



# 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 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.                                                       | $x^2 - 9 = 0$<br>$x^2 = 9$<br>$x = 3$ or $-3$                                                                                            |
| $x^2 + 2x - 8 = 0$  | Factoring                                  | It has only a few factors to check.                                          | $x^2 + 2x - 8 = 0$<br>$(x + 4)(x - 2) = 0$<br>$x = -4$ or $2$                                                                            |
| $2x^2 + 5x - 9 = 0$ | Quadratic Formula                          | The equation cannot be factored.                                             | $x = \frac{-5 \pm \sqrt{5^2 - 4(2)(-9)}}{2(2)}$<br>$x = \frac{-5 \pm \sqrt{97}}{4}$                                                      |
| $x^2 - 8x + 3 = 0$  | Completing the Square or Quadratic Formula | The coefficient of the $x^2$ -term is 1 but the equation cannot be factored. | $x^2 - 8x + 3 = 0$<br>$x^2 - 8x = -3$<br>$x^2 - 8x + 16 = -3 + 16$<br>$(x - 4)^2 = 13$<br>$x - 4 = \pm\sqrt{13}$<br>$x = 4 \pm\sqrt{13}$ |

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.

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

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

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

**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.

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

$$\text{Subtracting: } \frac{8 - 4}{x^2 + 3x + 10} - \frac{8 + 2}{x^2 + 3x + 16} = \frac{8 - 4}{(x + 3)(x + 2)} - \frac{8 + 2}{(x + 3)(x + 5)}$$

Using one of each factor, the LCM is  $(x - 2)(x + 3)(x + 4)$ . Multiply each fraction's numerator and denominator by the factors missing from the LCM.

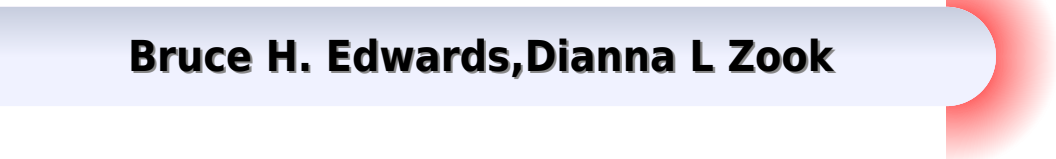
**Hint:** The common denominator is the LCM (least common multiple) of the denominators.

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

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

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**Bruce H. Edwards, Dianna L Zook**



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