



# CALCULUS

## Equations & Answers™

Essential Tools for Understanding Calculus – Rules, Concepts, Variables, Equations,  
Examples, Helpful Hints & Common Pitfalls

### STRATEGY FOR SOLVING PROBLEMS EFFECTIVELY

- I. Understand the **principle** (business or scientific) required.
- II. Develop a mathematical strategy.
  - A. There are **eight** useful steps that will help you develop the correct strategy.
    1. **Sketch, diagram or chart** the relationships and information that is subject of the problem.
    2. Identify all relevant **variables, concepts and constants**.
    3. Describe the problem situations using appropriate mathematical **relationships, functions, formulas, equations or graphs**.
    4. Collect all **essential** information and **data**.
    5. **Highlight** extra and **unnecessary** information and data.
    6. Derive a mathematical expression or statement for the problem, making sure all measurements are in the **correct unit**.
    7. Complete the appropriate **mathematical manipulations** and **solution techniques**.
    8. **Check the final answer** by using the original problem and information to make certain that the answers, units, signs, magnitudes, etc., all make sense and are correct!

### FUNCTIONS

- I. **Definitions**
  - A. A **relation** is a set of order pairs, written  $(x, y)$  or  $(x, f(x))$ .
  - B. A **function** is a relation that has  $x$ -values that are all different for different  $y$ -values. A **vertical line test** can be used to determine a function; every vertical line intersects the graph, at most, once.
  - C. A **one-to-one function** is a function that has  $y$ -values that are all different for different  $x$ -values. A **horizontal line test** can be used to determine a one-to-one function; every horizontal line intersects the graph, at most, once.
  - D. **Domain** is the set of all  $x$ -values of a relation.
  - E. **Range** is the set of all  $y$ -values of a relation.
  - F. A function is an **even function** if  $f(-x) = f(x)$ .
  - G. A function is an **odd function** if  $f(-x) = -f(x)$ .
  - H. The **one-to-one functions**  $f(x)$  and  $g(x)$  are **inverse functions** if  $f(g(x)) = g(f(x)) = x$ .  $f^{-1}(x)$  and  $g^{-1}(x)$  indicate the inverse functions of  $f(x)$  and  $g(x)$ , respectively. Inverse functions are reflections over the line graph of  $y = x$ .
- I. **Dependent variable** is the output variable in an equation and depends on or is determined by the input variable.
- J. **Independent variable** is the input variable in an equation.
- II. **Common Function Summary**
  - A. Linear:  $f(x) = mx + b$ 
    1.  $m$  is the slope;  
 $m = \frac{y_2 - y_1}{x_2 - x_1} = \frac{y_2 - y_1}{x_2 - x_1} = \frac{\Delta y}{\Delta x} = \frac{\text{rise}}{\text{run}}$
    2.  $b$  is the  $y$ -intercept.
    3. It is a constant function when  $m = 0$ ; it is a horizontal line.
  - B. Absolute value:  $f(x) = a|x - h| + k$ 
    1.  $(h, k)$  is the vertex.
    2. If  $a > 0$ , the graph opens up.

3. If  $a < 0$ , the graph opens down.
4.  $a$  and the slopes of the two sides of the graph.
- C. Square root:  $f(x) = a\sqrt{x - h} + k$ 
  1.  $(h, k)$  is the endpoint.
  2. If  $a > 0$ , the graph goes to the right.
  3. If  $a < 0$ , the graph goes to the left.
- D. Polynomial:  $f(x) = a_n x^n + a_{n-1} x^{n-1} + \dots + a_1 x + a_0$ 
  1.  $a_0$  is the  $y$ -intercept.
  2. There are, at most,  $n$  zeros or  $x$ -intercepts where  $f(x) = 0$ .
  3. There are, at most,  $n - 1$  points of change or turns in the graph.
  4. The extreme left and right sections of the graph both go up or both go down if  $n$  is even, and go in opposite directions if  $n$  is odd.
- E. Quadratic:  $f(x) = a(x - h)^2 + k$ 
  1. This is a special case of a polynomial.
  2.  $(h, k)$  is the vertex.
  3. If  $a > 0$ , the graph opens up.
  4. If  $a < 0$ , the graph opens down.
  5. Use quadratic formula to solve for the zeros or  $x$ -intercepts:  $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ .
- F. Rational:  $f(x) = \frac{p(x)}{q(x)}$ 
  1.  $p(x)$  and  $q(x)$  are polynomials, and  $q(x) \neq 0$ .
  2. If degree  $p(x) <$  degree  $q(x)$ , the asymptote is the  $x$ -axis where  $y = 0$ .
  3. If degree  $p(x) =$  degree  $q(x)$ , the asymptote is  $y =$  (lead coefficient of  $p(x)$ ) / (lead coefficient of  $q(x)$ ).
  4. If degree  $p(x) >$  degree  $q(x)$ , the asymptote is  $y =$  (the quotient of  $p(x) \div q(x)$ ); a diagonal asymptote.
- G. Exponential:  $f(x) = a^x$ 
  1.  $a > 0$  and  $a \neq 1$ .
  2. If  $a > 1$ , the function is increasing.
  3. If  $a < 1$ , the function is decreasing.
  4. Rules for exponents:
    - a.  $a^m \cdot a^n = a^{m+n}$
    - b.  $\frac{a^m}{a^n} = a^{m-n}$
    - c.  $(a^m)^n = a^{mn}$
    - d.  $a^{-m} = \frac{1}{a^m}$
    - e.  $\frac{1}{a^{-m}} = a^m$
    - f.  $(xy)^m = x^m y^m$
    - g.  $\frac{x^m}{y^m} = \left(\frac{x}{y}\right)^m$
    - h.  $x^{\frac{m}{n}} = \sqrt[n]{x^m} = (\sqrt[n]{x})^m$
    - i.  $\sqrt[n]{xy} = \sqrt[n]{x} \cdot \sqrt[n]{y}$
    - j.  $\sqrt[n]{\frac{x}{y}} = \frac{\sqrt[n]{x}}{\sqrt[n]{y}}$
    - k.  $\sqrt[n]{\sqrt[n]{x}} = \sqrt[n^2]{x}$
  5. If  $a^m = a^n$ , then  $m = n$ .  
or, If  $a^m = b^n$ , then  $m = n \log_a b$  if  $a \neq 0$ .
- H. Logarithmic:  $f(x) = \log_a x$ 
  1.  $x > 0$ .
  2.  $a > 0$  and  $a \neq 1$ .
  3. **IF**  $f(x) = \log_a x$ , **IF and only IF**,  $a^{f(x)} = x$ .
  4.  $a$  is the base.
  5. Logarithms are exponents.
  6. Rules for logarithms:
    - a.  $\log_a 1 = 0$
    - b.  $\log_a a = 1$
    - c.  $\log_a a^x = x$
    - d.  $a^{\log_a x} = x$
    - e. If  $\log_a x = \log_a y$ , then  $x = y$ .

