Precalculus
Homework
Trig cofunction identities and angle-sum formulas

1. Convert from degrees to radians.

   (a) 15°.
   answer: $\frac{\pi}{12} \approx 0.261799388$

   (b) 30°.
   answer: $\frac{\pi}{6} \approx 0.523598776$

   (c) 36°.
   answer: $\frac{\pi}{5} \approx 0.628318531$

   (d) 45°.
   answer: $\frac{\pi}{4} \approx 0.785398163$

   (e) 60°.
   answer: $\frac{\pi}{3} \approx 1.047197551$

   (f) 75°.
   answer: $\frac{5\pi}{12} \approx 1.308997$

   (g) 90°.
   answer: $\frac{\pi}{2}$

   (h) 120°.
   answer: $\frac{2\pi}{3}$

   (i) 135°.
   answer: $\frac{3\pi}{4}$

   (j) 150°.
   answer: $\frac{5\pi}{6}$

   (k) 180°.
   answer: π

   (l) 225°.
   answer: $\frac{5\pi}{4}$

   (m) 270°.
   answer: $\frac{3\pi}{2}$

   (n) 305°.
   answer: $\frac{61\pi}{36} \approx 5.323254$

   (o) 360°.
   answer: 2π

   (p) 405°.
   answer: $\frac{9\pi}{4}$

   (q) 1200°.
   answer: $\frac{20\pi}{3}$

   (r) -900°.
   answer: -5π

   (s) -2014°.
   answer: $-\frac{1007}{90}\pi \approx -35.150931$

2. Convert from radians to degrees. The answer key has not been proofread, use with caution.

   (a) 4π.
   answer: 720°

   (b) $-\frac{7}{6}\pi$.
   answer: -210°

   (c) $\frac{7}{12}\pi$.
   answer: 105°

   (d) $\frac{4}{3}\pi$.
   answer: 240°

   (e) $-\frac{3}{8}\pi$.
   answer: -67.5°

   (f) 2014π.
   answer: 362520°

   (g) 5.
   answer: $\left(\frac{900}{\pi}\right)^\circ \approx 286^\circ$

   (h) -2014.
   answer: -362520°

3. Find the indicated circle arc-length. The answer key has not been proofread, use with caution.

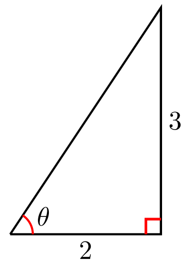
   (a) Circle of radius 3, arc of measure 36°.
   answer: $\frac{3\pi}{5} \approx 1.884956$

   (b) Circle of radius $\frac{1}{2}$, arc of measure 100°.
   answer: $\frac{5\pi}{18} \approx 0.872665$

   (c) Circle of radius 1, arc of measure 3 (radians).
   answer: 3

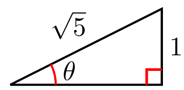
   (d) Circle of radius 3, arc of measure 300°.
   answer: $5\pi \approx 15.707963$

4. Find the 6 trigonometric functions of the indicated angle in the indicated right triangle.



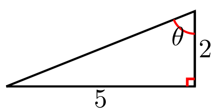
(a)

answer: $\sin\theta = \frac{3}{13}\sqrt{13}$, $\cos\theta = \frac{2}{13}\sqrt{13}$, $\tan\theta = \frac{3}{2}$, $\cot\theta = \frac{2}{3}$, $\sec\theta = \frac{\sqrt{13}}{2}$, $\csc\theta = \frac{\sqrt{13}}{3}$



(b)

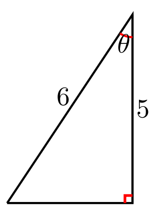
answer: $\sin\theta = \frac{\sqrt{5}}{5}$, $\cos\theta = \frac{2\sqrt{5}}{5}$, $\tan\theta = \frac{1}{2}$, $\cot\theta = 2$, $\sec\theta = \frac{\sqrt{5}}{2}$, $\csc\theta = \sqrt{5}$



(c)

answer: $\sin\theta = \frac{5}{\sqrt{29}} = \frac{5\sqrt{29}}{29}$, $\cos\theta = \frac{2}{\sqrt{29}} = \frac{2\sqrt{29}}{29}$, $\tan\theta = \frac{5}{2}$, $\cot\theta = \frac{2}{5}$, $\sec\theta = \frac{\sqrt{29}}{2}$, $\csc\theta = \frac{\sqrt{29}}{5}$

