



# Pre-Calculus

$\lim_{x \rightarrow \infty} f(x) = 1$   
Equations & Answers

## FUNCTIONS & THEIR GRAPHS

### Definitions

- A function is a relation in which each element of the domain is paired with only one element of the range.
- In most cases,  $x$  is the independent variable and  $y$  or  $f(x)$  is the dependent variable.

### Linear Functions

A function whose graph is a non-vertical line or part of a non-vertical line. There are 3 forms of linear equations: slope-intercept, point-slope, and standard form.

- Slope-intercept form:**  $y = mx + b$ , where  $m$  is the slope and  $b$  is the  $y$ -intercept of the line.

EX: If a line has a slope of 3 and  $y$ -intercept of 5, the equation is  $y = 3x + 5$ .

- Point-slope form:**  $y - y_1 = m(x - x_1)$ , where  $m$  is the slope and  $(x_1, y_1)$  is a point on the line.

EX: If a line has a slope of -2 and contains the point  $(0, -4)$ , the equation is  $y - (-4) = -2(x - 0)$  or  $y + 4 = -2(x - 0)$ .

- Standard form:**  $Ax + By = C$ , where  $A$ ,  $B$ , and  $C$  are integers and  $A$  is positive. The slope is  $-\frac{A}{B}$  and the  $y$ -intercept is  $-\frac{C}{B}$ . This form of a line is most often used to find intercepts by plugging 0 in for  $x$  and  $y$  separately and solving.

EX: Given the line  $3x + 2y = 4$ , the slope is  $-\frac{3}{2}$  and the  $y$ -intercept is 2. The intercepts can also be found by substitution:

$x$ -intercept (plug in 0 for  $y$ ):

$$3x + 2y = 4 \quad 3x + 2(0) = 4 \quad 3x = 4 \quad x = \frac{4}{3}$$

$y$ -intercept (plug in 0 for  $x$ ):

$$3x + 2y = 4 \quad 3(0) + 2y = 4 \quad 2y = 4 \quad y = 2$$

### 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 odd, there is at least one real zero; when the degree is even, there may be no real zeros.
  - Both types can have imaginary roots of the form  $a + bi$ .
- EX:  $f(x) = 2x^3 + 3x^2 - x + 4$  has a degree of 3, one real zero at  $x = -2.1608$ , and two non-real roots.

### Quadratic Functions

Written in the form  $f(x) = ax^2 + bx + c$ , where  $a \neq 0$

- The **axis of symmetry** is the vertical line with equation  $x = -\frac{b}{2a}$ .
- The  $y$ -intercept is  $c$ .
- Quadratic functions can be written in **vertex form**,  $f(x) = a(x - h)^2 + k$ , where  $(h, k)$  is the vertex of a parabola that opens up when  $a > 0$  and opens down when  $a < 0$ .
- Quadratic functions can have none, one, or two real-number solutions.
- The graph is a parabola if the parabola opens left or right—it is not a function.
- The vertex is the **critical point** where the graph changes from increasing to decreasing or decreasing to increasing.

### Methods for Finding Roots

Equation	Method	Justification	Solution
$x^2 - 9 = 0$	Square Roots	There is no $x$ -term.	$x^2 - 9 = 0$ $x^2 = 9$ $x = 3$ or $-3$
$x^2 + 2x - 8 = 0$	Factoring	It has only a few factors to check.	$x^2 + 2x - 8 = 0$ $(x + 4)(x - 2) = 0$ $x = -4$ or $2$
$2x^2 + 5x - 9 = 0$	Quadratic Formula	The equation cannot be factored.	$x = \frac{-5 \pm \sqrt{5^2 - 4(2)(-9)}}{2(2)}$ $x = \frac{-5 \pm \sqrt{25 + 72}}{4}$ $x = \frac{-5 \pm \sqrt{97}}{4}$
$x^2 - 8x + 3 = 0$	Completing the Square or Quadratic Formula	The coefficient of the $x^2$ -term is 1 but the equation cannot be factored.	$x^2 - 8x + 3 = 0$ $x^2 - 8x = -3$ $x^2 - 8x + 16 = -3 + 16$ $(x - 4)^2 = 13$ $x - 4 = \pm\sqrt{13}$ $x = 4 \pm\sqrt{13}$

The **discriminant** is the expression under the radical in the Quadratic Formula and can be used to determine the number of real solutions.

