f(x)$ approaches $-\infty$.

As the values of x approach $-\infty$, $f(x)$ approaches 0.

As the values of x approach $+\infty$, $f(x)$ approaches $+\infty$. 
Function Notation

\[ f(x) \]

\[ f(x) \] is read “the value of \( f \) at \( x \)” or “\( f \) of \( x \)”

Example:

\[ f(x) = -3x + 5, \text{ find } f(2). \]
\[ f(2) = -3(2) + 5 \]
\[ f(2) = -6 + 5 \]
\[ f(2) = -1 \]

Letters other than \( f \) can be used to name functions, e.g., \( g(x) \) and \( h(x) \)
Parent Functions
(Linear, Quadratic)

Linear
\[ f(x) = x \]

Quadratic
\[ f(x) = x^2 \]
Parent Functions
(Absolute Value, Square Root)

Absolute Value

\[ f(x) = |x| \]

Square Root

\[ f(x) = \sqrt{x} \]
Parent Functions
(Cubic, Cube Root)

Cubic

\[ f(x) = x^3 \]

Cube Root

\[ f(x) = \sqrt[3]{x} \]
Parent Functions (Rational)

\[ f(x) = \frac{1}{x} \]

\[ f(x) = \frac{1}{x^2} \]
Parent Functions
(Exponential, Logarithmic)

Exponential
\[ f(x) = b^x \]
\[ b > 1 \]

Logarithmic
\[ f(x) = \log_b x \]
\[ b > 1 \]
Transformations of Parent Functions (Translation)

Parent functions can be transformed to create other members in a family of graphs.

<table>
<thead>
<tr>
<th>Translations</th>
<th>( g(x) = f(x) + k ) is the graph of ( f(x) ) translated vertically –</th>
<th>( k ) units up when ( k &gt; 0 ).</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( g(x) = f(x - h) ) is the graph of ( f(x) ) translated horizontally –</td>
<td>( h ) units right when ( h &gt; 0 ).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>( h ) units left when ( h &lt; 0 ).</td>
</tr>
</tbody>
</table>
Transformations of Parent Functions (Reflection)

Parent functions can be transformed to create other members in a family of graphs.

<table>
<thead>
<tr>
<th>Reflections</th>
<th>$g(x) = -f(x)$ is the graph of $f(x)$ – reflected over the $x$-axis.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$g(x) = f(-x)$ is the graph of $f(x)$ – reflected over the $y$-axis.</td>
</tr>
</tbody>
</table>
Transformations of Parent Functions  
(Dilations)

Parent functions can be transformed to create other members in a family of graphs.

<table>
<thead>
<tr>
<th>Dilations</th>
</tr>
</thead>
<tbody>
<tr>
<td>$g(x) = a \cdot f(x)$ is the graph of $f(x)$ –</td>
</tr>
<tr>
<td><strong>vertical dilation</strong> (stretch) if $a &gt; 1$. STRETCHES AWAY from X-AXIS</td>
</tr>
<tr>
<td><strong>vertical dilation</strong> (compression) if $0 &lt; a &lt; 1$. COMPRESSES TOWARD the X-AXIS</td>
</tr>
<tr>
<td>$g(x) = f(ax)$ is the graph of $f(x)$ –</td>
</tr>
<tr>
<td><strong>horizontal dilation</strong> (compression) if $a &gt; 1$. COMPRESSES TOWARD the Y-AXIS</td>
</tr>
<tr>
<td><strong>horizontal dilation</strong> (stretch) if $0 &lt; a &lt; 1$. STRETCHES AWAY FROM the Y-AXIS</td>
</tr>
</tbody>
</table>
Linear Function
(Transformational Graphing)

Translation
\[ g(x) = x + b \]

Examples:
\[ f(x) = x \]
\[ t(x) = x + 4 \]
\[ h(x) = x - 2 \]

Vertical translation of the parent function,
\[ f(x) = x \]
Linear Function
(Transformational Graphing)

Vertical Dilation \((m>0)\)

\[ g(x) = mx \]

Examples:
\[
\begin{align*}
  f(x) &= x \\
  t(x) &= 2x \\
  h(x) &= \frac{1}{2}x
\end{align*}
\]

Vertical dilation (stretch or compression) of the parent function, \(f(x) = x\)
Linear Function
(Transformational Graphing)
Vertical Dilation/Reflection \((m<0)\)

\[ g(x) = mx \]