(d)



answer: $\sin\theta = \frac{\sqrt{11}}{6}$, $\cos\theta = \frac{5}{6}$, $\tan\theta = \frac{\sqrt{11}}{5}$, $\cot\theta = \frac{5}{\sqrt{11}} = \frac{5\sqrt{11}}{11}$, $\sec\theta = \frac{6}{5}$, $\csc\theta = \frac{6}{\sqrt{11}} = \frac{6\sqrt{11}}{11}$

5. Find the exact value of the trigonometric function (using radicals).

(a) $\cos 135°$.

answer:

(b) $\sin 225°$.

answer:

(c) $\cos 495°$.

answer:

(d) $\sin 560°$.

answer:

(e) $\sin\left(\frac{3\pi}{2}\right)$.

answer:

(f) $\cos\left(\frac{11\pi}{6}\right)$.

answer:

(g) $\sin\left(\frac{2015\pi}{3}\right)$.

answer:

(h) $\cos\left(\frac{17\pi}{3}\right)$.

answer:

6. Find all solutions of the equation in the interval $[0, 2\pi)$. The answer key has not been proofread, use with caution.

(a) $\sin x = -\frac{\sqrt{2}}{2}$.

answer: $x = \frac{5\pi}{4}, \frac{7\pi}{4}$

(b) $\cos x = \frac{\sqrt{3}}{2}$.

answer: $x = \frac{\pi}{6}, \frac{11\pi}{6}$

(c) $\sin(3x) = \frac{1}{2}$.

answer: $x = \frac{\pi}{18}, \frac{5\pi}{18}, \frac{13\pi}{18}, \frac{17\pi}{18}, \frac{25\pi}{18}, \frac{16\pi}{9}$

(d) $\cos(7x) = 0$.

answer: $x = \frac{\pi}{14}, \frac{3\pi}{14}, \frac{5\pi}{14}, \frac{\pi}{2}, \frac{9\pi}{14}, \frac{11\pi}{14}, \frac{13\pi}{14}, \frac{15\pi}{14}, \frac{17\pi}{14}, \frac{19\pi}{14}, \frac{3\pi}{2}, \frac{23\pi}{14}, \frac{25\pi}{14}, \frac{27\pi}{14}$

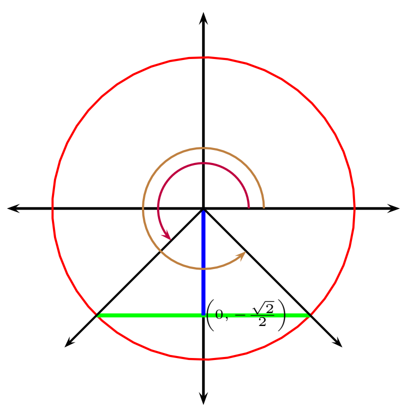
(e) $\cos\left(3x + \frac{\pi}{2}\right) = 0$.

answer: $x = 0, \frac{\pi}{3}, \frac{2\pi}{3}, \pi, \frac{4\pi}{3}, \frac{5\pi}{3}$

(f) $\sin\left(5x - \frac{\pi}{3}\right) = 0$.

answer: $x = \frac{\pi}{15}, \frac{4\pi}{15}, \frac{7\pi}{15}, \frac{2\pi}{3}, \frac{13\pi}{15}, \frac{16\pi}{15}, \frac{19\pi}{15}, \frac{22\pi}{15}, \frac{5\pi}{3}, \frac{28\pi}{15}$

Solution. 6.a



$$\sin x = -\frac{\sqrt{2}}{2}$$

Since $\sin x$ is negative it must be either in Quadrant III or IV. Therefore the angle x is coterminal either with $225° = \frac{5\pi}{4}$ (Quadrant III) or $315° = \frac{7\pi}{4}$ (Quadrant IV).

Case 1. x is coterminal with $225° = \frac{5\pi}{4}$. We can compute

$$\begin{array}{rcll} x &=& \frac{5\pi}{4} + 2k\pi & \Big| \; k \text{ is any integer} \\ x &=& \frac{5\pi}{4} + \frac{8k\pi}{4} & \\ x &=& \frac{5\pi + 8k\pi}{4} & \\ x &=& \frac{\pi(5+8k)}{4} & \end{array}$$

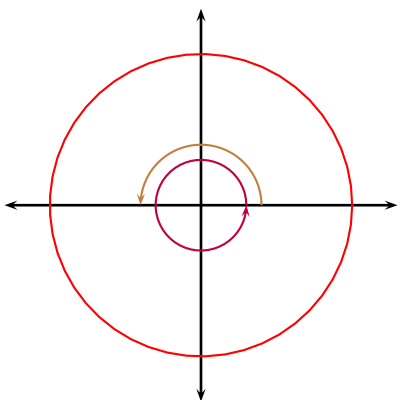
We are looking for solutions in the interval $[0, 2\pi)$ and so we must discard those values of the integer k for which $\frac{\pi(7+8k)}{4}$ is negative or is greater than or equal to 2π. Therefore the only solution in this case is $x = \frac{5\pi}{4}$.

