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VCE Mathematical Methods ½
Circular Function II [4.2]
Workbook

Outline:

Learning Objectives:

- [ ] **MM12 [4.2.1]** - Solve General Solutions for Trigonometric Functions
- [ ] **MM12 [4.2.2]** - Solve Hidden Quadratic Equations for Trigonometric Functions

Section A: Particular and General Solutions

Sub-Section: Recap of Particular Solutions

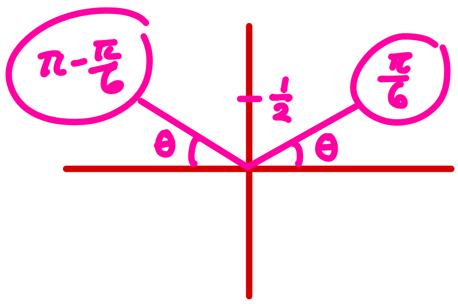
Active Recall: Period of trigonometric function

$$\textbf{Period of } \sin(nx) \textbf{ and } \cos(nx) \textbf{ functions} = \_\_\_\_\_\_\_\_$$

$$\textbf{Period of } \tan(nx) \textbf{ functions} = \_\_\_\_\_\_\_\_$$

$$\textbf{where } n = \textbf{coefficient of } x \textbf{ and } n > 0$$

Discussion: How often would the solution to $\sin(x) = \frac{1}{2}$ repeat?



$\Rightarrow$ every period (repeats)

Active Recall: Particular Solutions

- Solving trigonometric equations **for finite solutions.**
- **Steps**
  1. Make the trigonometric function the subject.
  2. Find the necessary ________ for one period.
  3. Solve for x by equating the necessary angles to the ________ of the trigonometric functions.
  4. Add and subtract the ________ to find all other solutions in the domain.

Question 1 Walkthrough.

Solve the following equation for x over the domain specified:

$$2\cos(2x) + \sqrt{2} = 0 \text{ for } x \in [0, 2\pi]$$

1. Make Trig the Subject:

$$\cos(2x) = \frac{-\sqrt{2}}{2}$$

2/3. Find angles for 1 period:

① Find θ: (exact value)

$$\cos\left(\frac{\pi}{4}\right) = \frac{\sqrt{2}}{2} \quad \text{(ref angle)}$$

$\theta = \frac{\pi}{4}$

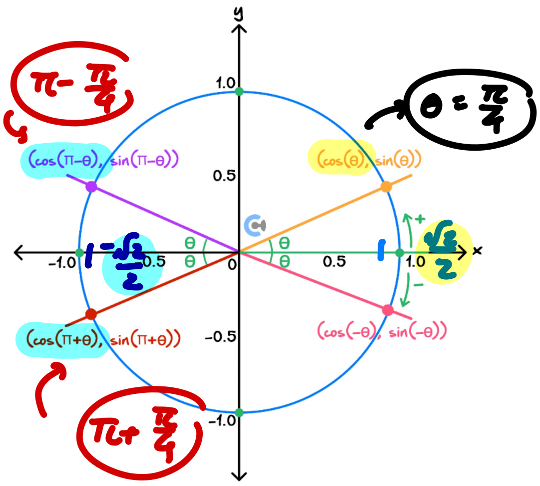
② Find other angle(s):

$$\cos(2x) = \frac{-\sqrt{2}}{2} \Rightarrow Q2, Q3$$

$\pi - \theta, \pi + \theta$

$$2x = \pi - \frac{\pi}{4}, \pi + \frac{\pi}{4}$$

$$\therefore x = \frac{3\pi}{8}, \frac{5\pi}{8}$$



4. ± Period For All Solutions

$$\therefore P = \frac{2\pi}{2} = \frac{8\pi}{8}$$

$$D \in \left[0, \frac{16\pi}{8}\right]$$

$$\therefore x = \frac{3\pi}{8}, \frac{11\pi}{8}, \frac{5\pi}{8}, \frac{13\pi}{8}$$