Examples:
\[
\begin{align*}
f(x) &= x \\
t(x) &= -x \\
h(x) &= -3x \\
d(x) &= \frac{1}{3}x \\
\end{align*}
\]

Vertical dilation (stretch or compression) with a reflection of \(f(x) = x\)
Quadratic Function
(Transformational Graphing)
Vertical Translation

$h(x) = x^2 + c$

Examples:

$f(x) = x^2$
$g(x) = x^2 + 2$
$t(x) = x^2 - 3$

Vertical translation of $f(x) = x^2$
**Quadratic Function**  
(Transformational Graphing)  

**Vertical Dilation** ($a > 0$)  

$$ f(x) = x^2 $$  
$$ g(x) = a \cdot f(x) $$

**Examples:**

$$ f(x) = x^2 $$  
$$ g(x) = 2 \cdot f(x) $$  
$$ g(x) = 2x^2 $$  
$$ t(x) = \frac{1}{3} \cdot f(x) $$  
$$ t(x) = \frac{1}{3}x^2 $$

Vertical dilation (stretch or compression) of  
$$ f(x) = x^2 $$
Quadratic Function
(Transformational Graphing)

**Horizontal Dilation** \((a>0)\)

\[ f(x) = x^2 \]
\[ g(x) = f(b \cdot x) \]

**Examples:**

\[ f(x) = x^2 \]
\[ h(x) = f(2 \cdot x) \]
\[ h(x) = (2x)^2 = 4x^2 \]
\[ r(x) = f\left(\frac{1}{2} \cdot x\right) \]
\[ r(x) = \left(\frac{1}{2} x\right)^2 = \frac{1}{4} x^2 \]

Horizontal dilation (**stretch or compression**) of \(f(x) = x^2\)
Quadratic Function  
(Transformational Graphing) 
Vertical Dilation/Reflection \((a<0)\) 
\[ h(x) = a x^2 \]

Examples: 
\[ f(x) = x^2 \]
\[ g(x) = -2x^2 \]
\[ t(x) = - \frac{1}{3}x^2 \]

Vertical dilation (stretch or compression) with a reflection of \(f(x) = x^2\)
Quadratic Function
(Transformational Graphing)

Horizontal Translation

\[ h(x) = (x + c)^2 \]

Examples:
\[ f(x) = x^2 \]
\[ g(x) = (x + 2)^2 \]
\[ t(x) = (x - 3)^2 \]

Horizontal translation of \( f(x) = x^2 \)
Multiple Representations of Functions

Equation

\[ y = |x| \]

Table

<table>
<thead>
<tr>
<th>( x )</th>
<th>( y )</th>
</tr>
</thead>
<tbody>
<tr>
<td>-2</td>
<td>2</td>
</tr>
<tr>
<td>-1</td>
<td>1</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Graph

Words

\textit{y equals the absolute value of } x
Inverse of a Function

The graph of an inverse function is the reflection of the original graph over the line, \( y = x \).

Example:

\[ f(x) = \sqrt{x} \]

Domain is restricted to \( x \geq 0 \).

\[ f^{-1}(x) = x^2 \]

Domain is restricted to \( x \geq 0 \).

Restrictions on the domain may be necessary to ensure the inverse relation is also a function.
Continuity

da function that is continuous at every point in its domain

Example:
Discontinuity
(e.g., asymptotes)

Example:

\[ f(x) = \frac{1}{x+2} \]

\( f(-2) \) is not defined, so \( f(x) \) is discontinuous.
Discontinuity
(e.g., removable or point)

Example:

\[ f(x) = \frac{x^2 + x - 6}{x - 2} \]

\( f(2) \) is not defined.

<table>
<thead>
<tr>
<th>( x )</th>
<th>( f(x) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>-3</td>
<td>0</td>
</tr>
<tr>
<td>-2</td>
<td>1</td>
</tr>
<tr>
<td>-1</td>
<td>2</td>
</tr>
<tr>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>error</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>

\[ f(x) = \frac{x^2 + x - 6}{x - 2} = \frac{(x + 3)(x - 2)}{x - 2} = x + 3, \; x \neq 2 \]
Discontinuity
(e.g., removable or point)

Example:
\( f(-2) \) is not defined
Direct Variation

\[ y = kx \quad \text{or} \quad k = \frac{y}{x} \]

constant of variation, \( k \neq 0 \)

Example:
\[ y = 3x \quad \text{or} \quad 3 = \frac{y}{x} \]

