



Pre-Calculus

Functions

A **function** is a relation in which each element of the domain (independent variable) is paired with only one element of the range (dependent variable). In many cases x is the independent variable and y or $f(x)$ is the dependent variable. In this guide y and $f(x)$ are interchangeable.



A function



Not a function



A function



A function

A relation can be tested to see whether it is a function by the vertical line test. Draw a vertical line through any graph, and if it hits an x -value more than once, it is not a function.

Linear Functions

A function is a linear function if it can be written in the form $f(x) = mx + b$ or $y = mx + b$ where m is the slope and b is the y -intercept.

EX: $f(x) = 4x - 1$ is a linear function. The slope is $\frac{4}{1}$ (rise over run), and the y -intercept is -1 .

The standard form of a linear function is $0 = Ax + By + C$. The slope is $m = -\frac{A}{B}$, and the y -intercept is $-\frac{C}{B}$.

The zeros of a function are found by setting y to 0 and solving for x .

EX: Find the zeros of $f(x) = 4x - 1$.

$$0 = 4x - 1 \quad -1 = 4x \quad -\frac{1}{4} = x$$

Polynomial Functions

A function is a polynomial function if it can be written in the form $f(x) = ax^n + bx^{n-1} + cx^{n-2} + \dots + dx + e$.

The greatest power of a polynomial with one variable is called its **degree**.
When the degree of the function is an odd integer, there is at least one real zero.

When the degree is an even integer, there may be no real zeros.

Both types can have imaginary roots of the form $a + bi$.

EX: $f(x) = 2x^4 + x^3 + x + 10$ has a degree of 4. There are four roots to this polynomial.

EX: $f(x) = 2x^3 + x^2 - 2x + 3$ has a degree of 3. This function has one real zero at $x = -1.17$ and two non-real roots. (see graph)

EX: $f(x) = x^2 + 1$ has a degree of 2. This function has two non-real roots. Its graph does not cross the x -axis.


 $x = -1.17213$
 $y = 0.00086$

Quadratic Functions

One commonly studied polynomial function is a quadratic function.

A quadratic function takes the form $f(x) = ax^2 + bx + c$.

The graph of a quadratic equation is a **parabola**.

Some parabolas represent quadratic equations but not quadratic functions. (see graph)

Quadratic equations can have zero, one, or two solutions.

The vertex of a parabola is its **critical point**. This is where the graph changes from increasing to decreasing or from decreasing to increasing.

The quadratic formula $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ can be used to find the roots of all quadratic equations.

The value under the square root symbol is the **discriminant**. It tells the type of roots of a quadratic equation.

$b^2 - 4ac > 0$, two distinct real roots

$b^2 - 4ac = 0$, exactly one real root

$b^2 - 4ac < 0$, no real roots (two distinct imaginary roots)

EX: Find the roots of $f(x) = x^2 - 4x + 1$

The discriminant $b^2 - 4ac$ is $(-4)^2 - 4(1)(1) > 0$, so there are two real roots.

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-(-4) \pm \sqrt{4^2 - 4(1)(1)}}{2(1)}$$

$$x = 3.732 \text{ and } x = 0.267$$

EX: Find the number and type of the roots of $f(x) = 2x^2 + 2x + 1$

The discriminant is less than 0, so there are two imaginary roots. A graph of this function does not cross the x -axis.



EX: Find the number and type of the roots of $f(x) = x^2 + 2x + 1$. The discriminant is 0, so there is one real root. A graph of this function intersects the x -axis in one place, at -1 .

Rational Functions

A function is a rational function if it can be written in the form $f(x) = \frac{g(x)}{h(x)}$.

EX: $f(x) = \frac{x}{x+3}$, $f(x) = \frac{2}{x}$, and $f(x) = \frac{1}{x-2} + 3$ are rational functions.

The parent function for all rational functions is $f(x) = \frac{1}{x}$.

The graph of the parent rational function consists of two parts, one in quadrant I and one in quadrant III.

The branches of rational functions approach asymptotes.


A rational function with asymptotes at $x = 0$ & $y = 0$.