- A function can be identified using the **vertical line test**. If a vertical line passes through the graph of the function in more than one point, the graph is not a function.
- A function can be represented by an equation in terms of  $x$  and  $y$  or with function notation:  $y = 7x - 11$  or  $f(x) = 7x - 11$ .

**Discriminant:**  $b^2 - 4ac > 0$

EX:  $2x^2 - 7x + 3 = 0$

The discriminant is  $(-7)^2 - 4(2)(3) = 25$ , which is positive.

There are two real number solutions.



**Discriminant:**  $b^2 - 4ac = 0$

EX:  $x^2 - 8x + 16 = 0$

The discriminant is  $(-8)^2 - 4(1)(16) = 0$ .

There is one real number solution.



**Discriminant:**  $b^2 - 4ac < 0$

EX:  $2x^2 - 7x + 8 = 0$

The discriminant is  $(-7)^2 - 4(2)(8) = -15$ , which is negative.

There are no real number solutions.



### Rational Functions

A rational function is an equation of the form  $f(x) = \frac{p(x)}{q(x)}$ , where  $p(x)$  and  $q(x)$  are polynomial functions and  $q(x) \neq 0$ .

- Rational functions may have breaks in continuity that appear in the graph as vertical asymptotes or point discontinuities that appear as holes.
- Vertical asymptotes occur where a rational function is undefined.
- Point discontinuities occur where there is a common factor in the numerator and denominator.
- To multiply:** First multiply the numerators, then the denominators.
- To divide:** Multiply by the multiplicative inverse (reciprocal) of the divisor.

$$\frac{\frac{x^2-8}{3x+10} \cdot \frac{4x+6}{2x-2}}{\frac{5x-10}{3x+10} \cdot \frac{4x+6}{2x-2}} = \frac{(x^2-8)(4x+6)}{(5x-10)(4x+6)}$$

$$\begin{aligned} \frac{x^2+3x-10}{x^2+3x+2} \cdot \frac{x-2}{3x+3} &= \frac{(x+5)(x-2)}{(x+3)(x+2)} \cdot \frac{x-2}{3(x+1)} \\ &= \frac{(x+5)(x-2)(x-2)}{(x+3)(x+2)(x+1)} \end{aligned}$$

**Order is important for division.**

**To add and subtract:** There must be a common denominator. To find it for rational expressions with polynomials in the denominator, factor first to determine common factors.

$$\frac{5}{x^2-x-20} + \frac{7}{2x-10} = \frac{5}{(x+4)(x-5)} + \frac{7}{2(x-5)}$$

Using one of each factor, the LCM is  $2(x+4)(x-5)$ . Multiply each fraction's numerator and denominator by the factors missing from the LCM.

$$\begin{aligned} &= \frac{5}{(x+4)(x-5)} \cdot \frac{2}{2} + \frac{7}{2(x-5)} \cdot \frac{(x+4)}{(x+4)} \\ &= \frac{10}{2(x+4)(x-5)} + \frac{7(x+4)}{2(x-5)(x+4)} \\ &= \frac{10 + 7x + 28}{2(x+4)(x-5)} \end{aligned}$$

$$\text{Subtracting: } \frac{x-4}{x^2+3x-10} - \frac{x+2}{x^2+x-20} = \frac{x-4}{(x+5)(x-2)} - \frac{x+2}{(x-4)(x-5)}$$

Using one of each factor, the LCM is  $(x-2)(x+5)(x-4)$ . Multiply each fraction's numerator and denominator by the factors missing from the LCM.

**Hint:** The common denominator is the LCM (least common multiple) of the denominators.

**Warning:** The subtraction sign must be distributed to each part of the numerator of the second fraction.

$$\begin{aligned} &= \frac{x-4}{(x+5)(x-2)} \cdot \frac{x-4}{x-4} - \frac{x+2}{(x-4)(x-5)} \cdot \frac{x-2}{x-2} \\ &= \frac{x^2-8x+20}{(x+5)(x-2)(x-4)} - \frac{x^2-4}{(x-4)(x-5)(x+5)} \\ &= \frac{-8x+20}{(x+5)(x-2)(x-4)} \end{aligned}$$

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**Mark Steyvers**



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