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VCE Mathematical Methods ½
Circular Function I [0.16]
Workshop

Error Logbook:

New Ideas/Concepts	Didn't Read Question
Pg / Q #: _____ Notes:	Pg / Q #: _____ Notes:
Algebraic/Arithmetic/ Calculator Input Mistake	**Working Out Not Detailed Enough**
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Section A: Recap

Radians and Degrees

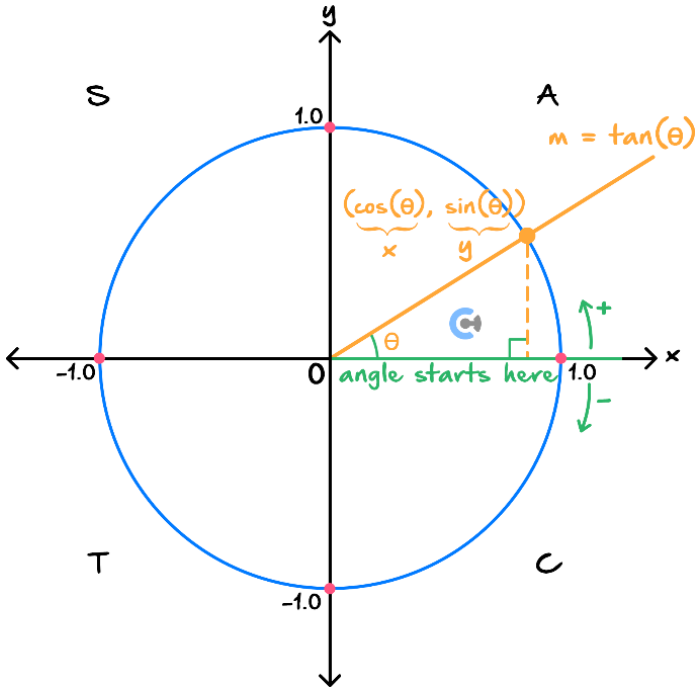
$$1^c = \left(\frac{180}{\pi}\right)^o$$

$$1^o = \left(\frac{\pi}{180}\right)^c$$

$$180^o = \pi^c$$

Unit Circle

- The unit circle is simply a circle of radius 1.