Case 2.

$$
\begin{aligned}
x &= \frac{7\pi}{4} + 2k\pi \\
x &= \frac{7\pi}{4} + \frac{8k\pi}{4} \\
x &= \frac{7\pi + 8k\pi}{4} \\
x &= \frac{\pi(7+8k)}{4}
\end{aligned}
$$

We are looking for solutions in the interval $[0, 2\pi)$ and so we must discard those values of the integer k for which $\frac{\pi(7+8k)}{4}$ is negative or is greater than or equal to 2π. Therefore the only solution in this case is $x = \frac{7\pi}{4}$.

Solution. 6.f



$$
\sin\left(5x - \tfrac{\pi}{3}\right) = 0
$$

Since $\sin 0 = 0$ and $\sin 180^\circ = \sin \pi = 0$, the angle $5x - \frac{\pi}{3}$ must be coterminal with 0 or π.

Case 1. $5x - \frac{\pi}{3}$ is coterminal with 0. We compute

$$
\begin{aligned}
5x - \frac{\pi}{3} &= 0 + 2k\pi \\
5x &= \frac{\pi}{3} + 2k\pi \\
x &= \frac{\frac{\pi}{3} + 2k\pi}{5} \\
x &= \frac{\frac{\pi}{3} + \frac{6k\pi}{3}}{5} \\
x &= \frac{\frac{\pi + 6k\pi}{3}}{5} \\
x &= \frac{\pi + 6k\pi}{15} \\
x &= \frac{\pi(1+6k)}{15} \\
x &= \cancel{\ldots}, \frac{\pi[1+6(0)]}{15}, \frac{\pi[1+6(1)]}{15}, \frac{\pi[1+6(2)]}{15}, \frac{\pi(1+12)}{15}, \frac{\pi[1+6(3)]}{15}, \frac{\pi[1+6(4)]}{15}, \cancel{\ldots} \\
x &= \frac{\pi}{15}, \frac{7\pi}{15}, \frac{13\pi}{15}, \frac{19\pi}{15}, \frac{25\pi}{15}.
\end{aligned}
$$

Discard other values of k as they yield angles outside of $[0, 2\pi)$

Case 2.

$$
\begin{aligned}
5x-\frac{\pi}{3} &= \pi+2k\pi\\
5x &= \pi+\frac{\pi}{3}+2k\pi\\
5x &= \frac{4\pi}{3}+2k\pi\\
x &= \frac{\frac{4\pi}{3}+2k\pi}{5}\\
x &= \frac{\frac{4\pi}{3}+\frac{6k\pi}{3}}{5}\\
x &= \frac{\frac{4\pi+6k\pi}{3}}{5}\\
x &= \frac{4\pi+6k\pi}{15}\\
x &= \frac{2\pi(2+3k)}{15}\\
x &= \cancel{\dots}, \frac{2\pi[2+3(0)]}{15}, \frac{2\pi[2+3(1)]}{15}, \frac{2\pi[2+3(2)]}{15}, \frac{2\pi[2+3(3)]}{15}, \frac{2\pi[2+3(4)]}{15}, \cancel{\dots}\\
x &= \frac{4\pi}{15}, \frac{10\pi}{15}, \frac{16\pi}{15}, \frac{22\pi}{15}, \frac{28\pi}{15}.
\end{aligned}
$$

Discard other values of k as they yield angles outside of $[0, 2\pi)$

Our final answer (combined from the two cases) is $x = \frac{\pi}{15}, \frac{4\pi}{15}, \frac{7\pi}{15}, \frac{2\pi}{3}, \frac{13\pi}{15}, \frac{16\pi}{15}, \frac{19\pi}{15}, \frac{22\pi}{15}, \frac{5\pi}{3}$ or $\frac{28\pi}{15}$.

7. Use the known values of $\sin 30^\circ, \cos 30^\circ, \sin 45^\circ, \cos 45^\circ, \sin 60^\circ, \cos 60^\circ, \dots$, the angle sum formulas and the cofunction identities to find an exact value (using radicals) for the trigonometric function.