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Question 2

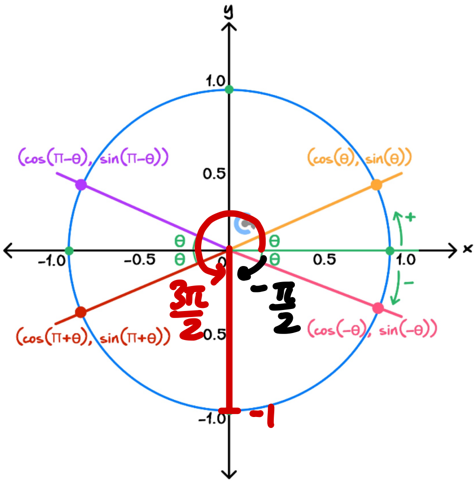
Solve the following equations for x over the domains specified:

a. $\sin(3x) = -1$ for $x \in [-\pi, \pi]$.

2/3. Find angle(s) for 1 period:

$$3x = \frac{3\pi}{2}$$

$$\therefore x = \frac{\pi}{2}$$



4. ± Period For All Solutions

$$\therefore P = \frac{2\pi}{3}$$

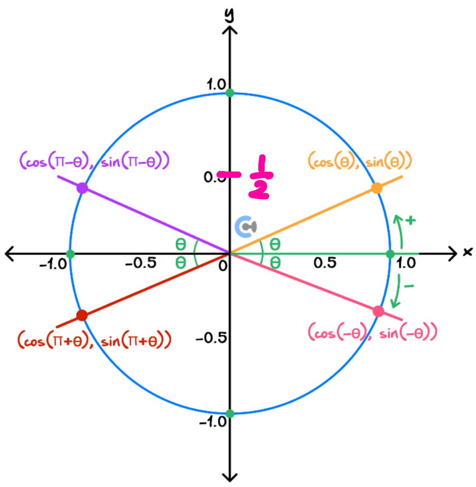
$D \in [-\pi, \pi]$

$$\therefore x = -\frac{5\pi}{6}, -\frac{\pi}{6}, \frac{\pi}{2}$$

b. $2\sin\left(2x - \frac{\pi}{2}\right) - 1 = 0$ for $x \in [0, 2\pi]$.

1. Make Trig the Subject:

$$\sin\left(2x - \frac{\pi}{2}\right) = \frac{1}{2} \Rightarrow \text{Q1, Q2} \quad \theta, \pi - \theta$$



2/3. Find angle(s) for 1 period:

① Find θ: (exact value)

$$\sin\left(\frac{\pi}{6}\right) = \frac{1}{2} \qquad \text{R.A}$$

② Find other angle(s):

$$\therefore 2x - \frac{\pi}{2} = \frac{\pi}{6}, \pi - \frac{\pi}{6}$$

$$2x = \frac{4\pi}{6}, \frac{8\pi}{6}$$

$$\therefore x = \frac{\pi}{3}, \frac{2\pi}{3}$$

4. ± Period For All Solutions

$$\therefore P = \frac{2\pi}{2} = \frac{3\pi}{3}$$

$D \in [0, \frac{6\pi}{3}]$

$$\therefore x = \frac{\pi}{3}, \frac{4\pi}{3}, \frac{2\pi}{3}, \frac{5\pi}{3}$$

Question 3 Walkthrough.