<table>
<thead>
<tr>
<th>( x )</th>
<th>( y )</th>
</tr>
</thead>
<tbody>
<tr>
<td>-2</td>
<td>-6</td>
</tr>
<tr>
<td>-1</td>
<td>-3</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
</tr>
</tbody>
</table>

\[ 3 = \frac{-6}{-2} = \frac{-3}{-1} = \frac{3}{1} = \frac{6}{2} \]

The graph of all points describing a direct variation is a line passing through the origin.
Inverse Variation

\[ y = \frac{k}{x} \quad \text{or} \quad k = xy \]

constant of variation, \( k \neq 0 \)

Example:

\[ y = \frac{3}{x} \quad \text{or} \quad xy = 3 \]

The graph of all points describing an inverse variation relationship are two curves that are reflections of each other.
Joint Variation

\[ z = kxy \quad \text{or} \quad k = \frac{z}{xy} \]

constant of variation, \( k \neq 0 \)

Examples:

Area of a triangle varies jointly as its length of the base, \( b \), and its height, \( h \).

\[ A = \frac{1}{2}bh \]

For Company ABC, the shipping cost in dollars, \( C \), for a package varies jointly as its weight, \( w \), and size, \( s \).

\[ C = 2.47ws \]
Arithmetic Sequence

A sequence of numbers that has a common difference between every two consecutive terms

Example: -4, 1, 6, 11, 16 ...

<table>
<thead>
<tr>
<th>Position</th>
<th>Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>-4</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>11</td>
</tr>
<tr>
<td>5</td>
<td>16</td>
</tr>
</tbody>
</table>

The common difference is the slope of the line of best fit.
Geometric Sequence

A sequence of numbers in which each term after the first term is obtained by multiplying the previous term by a constant ratio.

Example: 4, 2, 1, 0.5, 0.25 ...

<table>
<thead>
<tr>
<th>Position</th>
<th>Term</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>0.5</td>
</tr>
<tr>
<td>5</td>
<td>0.25</td>
</tr>
</tbody>
</table>
Fundamental Counting Principle

If there are $m$ ways for one event to occur and $n$ ways for a second event to occur, then there are $m \cdot n$ ways for both events to occur.

Example:
How many outfits can Joey make using 3 pairs of pants and 4 shirts?

$3 \cdot 4 = 12$ outfits
Permutation

An ordered arrangement of a group of objects

Both arrangements are included in possible outcomes.

Example:

5 people to fill 3 chairs (order matters). How many ways can the chairs be filled?

1\textsuperscript{st} chair – 5 people to choose from
2\textsuperscript{nd} chair – 4 people to choose from
3\textsuperscript{rd} chair – 3 people to choose from

# possible arrangements are 5 \cdot 4 \cdot 3 = 60
Permutation

(Formula)

To calculate the number of permutations

\[ n^P_r = \frac{n!}{(n-r)!} \]

\( n \) and \( r \) are positive integers, \( n \geq r \), and \( n \) is the total number of elements in the set and \( r \) is the number to be ordered.

Example: There are 30 cars in a car race. The first-, second-, and third-place finishers win a prize. How many different arrangements (order matters) of the first three positions are possible?

\[ 30^P_3 = \frac{30!}{(30-3)!} = \frac{30!}{27!} = 24360 \]
Combination

The number of possible ways to select or arrange objects when there is no repetition and order does not matter

Example: If Sam chooses 2 selections from triangle, square, circle and pentagon. How many different combinations are possible?

Order (position) does not matter so \( \triangle \bigcirc \) is the same as \( \bigcirc \triangle \)

There are 6 possible combinations.
Combination
(Formula)
To calculate the number of possible combinations using a formula

\[ n^C_r = \frac{n!}{r!(n - r)!} \]

\( n \) and \( r \) are positive integers, \( n \geq r \), and \( n \) is the total number of elements in the set and \( r \) is the number to be ordered.

Example: In a class of 24 students, how many ways can a group of 4 students be arranged (order does not matter)?

\[
24^C_4 = \frac{24!}{4!(24-4)!} = 10,626
\]
## Statistics Notation

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>$x_i$</td>
<td>$i^{th}$ element in a data set</td>
</tr>
<tr>
<td>$\mu$</td>
<td>mean of the data set</td>
</tr>
<tr>
<td>$\sigma^2$</td>
<td>variance of the data set</td>
</tr>
<tr>
<td>$\sigma$</td>
<td>standard deviation of the data set</td>
</tr>
<tr>
<td>$n$</td>
<td>number of elements in the data set</td>
</tr>
</tbody>
</table>
Mean

A measure of central tendency

Example:
Find the mean of the given data set.
Data set: 0, 2, 3, 7, 8

Balance Point

Numerical Average

\[ \mu = \frac{0 + 2 + 3 + 7 + 8}{5} = \frac{20}{5} = 4 \]
Median

A measure of central tendency

Examples:
Find the median of the given data sets.