   (a) The six trigonometric functions of $105^\circ = 45^\circ + 60^\circ$:

   - $\sin(105^\circ)$.

     answer: $\frac{\sqrt{6}+\sqrt{2}}{4}$

   - $\cos(105^\circ)$. Should your answer be a positive or a negative number?

     answer: $\frac{\sqrt{2}-\sqrt{6}}{4}$

   - $\tan(105^\circ)$.

     answer: $-\sqrt{3}-2$

   - $\cot(105^\circ)$.

     answer: $\sqrt{3}-2$

   - $\sec(105^\circ)$.

     answer: $-\sqrt{6}-\sqrt{2}$

   - $\csc(105^\circ)$.

     answer: $\sqrt{6}-\sqrt{2}$

   (b) The six trigonometric functions of $\frac{\pi}{12} = \frac{\pi}{3} - \frac{\pi}{4}$:

   - $\sin\left(\frac{\pi}{12}\right)$.

     answer: $\frac{\sqrt{6}-\sqrt{2}}{4}$

   - $\cos\left(\frac{\pi}{12}\right)$. Should $\sin\left(\frac{\pi}{12}\right)$ be larger or smaller than $\cos\left(\frac{\pi}{12}\right)$?

     answer: $\frac{\sqrt{2}+\sqrt{6}}{4}$

   - $\tan\left(\frac{\pi}{12}\right)$.

     answer: $-\sqrt{3}+2$

   - $\cot\left(\frac{\pi}{12}\right)$.

     answer: $\sqrt{3}+2$

   - $\sec\left(\frac{\pi}{12}\right)$.

     answer: $\sqrt{6}-\sqrt{2}$

   - $\csc\left(\frac{\pi}{12}\right)$.

     answer: $\sqrt{6}+\sqrt{2}$

8. Simplify to a trigonometric function of the angle θ. The answer key has not been proofread, use with caution.

   (a) $\sin\left(\frac{\pi}{2}-\theta\right)$.

   answer: $\cos\theta$

   (b) $\cos\left(\frac{13\pi}{2}-\theta\right)$.

   answer: $\sin\theta$

   (c) $\tan(\pi-\theta)$

   answer: $-\tan\theta$

   (d) $\cot\left(\frac{3\pi}{2}-\theta\right)$

   answer: $\tan\theta$

   (e) $\csc\left(\frac{3\pi}{2}+\theta\right)$

   answer: $\sec\theta$

9. Using the power-reducing formulas, rewrite the expression in terms of first powers of the cosines and sines of multiples of the angle θ.

   (a) $\sin^4 \theta$.

   answer: $\frac{1}{8}\cos(4\theta) - \frac{1}{2}\cos(2\theta) + \frac{3}{8}$

   (b) $\cos^4 \theta$.

   answer: $\frac{1}{8}\cos(4\theta) + \frac{1}{2}\cos(2\theta) + \frac{3}{8}$

   (c) $\sin^6 \theta$.

   answer: $\sin^6\theta = -\frac{1}{32}\cos(6\theta) + \frac{3}{16}\cos(4\theta) - \frac{15}{32}\cos(2\theta) + \frac{5}{16}$

   (d) $\cos^6 \theta$.

   answer: $\cos^6\theta = \frac{1}{32}\cos(6\theta) + \frac{3}{16}\cos(4\theta) + \frac{15}{32}\cos(2\theta) + \frac{5}{16}$

10. Use the sum-to-product formulas to find all solutions of the trigonometric equation in the interval $[0, 2\pi)$.

    Please note that typing a query such as "solve(sin(x)+sin (3x)=0)" at `www.wolframalpha.com` will provide you with a correct answer and a function plot.

    (a) $\sin(x) + \sin(3x) = 0$.

    answer: $x = 0, \frac{\pi}{2}, \pi, \frac{3\pi}{2}$

    (b) $\cos(x) + \cos(-3x) = 0$.

    answer: $x = \frac{\pi}{4}, \frac{\pi}{2}, \frac{3\pi}{4}, \pi, \frac{5\pi}{4}, \frac{3\pi}{2}, \frac{7\pi}{4}$

    (c) $\sin(x) - \sin(3x) = 0$.

    answer: $x = 0, \frac{\pi}{4}, \frac{3\pi}{4}, \pi, \frac{5\pi}{4}, \frac{7\pi}{4}$

    (d) $\cos(2x) - \cos(3x) = 0$.

    answer: $x = 0, \frac{2}{5}\pi, \frac{4\pi}{5}, \frac{6\pi}{5}, \frac{8\pi}{5}$