Solve the following equations for x over the domains specified:

$$3\tan(2x-\pi)-3\sqrt{3}=0 \text{ for } x\in[0,2\pi]$$

1. Make Trig the Subject:

$$\tan(2x-\pi)=\frac{3\sqrt{3}}{3}=\sqrt{3}$$

2/3. Find angle(s) for 1 period:

① Find θ: (exact value)

$$\tan\left(\frac{\pi}{3}\right)=\sqrt{3} \quad (R.A)$$

θ

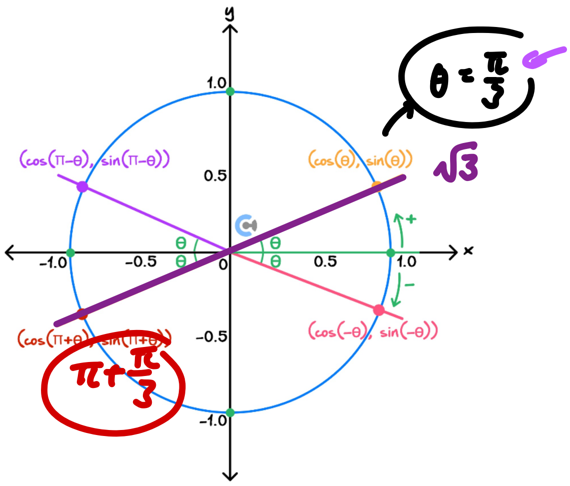
② Find other angle(s):

$$\therefore 2x-\pi=\frac{\pi}{3}$$

★ ONLY NEED 1 ANGLE

$$2x=\frac{4\pi}{3}$$

$$\therefore x=\frac{2\pi}{3}$$



4. ± Period For All Solutions

$$\therefore P=\frac{\pi}{2}$$

★ $P=\frac{\pi}{n}$

$D \in [0,2\pi]$

$$\therefore x=\frac{\pi}{6},\frac{2\pi}{3},\frac{7\pi}{6},\frac{10\pi}{6}$$

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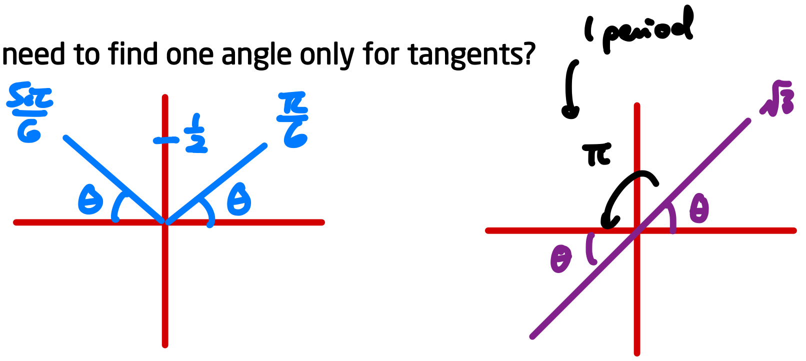
Discussion: Why do we need to find one angle only for tangents?



Question 4

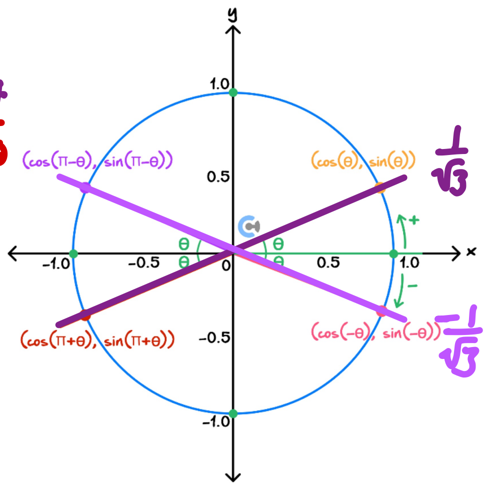
Solve the following equation for x over the domain specified:

$$\sqrt{3}\tan\left(x-\frac{\pi}{4}\right)+1=0 \text{ for } x\in(0,3\pi)$$

1. Make Trig the Subject:

$\tan(x-\frac{\pi}{4}) = \frac{-1}{\sqrt{3}} \Rightarrow Q2, Q4$

$\pi-\theta, -\theta$



2/3. Find angle(s) for 1 period:

① Find θ: (exact value)

$\tan(\frac{\pi}{6}) = \frac{1}{\sqrt{3}}$ (R.A)

