



# 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 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 zeros. (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.

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

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



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.



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

### 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  $y$ :  $x = 5y - 2$

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

• 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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**S Ben Porath**



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