$$\sin(\theta) = y$$

$$\cos(\theta) = x$$

$$\tan(\theta) = gradient$$

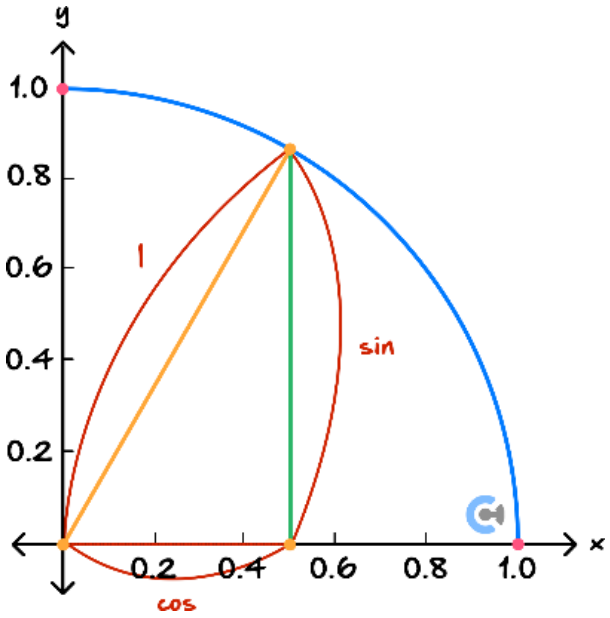
Period of a Trigonometric Function

$$period\ of\ \sin(nx)\ and\ \cos(nx)\ functions = \frac{2\pi}{n}$$

$$period\ of\ \tan(nx)\ functions = \frac{\pi}{n}$$

$$where\ n = coefficient\ of\ x\ and\ n > 0$$

Pythagorean Identities



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

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

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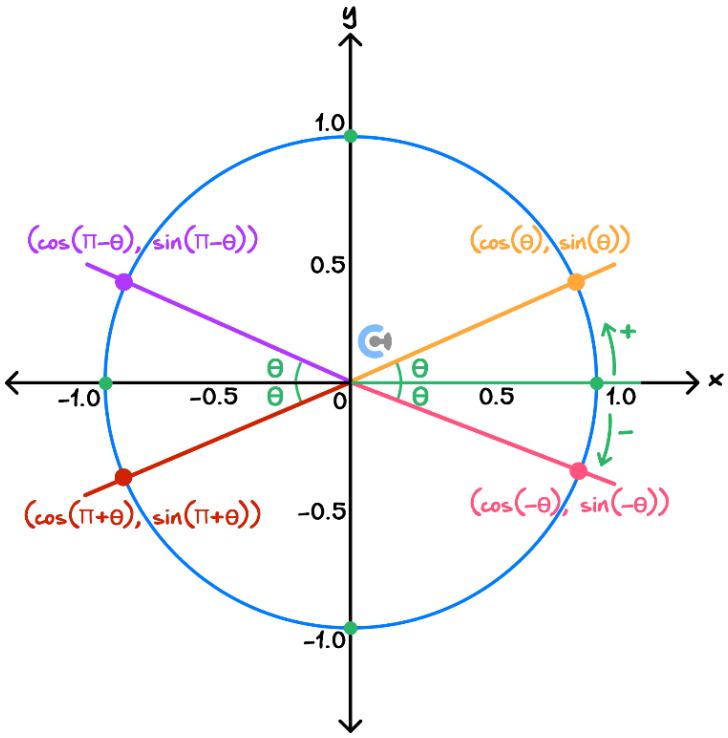
The Exact Values Table

x	$0\ (0^o)$	$\frac{\pi}{6}\ (30^o)$	$\frac{\pi}{4}\ (45^o)$	$\frac{\pi}{3}\ (60^o)$	$\frac{\pi}{2}\ (90^o)$
$\sin(x)$	0	$\frac{1}{2}$	$\frac{\sqrt{2}}{2}$	$\frac{\sqrt{3}}{2}$	1
$\cos(x)$	1	$\frac{\sqrt{3}}{2}$	$\frac{\sqrt{2}}{2}$	$\frac{1}{2}$	0
$\tan(x)$	0	$\frac{1}{\sqrt{3}}$	1	$\sqrt{3}$	Undefined

Supplementary Relationships



- Simply look at the quadrant to find the correct sign.
  - **Second Quadrant** $(\pi - \theta)$

$$\cos(\pi - \theta) = -\cos(\theta)$$

$$\sin(\pi - \theta) = +\sin(\theta)$$

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

- Third Quadrant $(\pi + \theta)$

$$\cos(\pi + \theta) = -\cos(\theta)$$

$$\sin(\pi + \theta) = -\sin(\theta)$$

$$\tan(\pi + \theta) = +\tan(\theta)$$

- Fourth Quadrant $(-\theta)$

$$\cos(-\theta) = +\cos(\theta)$$

$$\sin(-\theta) = -\sin(\theta)$$

$$\tan(-\theta) = -\tan(\theta)$$

Definition

Complementary Relationships

- Consider the quadrant for signs.