Operations of Functions

Sum: $(f + g)(x) = f(x) + g(x)$

Difference: $(f - g)(x) = f(x) - g(x)$

Product: $(f \cdot g)(x) = f(x) \cdot g(x)$

Quotient: $\left(\frac{f}{g}\right)(x) = \frac{f(x)}{g(x)}$, $g(x) \neq 0$

EX: Given $f(x) = x + 2$ and $g(x) = \frac{x}{x-4}$

Find the difference: $(f - g)(x) = x + 2 - \frac{x}{x-4} = \frac{(x+2)(x-4) - x}{x-4} = \frac{x^2 - 3x - 8}{x-4}$, $x \neq 4$

Find the product: $(f \cdot g)(x) = (x + 2) \cdot \left(\frac{x}{x-4}\right) = \frac{x^2 + 2x}{x-4}$, $x \neq 4$

Find the quotient: $\left(\frac{f}{g}\right)(x) = \frac{x+2}{\frac{x}{x-4}} = (x+2) \cdot \left(\frac{x-4}{x}\right) = \frac{x^2 - 2x - 8}{x}$, $x \neq 0$

Composition of Functions

$(f \circ g)(x) = f(g(x))$

EX: Given $f(x) = x + 2$ and $g(x) = \frac{x}{x-4}$, find $(f \circ g)(x)$

$x + 2$ becomes $\left(\frac{x}{x-4}\right) + 2 = \frac{x}{x-4} + \frac{2(x-4)}{x-4} = \frac{x + 2x - 8}{x-4} = \frac{3x - 8}{x-4}$, $x \neq 4$

EX: Using the same functions, find $(g \circ f)(x)$. $\left(\frac{x}{x-4}\right)$ becomes $\frac{\frac{x+2}{x+2-4}}{\frac{x+2}{x+2-4}} = \frac{x+2}{x+2-4}$, $x \neq 2$

Inverse Functions

To find the inverse of a function, interchange x and y and solve the equation for y .

EX: Find the inverse of $y = 5x - 2$

Interchange x and y : $x = 5y - 2$

$$x + 2 = 5y \quad \frac{x+2}{5} = y$$

To show two functions are inverses, show that $(f \circ g)(x) = x$ and $(g \circ f)(x) = x$

EX: Given $f(x) = 2x - 4$, $g(x) = \frac{x+4}{2}$, $(f \circ g)(x) = 2\left(\frac{x+4}{2}\right) - 4 = x$, and

$$(g \circ f)(x) = \frac{(2x-4)+4}{2} = x$$

Families of Functions

A **parent graph** is the basic graph in a family. All the other family members translate, rotate, reflect, shrink, or stretch based on changes in values.

For a general quadratic function, $f(x) = a(x + h)^2 + c$, the following rules show how the function is transformed.

When a is negative, the graph reflects across the x -axis.

When a is between 0 and 1, the graph shrinks or compresses.

When a is greater than 1, the graph expands.

When h is positive, the graph translates to the left.

When h is negative, the graph translates to the right.

When c is positive, the graph translates up.

When c is negative, the graph translates down.

Note: The parent function (in this case quadratic) could also be an absolute value function, a rational function, an exponential function, etc.

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Annelies Wilder-Smith



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Table of Contents Answers For Plato Learning Pre Calculus

1. Understanding the eBook Answers For Plato Learning Pre Calculus
 - The Rise of Digital Reading Answers For Plato Learning Pre Calculus
 - Advantages of eBooks Over Traditional Books
2. Identifying Answers For Plato Learning Pre Calculus
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Answers For Plato Learning Pre Calculus
 - User-Friendly Interface
4. Exploring eBook Recommendations from Answers For Plato Learning Pre Calculus
 - Personalized Recommendations
 - Answers For Plato Learning Pre Calculus User Reviews and Ratings
 - Answers For Plato Learning Pre Calculus and Bestseller Lists

5. Accessing Answers For Plato Learning Pre Calculus Free and Paid eBooks
 - Answers For Plato Learning Pre Calculus Public Domain eBooks
 - Answers For Plato Learning Pre Calculus eBook Subscription Services
 - Answers For Plato Learning Pre Calculus Budget-Friendly Options
6. Navigating Answers For Plato Learning Pre Calculus eBook Formats
 - ePub, PDF, MOBI, and More
 - Answers For Plato Learning Pre Calculus Compatibility with Devices
 - Answers For Plato Learning Pre Calculus Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Answers For Plato Learning Pre Calculus
 - Highlighting and Note-Taking Answers For Plato Learning Pre Calculus
 - Interactive Elements Answers For Plato Learning Pre Calculus
8. Staying Engaged with Answers For Plato Learning Pre Calculus
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Answers For Plato Learning Pre Calculus
9. Balancing eBooks and Physical Books Answers For Plato Learning Pre Calculus
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Answers For Plato Learning Pre Calculus
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Answers For Plato Learning Pre Calculus
 - Setting Reading Goals Answers For Plato Learning Pre Calculus
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Answers For Plato Learning Pre Calculus
 - Fact-Checking eBook Content of Answers For Plato Learning Pre Calculus
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development
- Exploring Educational eBooks

14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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