

MAT 142: Angles and Measure

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Reminders

Last class we completed our study of exponential and logarithmic functions. Today we begin **trigonometry** — the final major topic of the semester.

Try the following warm-up problems as review, challenge, and bridge.

Problem 1: A projectile is launched vertically from ground level, with initial velocity 64 feet per second. The height (in feet) of the projectile after t seconds is given by the function $h(t) = -16t^2 + 64t$. Find the maximum height of the projectile and the time at which it reaches that height.

Problem 2: Solve $e^{2x} - 5e^x + 6 = 0$.

Problem 3: Consider the projectile from the first problem. How does the scenario change if the projectile is launched at a 60° angle instead of vertically? Are the answers the same? Why or why not? What do you need to know in order to solve this updated problem?

Objectives

Trigonometry connects angles to lengths and coordinates. It is the mathematical language of anything that rotates, oscillates, or repeats — from sound waves to planetary orbits to signal processing.

After today's class meeting, you should be able to:

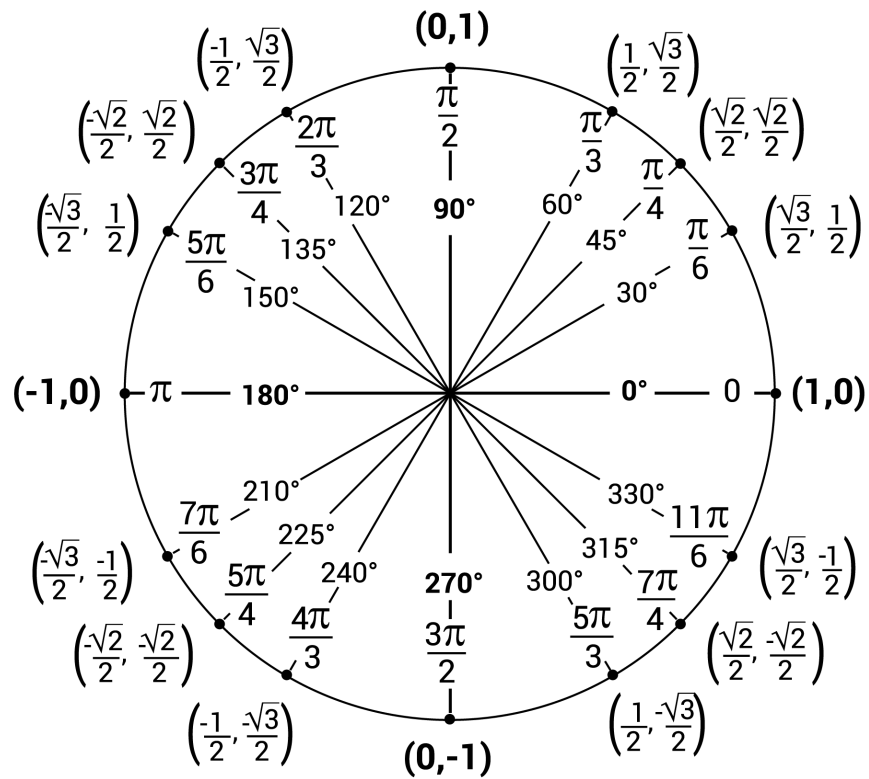
- Measure angles in both degrees and radians and convert between the two.
- Identify coterminal angles and find a coterminal angle in $[0^\circ, 360^\circ)$ or $[0, 2\pi)$.
- Use the unit circle to evaluate **sin()**, **cos()**, and **tan()** at common angles.
- Evaluate trigonometric functions at angles outside $[0^\circ, 360^\circ)$ using coterminal angles.

The Unit Circle

The **unit circle** is a circle of radius **1**, centered at the origin. It is the foundation of trigonometry.

Each point on the unit circle corresponds to an angle θ measured from the positive x -axis, and is labeled with its coordinates (x, y) .

The unit circle includes the angles that are multiples of 30° (or $\frac{\pi}{6}$ rad) and multiples of 45° (or $\frac{\pi}{4}$ rad) — the angle increments you will encounter most often.



Unit Circle

Degree and Radian Measure

There are two standard units for measuring angles.

Degrees: A full revolution around a circle measures 360° . This is the unit most familiar from everyday life.

Radians: A full revolution around a circle is 2π rad. *Radians* are the natural unit for mathematics — many formulas in calculus and beyond require radian measure.

Converting between the two uses the fact that $360^\circ = 2\pi$ rad, so the ratio $\frac{2\pi \text{ rad}}{360^\circ} = 1$:

$$d^\circ = d^\circ \cdot \frac{2\pi \text{ rad}}{360^\circ} \quad \text{and} \quad r \text{ rad} = r \text{ rad} \cdot \frac{360^\circ}{2\pi \text{ rad}}$$

Sign and direction: Angles are measured from the positive x -axis. Counter-clockwise is the positive direction; clockwise is negative. Angles with measure exceeding 360° (or less than -360°) represent more than one full revolution.