- First Quadrant $\left(\frac{\pi}{2} - \theta\right)$

$$\cos\left(\frac{\pi}{2} - \theta\right) = +\sin(\theta)$$

$$\sin\left(\frac{\pi}{2} - \theta\right) = +\cos(\theta)$$

$$\tan\left(\frac{\pi}{2} - \theta\right) = +\frac{1}{\tan(\theta)}$$

- Second Quadrant $\left(\frac{\pi}{2} + \theta\right)$

$$\sin\left(\frac{\pi}{2} + \theta\right) = +\cos(\theta)$$

$$\cos\left(\frac{\pi}{2} + \theta\right) = -\sin(\theta)$$

$$\tan\left(\frac{\pi}{2}+\theta\right)=-\frac{1}{\tan(\theta)}$$

- Third Quadrant $\left(\frac{3\pi}{2}-\theta\right)$

$$\sin\left(\frac{3\pi}{2}-\theta\right)=-\cos(\theta)$$

$$\cos\left(\frac{3\pi}{2}-\theta\right)=-\sin(\theta)$$

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

- Fourth Quadrant $\left(\frac{3\pi}{2}+\theta\right)$

$$\sin\left(\frac{3\pi}{2}+\theta\right)=-\cos(\theta)$$

$$\cos\left(\frac{3\pi}{2}+\theta\right)=+\sin(\theta)$$

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

Steps:

1. Note complementary relationship by identifying a vertical angle $\left(\frac{\pi}{2},\frac{3\pi}{2}\right)$.
2. Equate to the opposite trigonometric function $\cos$ /$\sin$ / $\frac{1}{\tan(\theta)}$.
3. Determine the sign $(\pm)$ by considering the quadrant.

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Supplementary v/s Complementary

Supplementary: $trig(Horizontal\ Angle \pm \theta)$

Complementary: $trig(Vertical\ Angle \pm \theta)$

Particular Solutions

- Solving trigonometric equations **for finite solutions.**
- **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 and subtract the period to find all other solutions in the domain.

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Section B: Warm Up (13 Marks)

INSTRUCTION:

- Regular: 13 Marks. 13 Minutes Writing.
- Extension: Skip.

Question 1 (7 marks)

a. Find $\left(\frac{3\pi}{4}\right)^c$ in degrees. (1 mark)

135^∘

b. Find $150°$ in radians. (1 mark)

5π/6

c. Determine the period of $\sin(3x)$. (1 mark)

2π/3

d. Determine the period of $\tan\left(\frac{\pi x}{3}\right)$. (1 mark)

3

e. Evaluate $\sin\left(\frac{3\pi}{2}\right)$. (1 mark)

-1

f. Evaluate $\cos\left(-\frac{\pi}{6}\right)$. (1 mark)

√3/2

g. Evaluate $\tan\left(\frac{7\pi}{4}\right)$. (1 mark)

-1

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Question 2 (6 marks)

Given that $\sin(x) = \frac{5}{13}$ and $\frac{\pi}{2} < x < \pi$, find:

a. $\cos(x)$. (2 marks)

-12/13

b. $\tan(x)$. (1 mark)

-5/12

c. $\cos\left(x + \frac{\pi}{2}\right)$. (1 mark)

-5/13

d. $\sin(2\pi - x)$. (1 mark)

-5/13

e. $\tan\left(\frac{\pi}{2}+x\right)$. (1 mark)

12/5

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Section C: Exam 1 Questions (17 Marks)

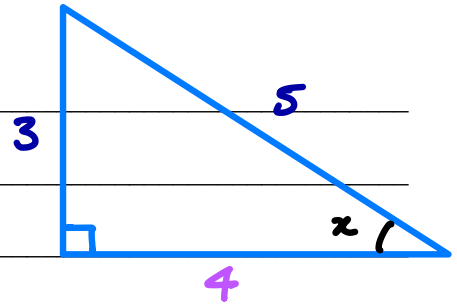
INSTRUCTION:

- Regular: 17 Marks. 5 Minutes Reading. 25 Minutes Writing.
- Extension: 17 Marks. 5 Minutes Reading. 17 Minutes Writing.