② Find other angle(s):

$\therefore x-\frac{\pi}{4} = \pi-\frac{\pi}{6}$

$x = \frac{5\pi}{6}+\frac{\pi}{4} = \frac{26\pi}{24}$

$\therefore x = \frac{13\pi}{12}$

4. ± Period For All Solutions

$\therefore P: \frac{\pi}{1} = \frac{12\pi}{12}$

DE $(0, \frac{36\pi}{12})$

$\therefore x = \frac{\pi}{12}, \frac{13\pi}{12}, \frac{25\pi}{12}$

Sub-Section: General Solutions

integer

Discussion: How many solutions would there be for $x \in R$?

± WHOLE periods

infinite solutions ⇒ General form parameter

base angle + Period · n

General Solutions

- Finding infinite solutions to a trigonometric equation.
- Steps
  1. Make the trigonometric function the subject.
  2. Find the necessary angle for one period.
  3. Solve for x by equating the necessary angles to the inside of the trigonometric functions.
  4. Add $Period \cdot n$ where $n \in Z$.

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Question 5 Walkthrough.

Find the general solutions to the following equations:

$$2\sin\left(2x+\frac{\pi}{2}\right)-1=0$$

y (+)

$$\sin\left(2x+\frac{\pi}{2}\right)=\frac{1}{2}$$

Q1 Q2

$$2x+\frac{\pi}{2}=\frac{\pi}{6},\ \pi-\frac{\pi}{6}$$

$$2x=-\frac{2\pi}{6},\ \frac{2\pi}{6}$$

$$\therefore x=-\frac{\pi}{6},\ \frac{\pi}{6}$$

$$\therefore P=\frac{2\pi}{2}=\pi$$

$$\therefore x=\pm\frac{\pi}{6}+\pi\cdot n,\ n\in Z$$

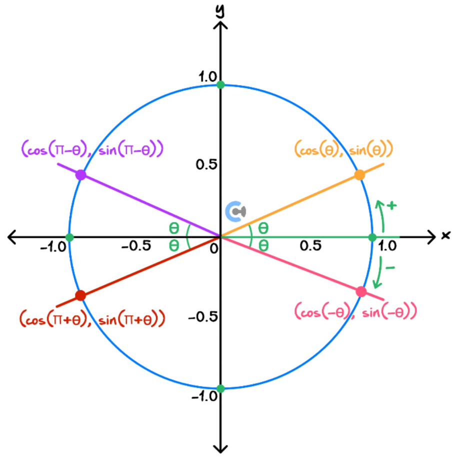
Active Recall: General Solutions

Steps

1. Make the trigonometric function the subject.
2. Find the necessary ______ for one period.
3. Solve for x by equating the necessary angles to the inside of the trigonometric functions.
4. Add ______ where $n \in Z$.

Question 6

Find the general solutions to the following equations:



a. $-2\sin\left(3x+\frac{\pi}{4}\right)=\sqrt{2}$

$\sin\left(3x+\frac{\pi}{4}\right) = \frac{-\sqrt{2}}{2} \Rightarrow$ Q3, Q4: $\pi+\theta$, $-\theta$