Converting Angles

Example 1: (1) Convert 135° to radians. (2) Convert $\frac{11\pi}{6}$ rad to degrees.

(1) Multiply by the degree-to-radian conversion factor.

$$135^\circ$$

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$$\begin{aligned} 135^\circ &= 135^\circ \left(\frac{2\pi \text{ rad}}{360^\circ} \right) \\ &= \frac{270\pi}{360} \end{aligned}$$

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Converting Angles

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(1) Multiply by the degree-to-radian conversion factor. (2) Multiply by the radian-to-degree conversion factor.

$$\begin{aligned} 135^\circ &= 135^\circ \left(\frac{2\pi \text{ rad}}{360^\circ} \right) \\ &= \frac{270\pi}{360} \\ &= \frac{27\pi}{36} \\ &= \boxed{\frac{3\pi}{4}} \end{aligned}$$

$$\frac{11\pi}{6} \text{ rad}$$

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$$\frac{11\pi}{6} \text{ rad} = \left(\frac{11\pi}{6} \text{ rad} \right) \left(\frac{360^\circ}{2\pi \text{ rad}} \right)$$

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$$\begin{aligned} \frac{11\pi}{6} \text{ rad} &= \left(\frac{11\pi}{6} \text{ rad} \right) \left(\frac{360^\circ}{2\pi \text{ rad}} \right) \\ &= \frac{11 \cdot 360^\circ}{12} \end{aligned}$$

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Converting Angles

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Angle Conversion Practice

Try It! 1: Complete the following conversions.

(a) Convert 780° to radians.

(b) Convert -50° to radians.

(c) Convert 3π rad to degrees.

(d) Convert $-\frac{\pi}{5}$ rad to degrees.

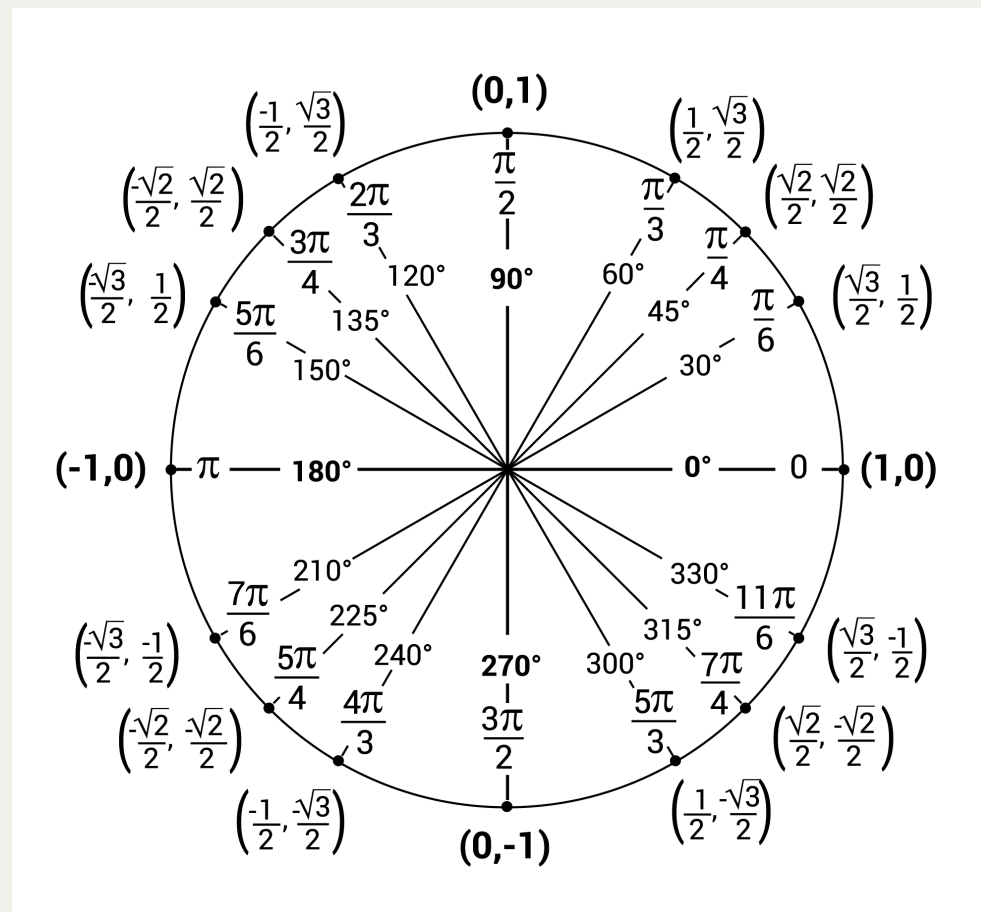
The Six Trigonometric Functions

For an angle θ whose terminal side intersects the unit circle at the point (x, y) , we define:

$$\sin(\theta) = y \qquad \csc(\theta) = \frac{1}{y}$$

$$\cos(\theta) = x \qquad \sec(\theta) = \frac{1}{x}$$

$$\tan(\theta) = \frac{y}{x} \qquad \cot(\theta) = \frac{x}{y}$$



Since x and y are coordinates on the unit circle, **sin** and **cos** always satisfy $-1 \leq \sin(\theta) \leq 1$ and $-1 \leq \cos(\theta) \leq 1$.

Evaluating Trig Functions

Example 2: Evaluate each of the following using the unit circle.

$$(a) \sin\left(\frac{5\pi}{6}\right) \quad (b) \cos\left(\frac{4\pi}{3}\right) \quad (c) \tan\left(\frac{7\pi}{6}\right) \quad (d) \cos(135^\circ) \quad (e) \tan(225^\circ)$$

$$(a) \frac{5\pi}{6}$$

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(a) $\frac{5\pi}{6}$ is in QII.

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(a) $\frac{5\pi}{6}$ is in QII. The point on the unit circle is $\left(-\frac{\sqrt{3}}{2}, \frac{1}{2}\right)$.

$$\sin\left(\frac{5\pi}{6}\right) = \boxed{\frac{1}{2}}$$

(b) $\frac{4\pi}{3}$

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(c) $\frac{7\pi}{6}$

$$\sin\left(\frac{5\pi}{6}\right) = \boxed{\frac{1}{2}}$$

(b) $\frac{4\pi}{3}$ is in QIII. The point is $\left(-\frac{1}{2}, -\frac{\sqrt{3}}{2}\right)$.

$$\cos\left(\frac{4\pi}{3}\right) = \boxed{-\frac{1}{2}}$$

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$$\tan\left(\frac{7\pi}{6}\right) = \frac{-1/2}{-\sqrt{3}/2} = \boxed{\frac{1}{\sqrt{3}}}$$

(d) 135°

(b) $\frac{4\pi}{3}$ is in QIII. The point is $\left(-\frac{1}{2}, -\frac{\sqrt{3}}{2}\right)$.

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(d) 135° is in QII. The point is $\left(-\frac{\sqrt{2}}{2}, \frac{\sqrt{2}}{2}\right)$.

$$\cos(135^\circ) = \boxed{-\frac{\sqrt{2}}{2}}$$

(b) $\frac{4\pi}{3}$ is in QIII. The point is $\left(-\frac{1}{2}, -\frac{\sqrt{3}}{2}\right)$.

$$\cos\left(\frac{4\pi}{3}\right) = \boxed{-\frac{1}{2}}$$

(e) 225°

Evaluating Trig Functions

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(b) $\frac{4\pi}{3}$ is in QIII. The point is $\left(-\frac{1}{2}, -\frac{\sqrt{3}}{2}\right)$.

$$\cos\left(\frac{4\pi}{3}\right) = \boxed{-\frac{1}{2}}$$

(e) 225° is in QIII.

Evaluating Trig Functions

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$$\tan\left(\frac{7\pi}{6}\right) = \frac{-1/2}{-\sqrt{3}/2} = \boxed{\frac{1}{\sqrt{3}}}$$

(d) 135° is in QII. The point is $\left(-\frac{\sqrt{2}}{2}, \frac{\sqrt{2}}{2}\right)$.

$$\cos(135^\circ) = \boxed{-\frac{\sqrt{2}}{2}}$$

(b) $\frac{4\pi}{3}$ is in QIII. The point is $\left(-\frac{1}{2}, -\frac{\sqrt{3}}{2}\right)$.

$$\cos\left(\frac{4\pi}{3}\right) = \boxed{-\frac{1}{2}}$$

(e) 225° is in QIII. The point is $\left(-\frac{\sqrt{2}}{2}, -\frac{\sqrt{2}}{2}\right)$.

$$\tan(225^\circ) = \frac{-\sqrt{2}/2}{-\sqrt{2}/2}$$

Evaluating Trig Functions

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(d) 135° is in QII. The point is $\left(-\frac{\sqrt{2}}{2}, \frac{\sqrt{2}}{2}\right)$.

$$\cos(135^\circ) = \boxed{-\frac{\sqrt{2}}{2}}$$

(b) $\frac{4\pi}{3}$ is in QIII. The point is $\left(-\frac{1}{2}, -\frac{\sqrt{3}}{2}\right)$.

$$\cos\left(\frac{4\pi}{3}\right) = \boxed{-\frac{1}{2}}$$

(e) 225° is in QIII. The point is $\left(-\frac{\sqrt{2}}{2}, -\frac{\sqrt{2}}{2}\right)$.

$$\tan(225^\circ) = \frac{-\sqrt{2}/2}{-\sqrt{2}/2} = \boxed{1}$$

Coterminal Angles

Angles outside $[0^\circ, 360^\circ)$ or $[0, 2\pi)$ are common, especially in applications. We can still evaluate trigonometric functions at these angles by finding a **coterminal** reference angle.