- I.  $f(x) = \log_e x = \ln x$ ; this is the natural log.
- g.  $\log_a x = \frac{\log_b x}{\log_b a} = \frac{\log x}{\log a} = \frac{\ln x}{\ln a}$ ;  
this is the **change-of-base rule**.
- h.  $\log_a xy = \log_a x + \log_a y$
- i.  $\log_a \frac{x}{y} = \log_a x - \log_a y$
- j.  $\log_a x^y = y \log_a x$

#### I. Trigonometric

##### 1. Basics

- a. Angles can be measured in degrees and radians.
  - i. 1 radian =  $\left(\frac{180}{\pi}\right)$  degrees
  - ii. 1 degree =  $\left(\frac{\pi}{180}\right)$  radians
- ii. proportion conversion of angle measurements:  
angle in degrees  $\frac{\text{angle in radians}}{180^\circ} = \frac{\text{angle in radians}}{\pi \text{ radians}}$
- iv. unit circle
  - (a) center at  $(0, 0)$
  - (b) radius = one unit
  - (c) points on the circle =  $P(x, y)$
  - (d) Positive angles move counterclockwise from  $P(1, 0)$ .
  - (e) Negative angles move clockwise from  $P(1, 0)$ .
  - (f) Angles rotating one or more full times require adding  $\pm 2\pi$  for each rotation.

##### v. function definitions

- (a)  $\sin \theta = \frac{y}{r}$
- (b)  $\cos \theta = \frac{x}{r}$
- (c)  $\tan \theta = \frac{y}{x}$
- (d)  $\csc \theta = \frac{1}{\sin \theta}$
- (e)  $\sec \theta = \frac{1}{\cos \theta}$
- (f)  $\cot \theta = \frac{x}{y}$

##### vi. useful values

$\theta$  = degrees;  $r$  = radians;  $\emptyset$  = undefined

$\theta$	$0$	$30$	$45$	$60$	$90$	$180$
$r$	$0$	$\frac{\pi}{6}$	$\frac{\pi}{4}$	$\frac{\pi}{3}$	$\frac{\pi}{2}$	$\pi$
$\sin$	$0$	$\frac{1}{2}$	$\frac{\sqrt{2}}{2}$	$\frac{\sqrt{3}}{2}$	$1$	$0$
$\cos$	$1$	$\frac{\sqrt{3}}{2}$	$\frac{\sqrt{2}}{2}$	$\frac{1}{2}$	$0$	$-1$
$\tan$	$0$	$\frac{\sqrt{3}}{3}$	$1$	$\sqrt{3}$	$\emptyset$	$0$

##### 2. Graphing properties

- a. Amplitude of sine and cosine is half the difference between the maximum and the minimum values, or  $|a|$ .
- b. Period is the radians needed to complete one full cycle of the curve, or  $\frac{2\pi}{B}$ .
- c. Horizontal shift or phase shift is  $c$ .
- d. Vertical shift or average value is  $d$ .
- e. Sine:  $f(x) = a \sin(b(x - c)) + d$
- f. Cosine:  $f(x) = a \cos(b(x - c)) + d$
- g. Tangent:  $f(x) = a \tan(b(x - c)) + d$
- [CAUTION: Tangent has no amplitude, so  $a$  affects the vertical stretch and shrink only.]**
- h. Cosine is even; sine & tangent are odd.
3. Important identities & formulas

# Calculus 111 Study Guide

**Ping Wang, Fred Szabo**



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