$\sin\left(\frac{\pi}{4}\right) = \frac{\sqrt{2}}{2}$, $\theta = \frac{\pi}{4}$

$\therefore 3x+\frac{\pi}{4} = \pi+\frac{\pi}{4}, -\frac{\pi}{4}$

$3x = \pi, -\frac{\pi}{2}$

$\therefore x = \frac{\pi}{3}, -\frac{\pi}{6}$

Period $= \frac{2\pi}{3}$

$\therefore x = \frac{\pi}{3} + \frac{2\pi}{3}n, n \in Z$

$\therefore x = -\frac{\pi}{6} + \frac{2\pi}{3}n, n \in Z$

b. $2\cos\left(2x+\frac{\pi}{6}\right)=1$

$\cos\left(2x+\frac{\pi}{6}\right) = \frac{1}{2}$ (+): Q1, Q4

$2x+\frac{\pi}{6} = \frac{\pi}{3}, -\frac{\pi}{3}$

$2x = \frac{\pi}{6}, -\frac{\pi}{2}$

$\therefore x = \frac{\pi}{12}, -\frac{\pi}{4}$

$\therefore P = \frac{2\pi}{2} = \pi$

$\therefore x = \frac{\pi}{12} + \pi n, n \in Z$

OR

$\therefore x = -\frac{\pi}{4} + \pi n, n \in Z$

c. $4\sin\left(3x - \frac{\pi}{6}\right) = 2$

y $\quad$ (4)

$\sin\left(3x - \frac{\pi}{6}\right) = \frac{1}{2}$

$\quad$ Q1 $\quad$ Q2

$3x - \frac{\pi}{6} = \frac{\pi}{6}, \frac{5\pi}{6}$

$3x = \frac{\pi}{3}, \pi$

$\therefore x = \frac{\pi}{9}, \frac{\pi}{3}$

$\therefore \text{Period} = \frac{2\pi}{3}$

$\therefore x = \frac{\pi}{9} + \frac{2\pi}{3}n, \ n \in Z$

OR

$\therefore x = \frac{\pi}{3} + \frac{2\pi}{3}n, \ n \in Z$

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Question 7 Walkthrough.

Find the general solutions to the following equations:

$$\tan\left(\frac{1}{2}x-\pi\right)-\frac{1}{\sqrt{3}}=0$$

$$\tan\left(\frac{1}{2}x-\pi\right)=\frac{1}{\sqrt{3}}$$

$$\frac{1}{2}x-\pi=\frac{\pi}{6}$$

$$\frac{1}{2}x=\frac{7\pi}{6}$$

$$\therefore x=\frac{7\pi}{3}$$

$$\therefore P=\frac{\pi}{\left(\frac{1}{2}\right)}=2\pi$$

$$\therefore x=\frac{7\pi}{3}+2\pi n,\ n\in\mathbb{Z}$$

NOTE: We only need to find one angle for tangents!

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Question 8

Find the general solutions to the following equations:

a. $\sqrt{3} - \tan\left(2\left(x + \frac{\pi}{3}\right)\right) = 0$ $\rightarrow$ $\therefore P = \frac{\pi}{2}$

$\tan\left(2x + \frac{2\pi}{3}\right) = \sqrt{3}$

$2x + \frac{2\pi}{3} = \frac{\pi}{3}$

$2x = -\frac{\pi}{3} \Rightarrow \therefore x = -\frac{\pi}{6}$

$\therefore x = -\frac{\pi}{6} + \frac{\pi}{2}n, n \in Z$

b. $2\tan\left(2x - \frac{\pi}{4}\right) = 2$

$\tan\left(2x - \frac{\pi}{4}\right) = 1$ $\quad \therefore P = \frac{\pi}{2}$

$2x - \frac{\pi}{4} = \frac{\pi}{4}$

$\therefore x = \frac{\pi}{4} \Rightarrow \therefore x = \frac{\pi}{4} + \frac{\pi}{2}n, n \in Z$

c. $\sqrt{3}\tan\left(3x - \frac{\pi}{6}\right) = 1$

$\tan\left(3x - \frac{\pi}{6}\right) = \frac{1}{\sqrt{3}}$ $\quad \therefore P = \frac{\pi}{3}$

$3x - \frac{\pi}{6} = \frac{\pi}{6}$ $\rightarrow \therefore x = \frac{\pi}{9} + \frac{\pi}{3}n, n \in Z$

$3x = \frac{\pi}{3} \Rightarrow \therefore x = \frac{\pi}{9}$

Sub-Section: Equivalent General Solutions

Discussion: Is $3 + 6k, k \in Z$ the same as $9 + 6k, k \in Z$?