Definition: Two angles are *coterminal* if their terminal sides intersect the unit circle at the same point. This happens when the angles differ by a whole number of full revolutions:

$$\theta \text{ and } \gamma \text{ are coterminal} \iff \theta = \gamma + 360^\circ \cdot k \quad \text{or} \quad \theta = \gamma + 2\pi \cdot k \quad \text{for some integer } k$$

Strategy: To find a coterminal angle in $[0^\circ, 360^\circ)$ or $[0, 2\pi)$:

- If the angle is too large, subtract 360° (or 2π) repeatedly until in range.
- If the angle is negative, add 360° (or 2π) repeatedly until in range.

Finding Coterminal Angles

Example 3: Find a coterminal angle in $[0^\circ, 360^\circ)$ or $[0, 2\pi)$ for each of the following.

$$(a) 780^\circ \quad (b) -50^\circ \quad (c) -3\pi \text{ rad} \quad (d) \frac{-\pi}{5} \text{ rad}$$

(a) 780°

Finding Coterminal Angles

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(a) 780° is too large.

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$$(a) \ 780^\circ \quad (b) \ -50^\circ \quad (c) \ -3\pi \text{ rad} \quad (d) \ \frac{-\pi}{5} \text{ rad}$$

(a) 780° is too large. Subtract 360° twice (that's two full revolutions).

$$780^\circ - 360^\circ = 420^\circ$$

Finding Coterminal Angles

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(a) 780° is too large. Subtract 360° twice (that's two full revolutions).

$$780^\circ - 360^\circ = 420^\circ$$

$$420^\circ - 360^\circ = \boxed{60^\circ}$$

(b) -50°

Finding Coterminal Angles

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$$(a) 780^\circ \quad (b) -50^\circ \quad (c) -3\pi \text{ rad} \quad (d) \frac{-\pi}{5} \text{ rad}$$

(a) 780° is too large. Subtract 360° twice (that's two full revolutions). (c) -3π

$$780^\circ - 360^\circ = 420^\circ$$

$$420^\circ - 360^\circ = \boxed{60^\circ}$$

(b) -50° is negative, so add 360° .

$$-50^\circ + 360^\circ = \boxed{310^\circ}$$

Finding Coterminal Angles

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(a) 780° is too large. Subtract 360° twice (that's two full revolutions).

$$780^\circ - 360^\circ = 420^\circ$$

$$420^\circ - 360^\circ = \boxed{60^\circ}$$

(c) -3π is negative, so we'll add two full revolutions (add 2π twice).

$$-3\pi + 2\pi = -\pi$$

(b) -50° is negative, so add 360° .

$$-50^\circ + 360^\circ = \boxed{310^\circ}$$

Finding Coterminal Angles

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(b) -50° is negative, so add 360° .

$$-50^\circ + 360^\circ = \boxed{310^\circ}$$

(c) -3π is negative, so we'll add two full revolutions (add 2π twice).

$$-3\pi + 2\pi = -\pi$$

$$-\pi + 2\pi = \boxed{\pi \text{ rad}}$$

$$(d) \frac{-\pi}{5}$$

Finding Coterminal Angles

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$$780^\circ - 360^\circ = 420^\circ$$

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(b) -50° is negative, so add 360° .

$$-50^\circ + 360^\circ = \boxed{310^\circ}$$

(c) -3π is negative, so we'll add two full revolutions (add 2π twice).

$$-3\pi + 2\pi = -\pi$$

$$-\pi + 2\pi = \boxed{\pi \text{ rad}}$$

(d) $\frac{-\pi}{5}$ is negative, so we'll add 2π .

$$\frac{-\pi}{5} + 2\pi = \frac{-\pi}{5} + \frac{10\pi}{5}$$

Finding Coterminal Angles

Example 3: Find a coterminal angle in $[0^\circ, 360^\circ)$ or $[0, 2\pi)$ for each of the following.

$$(a) 780^\circ \quad (b) -50^\circ \quad (c) -3\pi \text{ rad} \quad (d) \frac{-\pi}{5} \text{ rad}$$

(a) 780° is too large. Subtract 360° twice (that's two full revolutions).