Question 3 (5 marks)

Q1,2

a. What value(s) can $\cos(x)$ take given that $\sin(x) = \frac{3}{5}$? (3 marks)



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

$\therefore \cos^2(x) = 1 - \left(\frac{3}{5}\right)^2$

$= 1 - \frac{9}{25}$

$= \frac{16}{25} \Rightarrow \therefore \cos(x) = \pm\frac{4}{5}$ if x is in Q1 or Q2

$\cos(x) = -\frac{4}{5}$ if x is in Q2

b. Hence, find the possible value(s) of $\tan(x)$. (2 marks)

If x is in Q1: $\tan(x) = \frac{\left(\frac{3}{5}\right)}{\left(\frac{4}{5}\right)} = \frac{3}{4}$ //

If x is in Q2: $\tan(x) = \frac{\left(\frac{3}{5}\right)}{\left(-\frac{4}{5}\right)} = -\frac{3}{4}$ //

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Question 4 (2 marks)

Given that the period of the function $\tan(n^2x)$ is 2. Find the value(s) of n.

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

$\therefore n^2 = \frac{\pi}{2} \Rightarrow n = \pm\sqrt{\frac{\pi}{2}} = \pm\frac{\sqrt{2\pi}}{2}$ //

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Question 5 (7 marks)

Given that $\sin(\alpha) = m$, and $\cos(\beta) = 0.2$.

a. Find the value of $\cos\left(\frac{\pi}{2} - \alpha\right)$. (2 marks)

$= \sin(\alpha)$

$= m$ //

y Q3 ⇒ ⊖

b. Find the value of $\sin\left(\frac{3\pi}{2} - \beta\right)$. (2 marks)

↳ comp

$= -\cos(\beta)$

$= -0.2$ //

c. Find the value(s) of $\tan(\alpha)$. (3 marks)

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

$\cos^2(\alpha) = 1 - m^2$

$\cos(\alpha) = \pm\sqrt{1-m^2}$

$\therefore \tan(\alpha) = \frac{m}{\sqrt{1-m^2}}$ if α is in Q1 or Q3 //

or

$\tan(\alpha) = \frac{-m}{\sqrt{1-m^2}}$ if α is in Q2 or Q4 //

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Question 6 (3 marks)

Consider the functions:

$$f(x) = \sin(nx) \quad \text{and} \quad g(x) = \cos(nx)$$

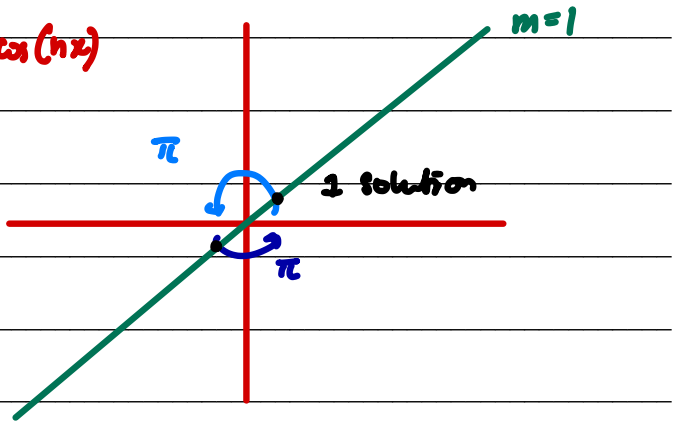
For what integer value of n will $f(x) = g(x)$ have exactly 6 solutions for, $x \in [0, 2\pi]$? Justify your answer.

$\therefore \sin(nx) = \cos(nx)$

$\div \cos(nx)$ ($\div \cos(nx)$)

$\tan(nx) = 1$

$\therefore p = \frac{\pi}{n}$



every period there will be 1 solution.

6 solutions ⇒ 6 periods

$\frac{\text{Interval}}{6} = \frac{2\pi}{6} = \frac{\pi}{3} = \frac{\pi}{n} \Rightarrow \therefore n = 3 \text{ or } -3$

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Section D: Tech Active Exam Skills

Calculator Commands: Solving Trigonometric Functions

TI

- solve($trig(..) = a, x$) | domain restriction
- | is under control equal.

Casio

- solve($trig(..) = a, x$) | domain restriction
- | is under maths 3.