$3+6k$

$k=-2$	$k=-1$	$k=0$	$k=1$	$k=2$
-9	-3	3	9	15

$9+6k$

$k=-2$	$k=-1$	$k=0$	$k=1$	$k=2$
-3	3	9	15	21

$\Rightarrow$ If base angle is k periods away from the other

Multiple Forms of a General Solution

$$a + Period \cdot n = b + Period \cdot n$$

If the difference of a and b is a multiple of period.

Question 9 Walkthrough.

Which one of the following is **not** the same as the rest?

A. $\frac{5\pi}{6} + \frac{\pi}{3}n, n \in Z$ $\quad \frac{5\pi}{6}$

B. $\frac{\pi}{2} + \frac{\pi}{3}n, n \in Z$ $\quad \frac{3\pi}{6}$ $\quad -\frac{2\pi}{6} = -1P$ $\quad P = \frac{2\pi}{6}$

C. $-\frac{\pi}{2} + \frac{\pi}{3}n, n \in Z$ $\quad -\frac{3\pi}{6}$ $\quad -\frac{6\pi}{6} = -3P$

D. $\frac{5\pi}{3} + \frac{\pi}{3}n, n \in Z$ $\quad \frac{10\pi}{6}$ $\quad \frac{13\pi}{6} = 2.167P \Rightarrow \times$

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NOTE: Very important for multiple choice questions in VCAA exams!

Question 10

Which one of the following is **not** the same as the rest?

A. $\frac{2\pi}{3} + \frac{\pi}{4}n, n \in Z$ $\quad \frac{16\pi}{24}$

B. $\frac{5\pi}{8} + \frac{\pi}{4}n, n \in Z$ $\quad \frac{15\pi}{24}$

C. $-\frac{\pi}{3} + \frac{\pi}{4}n, n \in Z$ $\quad -\frac{8\pi}{24}$

D. $\frac{7\pi}{6} + \frac{\pi}{4}n, n \in Z$ $\quad \frac{28\pi}{24}$

$P = \frac{6\pi}{24}$

$\frac{-24\pi}{24} = -4P$

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Section B: Advanced Trigonometric Algebra

Sub-Section: General Solutions with Domain Restrictions

Discussion: What is the main difference between the general and particular solution questions?

$\therefore$ Dom Restriction

Question 11 Walkthrough.

Solve the following trigonometric equation:

Q1, Q2

$$\sin\left(2x + \frac{\pi}{4}\right) = \frac{\sqrt{2}}{2} \text{ for } x \geq 0$$

Q1 Q2

$2x + \frac{\pi}{4} = \frac{\pi}{4}, \pi - \frac{\pi}{4}$

$2x = 0, \frac{\pi}{2}$

$\therefore x = 0, \frac{\pi}{4}$

$\therefore P = \frac{2\pi}{2} = \pi$

$\{0\} \cup Z^+$

$n = -1$ ✗ $n = 0$ ✓ $n = 1$ ✓ ...

$x = 0 + \pi n, n \in Z^+ \cup \{0\}$

OR

$x = \frac{\pi}{4} + \pi n, n \in Z^+ \cup \{0\}$

General Solution with Domain Restriction

$$E.G\ \text{trig}\left(2x + \frac{\pi}{4}\right) = \frac{\sqrt{2}}{2} \text{ for } x \geq 0$$

- We can have infinite solutions for a restricted domain.
- The value of n is also restricted.

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Your Turn!

Question 12

Solve the following trigonometric equations:

$(+) \Rightarrow Q1, Q4$

a. $\cos\left(2x - \frac{\pi}{6}\right) = \frac{1}{2}$ for $x < 0$.