$$780^\circ - 360^\circ = 420^\circ$$

$$420^\circ - 360^\circ = \boxed{60^\circ}$$

(b) -50° is negative, so add 360° .

$$-50^\circ + 360^\circ = \boxed{310^\circ}$$

(c) -3π is negative, so we'll add two full revolutions (add 2π twice).

$$-3\pi + 2\pi = -\pi$$

$$-\pi + 2\pi = \boxed{\pi \text{ rad}}$$

(d) $\frac{-\pi}{5}$ is negative, so we'll add 2π .

$$\begin{aligned} \frac{-\pi}{5} + 2\pi &= \frac{-\pi}{5} + \frac{10\pi}{5} \\ &= \boxed{\frac{9\pi}{5} \text{ rad}} \end{aligned}$$

Coterminal Angle Practice

Try It! 2: Find a coterminal angle in $[0^\circ, 360^\circ)$ or $[0, 2\pi)$ for each of the following.

(a) $\frac{-14\pi}{3}$ rad

(b) 1030°

(c) $\frac{24\pi}{11}$ rad

Trig via Coterminal Angles

Example 4: Use coterminal angles to evaluate each of the following.

$$(a) \sin\left(\frac{-11\pi}{4}\right) \quad (b) \cos(510^\circ) \quad (c) \tan\left(\frac{7\pi}{3}\right)$$

$$(a) \sin\left(\frac{-11\pi}{4}\right)$$

Trig via Coterminal Angles

Example 4: Use coterminal angles to evaluate each of the following.

$$(a) \sin\left(\frac{-11\pi}{4}\right) \quad (b) \cos(510^\circ) \quad (c) \tan\left(\frac{7\pi}{3}\right)$$

(a) $\sin\left(\frac{-11\pi}{4}\right)$ – add two full
revolutions to find a coterminal angle
in $[0, 2\pi)$

$$\sin\left(\frac{-11\pi}{4}\right) = \sin\left(\frac{-11\pi}{4} + 2\pi\right)$$

Trig via Coterminal Angles

Example 4: Use coterminal angles to evaluate each of the following.

$$(a) \sin\left(\frac{-11\pi}{4}\right) \quad (b) \cos(510^\circ) \quad (c) \tan\left(\frac{7\pi}{3}\right)$$

(a) $\sin\left(\frac{-11\pi}{4}\right)$ – add two full
revolutions to find a coterminal angle
in $[0, 2\pi)$

$$\begin{aligned}\sin\left(\frac{-11\pi}{4}\right) &= \sin\left(\frac{-11\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-11\pi}{4} + \frac{8\pi}{4}\right)\end{aligned}$$

Trig via Coterminal Angles

Example 4: Use coterminal angles to evaluate each of the following.

$$(a) \sin\left(\frac{-11\pi}{4}\right) \quad (b) \cos(510^\circ) \quad (c) \tan\left(\frac{7\pi}{3}\right)$$

(a) $\sin\left(\frac{-11\pi}{4}\right)$ – add two full
revolutions to find a coterminal angle
in $[0, 2\pi)$

$$\begin{aligned}\sin\left(\frac{-11\pi}{4}\right) &= \sin\left(\frac{-11\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-11\pi}{4} + \frac{8\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4}\right)\end{aligned}$$

Trig via Coterminal Angles

Example 4: Use coterminal angles to evaluate each of the following.

$$(a) \sin\left(\frac{-11\pi}{4}\right) \quad (b) \cos(510^\circ) \quad (c) \tan\left(\frac{7\pi}{3}\right)$$

(a) $\sin\left(\frac{-11\pi}{4}\right)$ – add two full revolutions to find a coterminal angle in $[0, 2\pi)$

$$\begin{aligned}\sin\left(\frac{-11\pi}{4}\right) &= \sin\left(\frac{-11\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-11\pi}{4} + \frac{8\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4} + 2\pi\right)\end{aligned}$$

Trig via Coterminal Angles

Example 4: Use coterminal angles to evaluate each of the following.

$$(a) \sin\left(\frac{-11\pi}{4}\right) \quad (b) \cos(510^\circ) \quad (c) \tan\left(\frac{7\pi}{3}\right)$$

(a) $\sin\left(\frac{-11\pi}{4}\right)$ – add two full revolutions to find a coterminal angle in $[0, 2\pi)$

$$\begin{aligned}\sin\left(\frac{-11\pi}{4}\right) &= \sin\left(\frac{-11\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-11\pi}{4} + \frac{8\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-3\pi}{4} + \frac{8\pi}{4}\right)\end{aligned}$$

Trig via Coterminal Angles

Example 4: Use coterminal angles to evaluate each of the following.

$$(a) \sin\left(\frac{-11\pi}{4}\right) \quad (b) \cos(510^\circ) \quad (c) \tan\left(\frac{7\pi}{3}\right)$$