Data set: 6, 7, 8, 9, 9
The median is 8.

Data set: 5, 6, 8, 9, 11, 12
The median is 8.5.
## Mode

A measure of central tendency

### Examples:

<table>
<thead>
<tr>
<th>Data Sets</th>
<th>Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>3, 4, 6, 6, 6, 6, 10, 11, 14</td>
<td>6</td>
</tr>
<tr>
<td>0, 3, 4, 5, 6, 7, 9, 10</td>
<td>none</td>
</tr>
<tr>
<td>5.2, 5.2, 5.2, 5.6, 5.8, 5.9, 6.0</td>
<td>5.2</td>
</tr>
<tr>
<td>1, 1, 2, 5, 6, 7, 7, 9, 11, 12</td>
<td>1, 7 bimodal</td>
</tr>
</tbody>
</table>
Summation

This expression means sum the values of $x$, starting at $x_1$ and ending at $x_n$.

$$\sum_{i=1}^{n} x_i = x_1 + x_2 + x_3 + \ldots + x_n$$

Example: Given the data set \{3, 4, 5, 5, 10, 17\}

$$\sum_{i=1}^{6} x_i = 3 + 4 + 5 + 5 + 10 + 17 = 44$$
Variance

A measure of the spread of a data set

\[
\text{variance}(\sigma^2) = \frac{\sum_{i=1}^{n} (x_i - \mu)^2}{n}
\]

The mean of the squares of the differences between each element and the mean of the data set

Note: The square root of the variance is equal to the standard deviation.
Standard Deviation
(Definition)

A measure of the spread of a data set

\[
\text{standard deviation } (\sigma) = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \mu)^2}{n}}
\]

The square root of the mean of the squares of the differences between each element and the mean of the data set or the square root of the variance
Standard Deviation (Graphic)

A measure of the spread of a data set

standard deviation (σ) = \sqrt{\frac{\sum_{i=1}^{n} (x_i - \mu)^2}{n}}

Comparison of two distributions with same mean (μ) and different standard deviation (σ) values
**z-Score**

**(Definition)**
The number of standard deviations an element is away from the mean

\[ z - \text{score} (z) = \frac{x - \mu}{\sigma} \]

where \( x \) is an element of the data set, \( \mu \) is the mean of the data set, and \( \sigma \) is the standard deviation of the data set.

**Example:** Data set A has a mean of 83 and a standard deviation of 9.74. What is the z-score for the element 91 in data set A?

\[ z = \frac{91-83}{9.74} = 0.821 \]
z-Score
(Graphic)

The number of standard deviations an element is from the mean

\[ z \text{-score} (z) = \frac{x - \mu}{\sigma} \]
Empirical Rule

Normal Distribution Empirical Rule (68-95-99.7 rule)—approximate percentage of element distribution
Elements within One Standard Deviation ($\sigma$) of the Mean ($\mu$) (Graphic)

- Elements within one standard deviation of the mean:
  - $\mu - \sigma$, $z = -1$
  - $\mu + \sigma$, $z = 1$

- Mean $\mu = 12$
- Standard Deviation $\sigma = 3.49$
Scatterplot

Graphical representation of the relationship between two numerical sets of data
Positive Linear Relationship (Correlation)

In general, a relationship where the dependent (y) values increase as independent values (x) increase.
Negative Linear Relationship (Correlation)

In general, a relationship where the dependent \((y)\) values decrease as independent \((x)\) values increase.
No Correlation

No relationship between the dependent ($y$) values and independent ($x$) values.
Curve of Best Fit
(Linear)

Equation of Curve of Best Fit

\[ y = 11.731x + 193.85 \]
Curve of Best Fit
(Quadratic)

Equation of Curve of Best Fit

\[ y = -0.01x^2 + 0.7x + 6 \]
Curve of Best Fit
(Exponential)

Bacteria Growth Over Time

Equation of Curve of Best Fit

\[ y = 20.512 \cdot (1.923)^x \]
Outlier Data
(Graphic)

Wingspan vs. Height

Gas Mileage for Gasoline-fueled Cars

Outlier

Outlier