Q1 Q4

$2x - \frac{\pi}{6} = \frac{\pi}{3}, -\frac{\pi}{3}$

$2x = \frac{\pi}{2}, -\frac{\pi}{6}$

$\therefore x = \frac{\pi}{4}, -\frac{\pi}{12}$

$\therefore \text{Period} = \frac{2\pi}{2} = \pi$

$n=0$ ✗
$n=-1$ ✓

$\therefore x = \frac{\pi}{4} + \pi \cdot n, \ n \in Z^-$

OR

$x = -\frac{\pi}{12} + \pi \cdot n, \ n \in Z^- \cup \{0\}$

b. $2\sin\left(3x + \frac{\pi}{3}\right) = \sqrt{3}$ for $x > 0$.

$n=0$ ✓
$n=1$ ✗

$\sin\left(3x + \frac{\pi}{3}\right) = \frac{\sqrt{3}}{2}$

Q1 Q2

$3x + \frac{\pi}{3} = \frac{\pi}{3}, \frac{2\pi}{3}$

$3x = 0, \frac{\pi}{3}$

$\therefore x = 0, \frac{\pi}{9}$

$\therefore \text{Period} = \frac{2\pi}{3}$

$n=0$ ✗
$n=1$ ✓

$\therefore x = 0 + \frac{2\pi}{3} \cdot n, \ n \in Z^+$

OR

$x = \frac{\pi}{9} + \frac{2\pi}{3} \cdot n, \ n \in Z^+ \cup \{0\}$

$n=-1$ ✗
$n=0$ ✓
$\vdots$

c. $\tan\left(2x - \frac{\pi}{4}\right) + \sqrt{3} = 0$ for $x \leq 0$.

$\tan\left(2x - \frac{\pi}{4}\right) = -\sqrt{3}$

Q4

$2x - \frac{\pi}{4} = -\frac{\pi}{3}$

$2x = \frac{-\pi}{12}$

$\therefore x = \frac{-\pi}{24}$ $\Rightarrow \therefore P = \frac{\pi}{2}$

$n = 1$ ✗
$n = 0$ ✓

$\therefore x = \frac{-\pi}{24} + \frac{\pi}{2} \cdot n, \; n \in Z^{-} \cup \{0\}$

NOTE: This was assessed in a VCAA exam!

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Sub-Section: Hidden Quadratics

Let's have a look at hidden quadratics for circular functions!

Hidden Quadratics

$$af(x)^2 + bf(x) + c = 0$$

Let $A = f(x)$

Question 13 Walkthrough.

Solve the following for the values of x:

$$\sin^2\left(x + \frac{\pi}{3}\right) + \sin\left(x + \frac{\pi}{3}\right) = 2, 0 \le x \le 3\pi$$

let $a = \sin\left(x + \frac{\pi}{3}\right)$: $\rightarrow \in [-1, 1]$

$a^2 + a = 2$

$a^2 + a - 2 = 0$

$(a+2)(a-1) = 0$

$a = -2$ or $a = 1$

reject as $a \in [-1, 1]$

$\therefore \sin\left(x + \frac{\pi}{3}\right) = 1$

$x + \frac{\pi}{3} = \frac{\pi}{2}$

$\therefore x = \frac{\pi}{6}$

$\therefore P = \frac{2\pi}{1} = \frac{12\pi}{6}$

$D \in \left[0, \frac{18\pi}{6}\right]$

$\therefore x = \frac{\pi}{6}, \frac{13\pi}{6}$

NOTE: sin and cos are between -1 and 1.

Question 14

Solve the following for the values of x:

a. $2\cos^2(2x) + 5\cos(2x) = 3, 0 \le x \le 2\pi$

Let $a = \cos(2x)$:

$2a^2 + 5a - 3 = 0$

$(2a-1)(a+3) = 0$

$\therefore a = \frac{1}{2}$ or -3

↳ reject as $a \in [-1, 1]$

$\cos(2x) = \frac{1}{2}$

$2x = \frac{\pi}{3}, -\frac{\pi}{3}$

$\therefore x = \frac{\pi}{6}, -\frac{\pi}{6}$

$P = \frac{2\pi}{2} = \pi$

$\therefore x = \cancel{-\frac{\pi}{6}}, \frac{5\pi}{6}, \frac{11\pi}{6}, \frac{\pi}{6}, \frac{7\pi}{6}$

b. $4\tan^2\left(x - \frac{\pi}{4}\right) - 3\tan^2\left(x - \frac{\pi}{4}\right) = 1, -\pi \le x \le \pi$

