



Pre-Calculus

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 1, the equation is $y = 3x + 1$.

• **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 $(5, -4)$, the equation is $y - (-4) = -2(x - 5)$ or $y + 4 = -2(x - 5)$.

• **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 $x = -2.1601$, 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.	$x = \frac{-5 \pm \sqrt{5^2 - 4(2)(-9)}}{2(2)}$ $x = \frac{-5 \pm \sqrt{95}}{4}$
$x^2 - 8x + 3 = 0$	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: $b^2 - 4ac > 0$

$$\text{EX: } 2x^2 - 7x + 3 = 0$$

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

There are two real number solutions.



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

$$\text{EX: } x^2 - 8x + 16 = 0$$

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

There is one real number solution.



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

$$\text{EX: } 2x^2 - 7x + 8 = 0$$

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.

$$\frac{x^2 - 4}{x^2 + 1} \cdot \frac{x + 4}{2x - 2} = \frac{(x^2 - 4)(x + 4)}{(x^2 + 1)(2x - 2)}$$

$$= \frac{(x - 2)(x + 2)(x + 4)}{(x^2 + 1)(2)(x - 1)}$$

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

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



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.

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

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

Using one of each factor, the LCM is $(h - 2)(h + 5)(h - 4)$.

Multiply each fraction's numerator and denominator by the factors missing from the LCM.



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



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

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

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