



Trigonometry

BACKGROUND AND DEFINITIONS

TRIGONOMETRY DEFINED

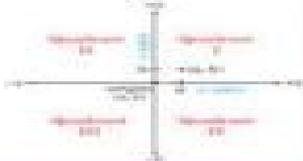
Trigonometry is the study of relationships between angles and lengths, especially in triangles.

THE COORDINATE PLANE

The Cartesian (or coordinate) plane is an infinite plane with two special perpendicular lines called axes. A point on the plane is identified by an ordered pair of coordinates—the distance from the two axes.

- x-axis:** Usually, the horizontal axis of the coordinate plane.
- y-axis:** Usually, the vertical axis of the coordinate plane.
- Origin:** (0, 0), the point of intersection of the x-axis and the y-axis.

- Quadrants:** The four regions of the coordinate plane created by the intersection of the two axes. By convention, they are numbered I, II, III, and IV counter-clockwise, starting with the upper-right quadrant.



FUNCTIONS

For more about functions, see the SparkCharts on Functions.

- Function:** A rule for generating values for every value you plug into the function, where x is a unique value that comes out. Often denoted as $f(x)$, for every value $x = a$ that you plug in, $f(a)$ is the result.
- Domain:** The set of possible generating values, x , for a function $f(x)$.
- Range:** The set of possible outcomes of $f(x)$.
- Graphing a function:** The process of plotting all the points $(x, f(x))$ in the coordinate plane.
- Vertical line test:** Checks if something is a function by looking at its graph: any vertical line in the coordinate plane must intersect the graph no more than once. That means x -values, there is at most one y -value.

ANGLES

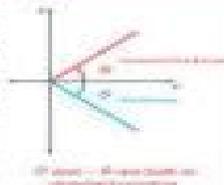
- Ray:** Part of a line with one fixed endpoint extending without bound in one direction.
- Two rays that share a common endpoint create an angle.** The common endpoint is called the **vertex** of the angle.
- Other:** we think of an angle as being formed by rotating a ray clockwise or counterclockwise. We then distinguish between the **initial side** (starting position of the ray) and the **terminal side** (end position of the ray) of the angle.



MEASURING ANGLES

We measure angles to see how wide or narrow they are. There are two standard units of measuring angles.

- Degree (°):** A unit of angular measure in which a complete revolution measures 360° ; each degree is subdivided into 60 minutes, and each minute is subdivided into 60 seconds.
- Radian (rad):** A unit of angular measure in which a complete revolution measures 2π radians. The radian measure of an angle is the length of arc on the unit circle cut off by that angle.
- Converting between degrees and radians:**
 - $1 \text{ revolution} = 360^\circ = 2\pi \text{ rad}$
 - $1 \text{ rad} = \frac{180^\circ}{\pi}$ and $\frac{1}{\text{radian}} = \frac{\pi}{180^\circ}$
 - $1^\circ = \frac{\pi}{180} \text{ rad}$ and $1 \text{ rad} = \frac{180}{\pi} \text{ degrees}$
- Labeling angles:** When viewed as geometric shapes, angles are usually labeled with capital letters—often after the vertex (like $\angle A$)—and often measured in degrees. When viewed as rotations, angle measures are often given Greek letters (θ , ϕ , α) and are usually specified in radians. In trigonometry—either in geometry—the distinction between angles and their measures is often not made (like $\angle A = 45^\circ$).



ANGLES IN THE COORDINATE PLANE

- Standard position:** An angle is in standard position when its vertex lies at the origin and its initial side lies along the positive x-axis.
- Unit circle:** The circle of radius 1 centered at the origin.
- Any angle shows a point on the unit circle.**
- Negative and positive angles:** If we rotate, positive angles are measured counterclockwise, negative angles are measured clockwise.
- Multiple rotations:** The angles θ , $\theta + 2\pi$, $\theta - 2\pi$, $\theta + 4\pi$, ... all define the same point on the unit circle.
- Reference angle:** For any angle in standard position, the reference angle is the positive acute angle formed by the terminal side and the x-axis.



TYPES OF ANGLES

- Zero angle:** $0^\circ = 0 \text{ rad}$. The initial side and the terminal side coincide. In standard position, the terminal side lies on the positive x-axis.
- Acute angle:** less than $90^\circ = \frac{\pi}{2} \text{ rad}$. Between a zero angle and a right angle. In standard position the terminal side lies in Quadrant I.
- Right angle:** $90^\circ = \frac{\pi}{2} \text{ rad}$. The initial side is perpendicular to the terminal side. In standard position, the terminal side lies on the positive y-axis.
- Obtuse angle:** greater than $90^\circ = \frac{\pi}{2} \text{ rad}$ and less than $180^\circ = \pi \text{ rad}$. Between a right angle and a straight angle. In standard position, the terminal side is in Quadrant II.
- Straight angle:** $180^\circ = \pi \text{ rad}$. The initial side and the terminal side lie on the same line. In standard position, the terminal side lies on the negative x-axis.
- Oblique angle:** either acute or obtuse (not zero, right, or straight).
- Complementary angles:** Two angles that sum to a right angle.
- Supplementary angles:** Two angles that sum to a straight angle.
- Vertical angles:** Two angles in standard position whose terminal sides coincide. Angles θ and ϕ are vertical if $\theta = \alpha + 2\pi$ for some integer k (positive or negative).