Let $a = \tan\left(x - \frac{\pi}{4}\right)$:

$4a^2 - 3a^2 = 1$

$a^2 = 1$

$\therefore a = \pm 1$

$\tan\left(x - \frac{\pi}{4}\right) = 1$ or $\tan\left(x - \frac{\pi}{4}\right) = -1$

$x - \frac{\pi}{4} = \frac{\pi}{4}$ $\qquad$ $x - \frac{\pi}{4} = -\frac{\pi}{4}$

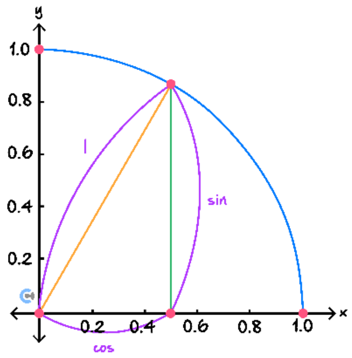
$\therefore x = \frac{\pi}{2}$ $\qquad$ $\therefore x = 0$

$P = \frac{\pi}{1} = \pi$

$D \in [-\pi, \pi]$

$\therefore x = -\frac{\pi}{2}, \frac{\pi}{2}, \cancel{\frac{3\pi}{2}}, -\pi, 0, \pi$

REMINDER: Pythagorean Identity



$$\sin^2(\theta) + \cos^2(\theta) = 1$$

- Can be used for finding one trigonometry function by using the other.

Question 15 Extension.

Find the general solution to the following equation:

$$-4\sin^2(3x) + 6\cos(3x) = 0$$

$\sin^2(3x) = 1 - \cos^2(3x)$

$-4\left(1 - \cos^2(3x)\right) + 6\cos(3x) = 0$

Let $a = \cos(3x)$:

$4a^2 + 6a - 4 = 0$

$2a^2 + 3a - 2 = 0$

$(2a-1)(a+2) = 0$

$\therefore a = \frac{1}{2}$ or $a = -2$

reject as $a \in [-1, 1]$

x Q1, Q4

$\therefore \cos(3x) = \frac{1}{2}$

$3x = \frac{\pi}{3}, -\frac{\pi}{3}$

$\therefore x = \frac{\pi}{9}, -\frac{\pi}{9}$

$\therefore P = \frac{2\pi}{3}$

$\therefore x = \pm\frac{\pi}{9} + \frac{2\pi}{3}n, n \in \mathbb{Z}$

TIP: $\sin^2(\theta) = 1 - \cos^2(\theta)$

Contour Check

Learning Objective: [4.2.1] - Solve general solutions for trigonometric functions

Key Takeaways

- **General Solutions**
  - Finding ______ solutions to a trigonometric equation.
  - **Steps**
    1. Make the trigonometric function the subject.
    2. Find the necessary ______ for one period.
    3. Solve for x by equating the necessary angles to the ______ of the trigonometric functions.
    4. Add ______ where $n \in Z$.
  - If there is a domain restriction, only step 4 changes, and we need to be more careful in specifying what values n can take.
- **Multiple Forms of a General Solution**

$$a + Period \cdot n = b + Period \cdot n$$

If the ______ of a and b is a multiple of period.

Learning Objective: [4.2.2] – Solve hidden quadratic equations for trigonometric functions

Key Takeaways

- Hidden Quadratics

$$af(x)^2 + bf(x) + c = 0$$

Let $A =$ [redacted]

- May need to use the Pythagorean identity $\sin^2(\theta) + \cos^2(\theta) =$ [redacted]

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