(a) $\sin\left(\frac{-11\pi}{4}\right)$ – add two full revolutions to find a coterminal angle in $[0, 2\pi)$

$$\begin{aligned}\sin\left(\frac{-11\pi}{4}\right) &= \sin\left(\frac{-11\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-11\pi}{4} + \frac{8\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-3\pi}{4} + \frac{8\pi}{4}\right) \\ &= \sin\left(\frac{5\pi}{4}\right)\end{aligned}$$

Trig via Coterminal Angles

Example 4: Use coterminal angles to evaluate each of the following.

$$(a) \sin\left(-\frac{11\pi}{4}\right) \quad (b) \cos(510^\circ) \quad (c) \tan\left(\frac{7\pi}{3}\right)$$

(a) $\sin\left(\frac{-11\pi}{4}\right)$ – add two full

revolutions to find a coterminal angle
in $[0, 2\pi)$

(b) $\cos(510^\circ)$

$$\begin{aligned}\sin\left(\frac{-11\pi}{4}\right) &= \sin\left(\frac{-11\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-11\pi}{4} + \frac{8\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-3\pi}{4} + \frac{8\pi}{4}\right) \\ &= \sin\left(\frac{5\pi}{4}\right) \\ &= \boxed{\frac{-\sqrt{2}}{2}}\end{aligned}$$

Trig via Coterminal Angles

Example 4: Use coterminal angles to evaluate each of the following.

$$(a) \sin\left(-\frac{11\pi}{4}\right) \quad (b) \cos(510^\circ) \quad (c) \tan\left(\frac{7\pi}{3}\right)$$

(a) $\sin\left(\frac{-11\pi}{4}\right)$ – add two full revolutions to find a coterminal angle in $[0, 2\pi)$

$$\begin{aligned}\sin\left(\frac{-11\pi}{4}\right) &= \sin\left(\frac{-11\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-11\pi}{4} + \frac{8\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-3\pi}{4} + \frac{8\pi}{4}\right) \\ &= \sin\left(\frac{5\pi}{4}\right) \\ &= \boxed{\frac{-\sqrt{2}}{2}}\end{aligned}$$

(b) $\cos(510^\circ)$ – subtract a full revolution.

$$\cos(510^\circ) = \cos(510^\circ - 360^\circ)$$

Trig via Coterminal Angles

Example 4: Use coterminal angles to evaluate each of the following.

$$(a) \sin\left(-\frac{11\pi}{4}\right) \quad (b) \cos(510^\circ) \quad (c) \tan\left(\frac{7\pi}{3}\right)$$

(a) $\sin\left(\frac{-11\pi}{4}\right)$ – add two full revolutions to find a coterminal angle in $[0, 2\pi)$

$$\begin{aligned}\sin\left(\frac{-11\pi}{4}\right) &= \sin\left(\frac{-11\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-11\pi}{4} + \frac{8\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-3\pi}{4} + \frac{8\pi}{4}\right) \\ &= \sin\left(\frac{5\pi}{4}\right) \\ &= \boxed{\frac{-\sqrt{2}}{2}}\end{aligned}$$

(b) $\cos(510^\circ)$ – subtract a full revolution.

$$\begin{aligned}\cos(510^\circ) &= \cos(510^\circ - 360^\circ) \\ &= \cos(150^\circ)\end{aligned}$$

Trig via Coterminal Angles

Example 4: Use coterminal angles to evaluate each of the following.

$$(a) \sin\left(-\frac{11\pi}{4}\right) \quad (b) \cos(510^\circ) \quad (c) \tan\left(\frac{7\pi}{3}\right)$$

(a) $\sin\left(\frac{-11\pi}{4}\right)$ – add two full revolutions to find a coterminal angle in $[0, 2\pi)$

$$\begin{aligned}\sin\left(\frac{-11\pi}{4}\right) &= \sin\left(\frac{-11\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-11\pi}{4} + \frac{8\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-3\pi}{4} + \frac{8\pi}{4}\right) \\ &= \sin\left(\frac{5\pi}{4}\right) \\ &= \boxed{\frac{-\sqrt{2}}{2}}\end{aligned}$$

(b) $\cos(510^\circ)$ – subtract a full revolution.

$$\begin{aligned}\cos(510^\circ) &= \cos(510^\circ - 360^\circ) \\ &= \cos(150^\circ) \\ &= \boxed{\frac{-\sqrt{3}}{2}}\end{aligned}$$

(c) $\tan\left(\frac{7\pi}{3}\right)$

Trig via Coterminal Angles

Example 4: Use coterminal angles to evaluate each of the following.

$$(a) \sin\left(-\frac{11\pi}{4}\right) \quad (b) \cos(510^\circ) \quad (c) \tan\left(\frac{7\pi}{3}\right)$$