TRIGONOMETRIC FUNCTIONS

The two ways of thinking about angles—as rotations from the standard position, or as static shapes in a geometric figure—give two ways of thinking about trigonometric functions.

...BASED ON THE UNIT CIRCLE

The angle θ defines a point $P = (x, y)$ on the unit circle. Interpreting the coordinates of this point give the trigonometric functions of θ .



- Sine:** $\sin \theta = y$, the y-coordinate of P . For all θ , $-1 \leq \sin \theta \leq 1$.
- Cosine:** $\cos \theta = x$, the x-coordinate of P . For all θ , $-1 \leq \cos \theta \leq 1$.
- Tangent:** $\tan \theta = \frac{y}{x}$, the slope of the line OP .
- Secant:** $\sec \theta = \frac{1}{\cos \theta} = \frac{1}{x}$.

- Cosecant:** $\csc \theta = \frac{1}{\sin \theta} = \frac{1}{y}$.
 - Cotangent:** $\cot \theta = \frac{x}{y} = \frac{1}{\tan \theta} = \frac{\cos \theta}{\sin \theta}$.
- Because θ and $\theta + 2\pi$ define the same point on the unit circle, all trigonometric functions are periodic with a period of 2π (like \cos , \sin , \csc), or π (like \tan).

...BASED ON A RIGHT TRIANGLE

In a right triangle, θ is an angle between the hypotenuse and the side adjacent to the right angle. Add θ and ϕ to get 90° . The side opposite θ is the side adjacent to ϕ . The angle $\angle C, A, B$, and the measure of angle $\angle C, A, B$.



- Sine:** $\sin \theta = \frac{y}{r} = \frac{\text{opposite side}}{\text{hypotenuse}}$
 - Cosine:** $\cos \theta = \frac{x}{r}$ for all acute angles θ .
 - Cotangent:** $\cot \theta = \frac{x}{y} = \frac{\text{adjacent side}}{\text{opposite side}}$
 - Tangent:** $\tan \theta = \frac{y}{x} = \frac{\text{opposite side}}{\text{adjacent side}}$
- TRIGONOMETRIC IDENTITIES:** Sine is Opposite over Hypotenuse, Cosine is Adjacent over Hypotenuse, Tangent is Opposite over Adjacent.
- Cosecant:** $\csc \theta = \frac{1}{\sin \theta} = \frac{\text{hypotenuse}}{\text{opposite side}} = \frac{1}{\sin \theta}$
 - Secant:** $\sec \theta = \frac{1}{\cos \theta} = \frac{\text{hypotenuse}}{\text{adjacent side}} = \frac{1}{\cos \theta}$
 - Cotangent:** $\cot \theta = \frac{1}{\tan \theta} = \frac{\text{adjacent side}}{\text{opposite side}} = \frac{1}{\tan \theta}$

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Table of Contents Trigonometry Sparkcharts

1. Understanding the eBook Trigonometry Sparkcharts
 - The Rise of Digital Reading Trigonometry Sparkcharts
 - Advantages of eBooks Over Traditional Books
2. Identifying Trigonometry Sparkcharts
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Trigonometry Sparkcharts
 - User-Friendly Interface
4. Exploring eBook Recommendations from Trigonometry Sparkcharts
 - Personalized Recommendations
 - Trigonometry Sparkcharts User Reviews and Ratings

- Trigonometry Sparkcharts and Bestseller Lists
- 5. Accessing Trigonometry Sparkcharts Free and Paid eBooks
 - Trigonometry Sparkcharts Public Domain eBooks
 - Trigonometry Sparkcharts eBook Subscription Services
 - Trigonometry Sparkcharts Budget-Friendly Options
- 6. Navigating Trigonometry Sparkcharts eBook Formats
 - ePub, PDF, MOBI, and More
 - Trigonometry Sparkcharts Compatibility with Devices
 - Trigonometry Sparkcharts Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Trigonometry Sparkcharts
 - Highlighting and Note-Taking Trigonometry Sparkcharts
 - Interactive Elements Trigonometry Sparkcharts
- 8. Staying Engaged with Trigonometry Sparkcharts
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Trigonometry Sparkcharts
- 9. Balancing eBooks and Physical Books Trigonometry Sparkcharts
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Trigonometry Sparkcharts
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Trigonometry Sparkcharts
 - Setting Reading Goals Trigonometry Sparkcharts
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Trigonometry Sparkcharts
 - Fact-Checking eBook Content of Trigonometry Sparkcharts
 - Distinguishing Credible Sources

13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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