QuickStudy ACADEMIC

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 $f(x) = 4x + 1$.

  $0 = 4x + 1 \qquad -1 = 4x \qquad -\frac{1}{4} = x$

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: $f(x) = 2x^4 + x^3 + 10$ 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.

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.

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

  $x = 3.732$ 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: $f(x) = \frac{x}{x+3}$, $f(x) = \frac{3}{x}$, 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 the x & y axes

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

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

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 $\frac{x+2}{x+2-4} = \frac{x+2}{x-2}$, $x \neq 2$

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: $x = 5y - 2$

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

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

  EX: Given $f(x) = 2x - 4$, $g(x) = \frac{x+4}{2}$, $[f \circ g](x) = \frac{2(x+4)}{2} - 4 = x$, 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, $f(x) = a(x + b)^2 + c$, 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 b is positive, the graph translates to the left.
  - When b 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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Jin-Ying Zhang

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