(a) $\sin\left(\frac{-11\pi}{4}\right)$ – add two full revolutions to find a coterminal angle in $[0, 2\pi)$

$$\begin{aligned}\sin\left(\frac{-11\pi}{4}\right) &= \sin\left(\frac{-11\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-11\pi}{4} + \frac{8\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-3\pi}{4} + \frac{8\pi}{4}\right) \\ &= \sin\left(\frac{5\pi}{4}\right) \\ &= \boxed{\frac{-\sqrt{2}}{2}}\end{aligned}$$

(b) $\cos(510^\circ)$ – subtract a full revolution.

$$\begin{aligned}\cos(510^\circ) &= \cos(510^\circ - 360^\circ) \\ &= \cos(150^\circ) \\ &= \boxed{\frac{-\sqrt{3}}{2}}\end{aligned}$$

(c) $\tan\left(\frac{7\pi}{3}\right)$ – subtract a full revolution.

$$\tan\left(\frac{7\pi}{3}\right) = \tan\left(\frac{7\pi}{3} - 2\pi\right)$$

Trig via Coterminal Angles

Example 4: Use coterminal angles to evaluate each of the following.

$$(a) \sin\left(-\frac{11\pi}{4}\right) \quad (b) \cos(510^\circ) \quad (c) \tan\left(\frac{7\pi}{3}\right)$$

(a) $\sin\left(\frac{-11\pi}{4}\right)$ – add two full revolutions to find a coterminal angle in $[0, 2\pi)$

$$\begin{aligned}\sin\left(\frac{-11\pi}{4}\right) &= \sin\left(\frac{-11\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-11\pi}{4} + \frac{8\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-3\pi}{4} + \frac{8\pi}{4}\right) \\ &= \sin\left(\frac{5\pi}{4}\right) \\ &= \boxed{\frac{-\sqrt{2}}{2}}\end{aligned}$$

(b) $\cos(510^\circ)$ – subtract a full revolution.

$$\begin{aligned}\cos(510^\circ) &= \cos(510^\circ - 360^\circ) \\ &= \cos(150^\circ) \\ &= \boxed{\frac{-\sqrt{3}}{2}}\end{aligned}$$

(c) $\tan\left(\frac{7\pi}{3}\right)$ – subtract a full revolution.

$$\begin{aligned}\tan\left(\frac{7\pi}{3}\right) &= \tan\left(\frac{7\pi}{3} - 2\pi\right) \\ &= \tan\left(\frac{7\pi}{3} - \frac{6\pi}{3}\right)\end{aligned}$$

Trig via Coterminal Angles

Example 4: Use coterminal angles to evaluate each of the following.

$$(a) \sin\left(-\frac{11\pi}{4}\right) \quad (b) \cos(510^\circ) \quad (c) \tan\left(\frac{7\pi}{3}\right)$$

(a) $\sin\left(\frac{-11\pi}{4}\right)$ – add two full revolutions to find a coterminal angle in $[0, 2\pi)$

$$\begin{aligned}\sin\left(\frac{-11\pi}{4}\right) &= \sin\left(\frac{-11\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-11\pi}{4} + \frac{8\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-3\pi}{4} + \frac{8\pi}{4}\right) \\ &= \sin\left(\frac{5\pi}{4}\right) \\ &= \boxed{\frac{-\sqrt{2}}{2}}\end{aligned}$$

(b) $\cos(510^\circ)$ – subtract a full revolution.

$$\begin{aligned}\cos(510^\circ) &= \cos(510^\circ - 360^\circ) \\ &= \cos(150^\circ) \\ &= \boxed{\frac{-\sqrt{3}}{2}}\end{aligned}$$

(c) $\tan\left(\frac{7\pi}{3}\right)$ – subtract a full revolution.

$$\begin{aligned}\tan\left(\frac{7\pi}{3}\right) &= \tan\left(\frac{7\pi}{3} - 2\pi\right) \\ &= \tan\left(\frac{7\pi}{3} - \frac{6\pi}{3}\right) \\ &= \tan\left(\frac{\pi}{3}\right)\end{aligned}$$

Trig via Coterminal Angles

Example 4: Use coterminal angles to evaluate each of the following.

$$(a) \sin\left(-\frac{11\pi}{4}\right) \quad (b) \cos(510^\circ) \quad (c) \tan\left(\frac{7\pi}{3}\right)$$

(a) $\sin\left(\frac{-11\pi}{4}\right)$ – add two full revolutions to find a coterminal angle in $[0, 2\pi)$

$$\begin{aligned}\sin\left(\frac{-11\pi}{4}\right) &= \sin\left(\frac{-11\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-11\pi}{4} + \frac{8\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-3\pi}{4} + \frac{8\pi}{4}\right) \\ &= \sin\left(\frac{5\pi}{4}\right) \\ &= \boxed{\frac{-\sqrt{2}}{2}}\end{aligned}$$

