



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):

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

y -intercept (plug in 0 for x):

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

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.	$x = \frac{-5 \pm \sqrt{5^2 - 4(2)(-9)}}{2(2)}$ $x = \frac{-5 \pm \sqrt{97}}{4}$
$x^2 - 8x + 3 = 0$	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.

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

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

To divide: Multiply by the multiplicative inverse (reciprocal) of the divisor.

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

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.

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

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

Using one of each factor, the LCM is $(x + 3)(x + 5)(x + 4)$. 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.

$$\begin{aligned} &= \frac{x - 4}{(x + 3)(x + 2)} - \frac{x + 2}{(x + 3)(x + 5)} \\ &= \frac{(x - 4)(x + 5) - (x + 2)(x + 3)}{(x + 3)(x + 2)(x + 5)} \\ &= \frac{x^2 - 4x + 20 - x^2 - 5x - 6}{(x + 3)(x + 2)(x + 5)} \\ &= \frac{-9x + 14}{(x + 3)(x + 2)(x + 5)} \end{aligned}$$

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Wolfgang Guggemos



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