(b) $\cos(510^\circ)$ – subtract a full revolution.

$$\begin{aligned}\cos(510^\circ) &= \cos(510^\circ - 360^\circ) \\ &= \cos(150^\circ) \\ &= \boxed{\frac{-\sqrt{3}}{2}}\end{aligned}$$

(c) $\tan\left(\frac{7\pi}{3}\right)$ – subtract a full revolution.

$$\begin{aligned}\tan\left(\frac{7\pi}{3}\right) &= \tan\left(\frac{7\pi}{3} - 2\pi\right) \\ &= \tan\left(\frac{7\pi}{3} - \frac{6\pi}{3}\right) \\ &= \tan\left(\frac{\pi}{3}\right) \\ &= \frac{\sqrt{3}/2}{1/2}\end{aligned}$$

Trig via Coterminal Angles

Example 4: Use coterminal angles to evaluate each of the following.

$$(a) \sin\left(-\frac{11\pi}{4}\right) \quad (b) \cos(510^\circ) \quad (c) \tan\left(\frac{7\pi}{3}\right)$$

(a) $\sin\left(\frac{-11\pi}{4}\right)$ – add two full revolutions to find a coterminal angle in $[0, 2\pi)$

$$\begin{aligned}\sin\left(\frac{-11\pi}{4}\right) &= \sin\left(\frac{-11\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-11\pi}{4} + \frac{8\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4}\right) \\ &= \sin\left(\frac{-3\pi}{4} + 2\pi\right) \\ &= \sin\left(\frac{-3\pi}{4} + \frac{8\pi}{4}\right) \\ &= \sin\left(\frac{5\pi}{4}\right) \\ &= \boxed{\frac{-\sqrt{2}}{2}}\end{aligned}$$

(b) $\cos(510^\circ)$ – subtract a full revolution.

$$\begin{aligned}\cos(510^\circ) &= \cos(510^\circ - 360^\circ) \\ &= \cos(150^\circ) \\ &= \boxed{\frac{-\sqrt{3}}{2}}\end{aligned}$$

(c) $\tan\left(\frac{7\pi}{3}\right)$ – subtract a full revolution.

$$\begin{aligned}\tan\left(\frac{7\pi}{3}\right) &= \tan\left(\frac{7\pi}{3} - 2\pi\right) \\ &= \tan\left(\frac{7\pi}{3} - \frac{6\pi}{3}\right) \\ &= \tan\left(\frac{\pi}{3}\right) \\ &= \frac{\sqrt{3}/2}{1/2} \\ &= \boxed{\sqrt{3}}\end{aligned}$$

Trig Evaluation Practice

Try It! 3: Use coterminal angles and the unit circle to evaluate each of the following.

(a) $\tan(-450^\circ)$

(b) $\sin\left(\frac{21\pi}{6}\right)$

(c) $\cos\left(\frac{-5\pi}{3}\right)$

Exit Ticket Task

Navigate to [our MAT142 Exit Ticket Form](#), answer the questions, and complete the *task* below.

Note. Today's discussion is listed as [19. Angles and Measure](#)



Task: Consider the angle $\theta = \frac{-17\pi}{6}$.

(a) Find a coterminal angle in $[0, 2\pi)$.

(b) Use the unit circle to evaluate $\sin(\theta)$ and $\cos(\theta)$.

Summary and Next Time...

Ideas From Today

- Angles are measured in **degrees** (one full revolution is 360°) or **radians** (one full revolution is 2π rad). Convert by multiplying by $\frac{2\pi \text{ rad}}{360^\circ}$ or $\frac{360^\circ}{2\pi \text{ rad}}$.
- Counter-clockwise angles are positive; clockwise are negative. Angles outside $[0^\circ, 360^\circ)$ represent multiple revolutions.
- For an angle θ with terminal point (x, y) on the unit circle: $\sin \theta = y$, $\cos \theta = x$, $\tan \theta = y/x$.
- **Coterminal angles** share the same terminal point on the unit circle. Find one in $[0^\circ, 360^\circ)$ or $[0, 2\pi)$ by adding or subtracting full revolutions.

Looking Ahead

- Next class we study the graphs of trigonometric functions — their shape, period, amplitude, and how transformations apply.
- We also define inverse trigonometric functions and use them to
 - find inverses of general trigonometric functions.
 - solve trigonometric equations.
- Understanding the unit circle values from today is essential preparation for that work.

Next Time:

Graphs of Trigonometric Functions, Inverses, and Solving Equations

Homework:

Begin Homework 12 on MyOpenMath