Mathematica

- Solve[$trig[] == a$ && domain restriction, x]

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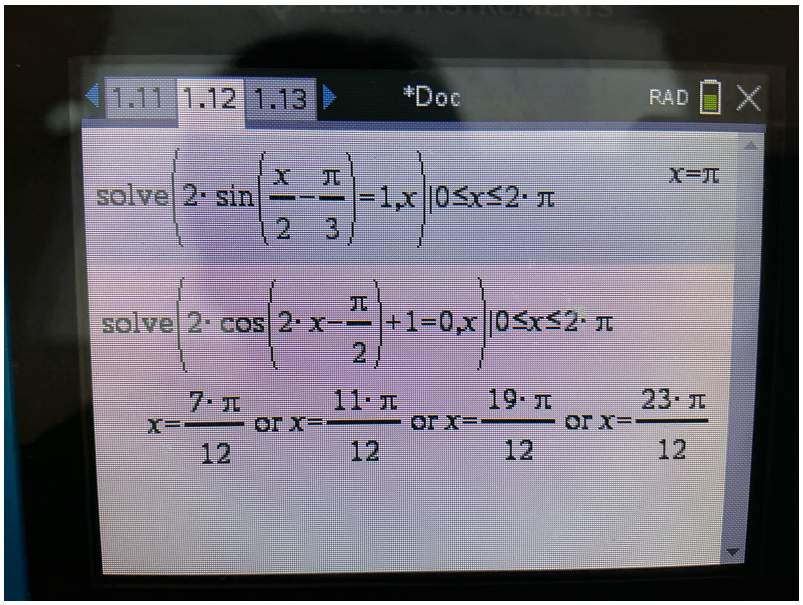
$2\cos\left(2x-\frac{\pi}{2}\right)+1=0 \quad \text{for } x \in [0,2\pi]$



Section E: Exam 2 Questions (26 Marks)

INSTRUCTION:

- Regular: 26 Marks. 5 Minutes Reading. 35 Minutes Writing.
- Extension: 26 Marks. 5 Minutes Reading. 26 Minutes Writing.

Question 7 (1 mark)

$\frac{\pi}{2}$ radians in degrees is given by:

A. 30°

B. 90°

C. 15°

D. 60°

Question 8 (1 mark)

For what values of k will $\sin(x + k) = \sin(x)$?

A. $2n\pi, n \in Z$

Sin repeats every 2π ⇒ General: $2\pi n, n \in \mathbb{Z}$

B. π

C. 3π

D. $\frac{\pi}{2}$

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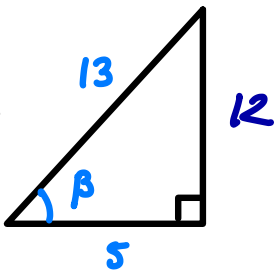
Question 9 (1 mark)

Given that $\sin(\alpha) = \frac{3}{5}$ and $\cos(\beta) = \frac{5}{13}$, with $\alpha \in \left(0, \frac{\pi}{2}\right)$ and $\beta \in \left(\frac{3\pi}{2}, 2\pi\right)$. Evaluate,

$$\frac{\sin(\beta)}{\cos(\alpha)}$$

x Q1 ⇒ + y Q4 ⇒ −



A. $\frac{13}{15}$

B. $-\frac{15}{13}$

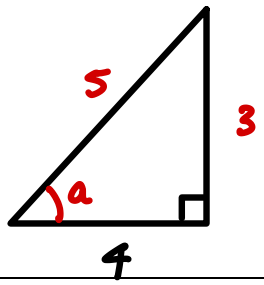
C. $\frac{39}{25}$

D. $-\frac{25}{39}$

$$\frac{-\frac{12}{13}}{+\frac{4}{5}} = \frac{-60}{52}$$

$$= \frac{-30}{26}$$

$$= -\frac{15}{13}$$ //



Question 10 (1 mark)

What are the coordinates of the unit circle in terms of x?

$r = 1$

$(h,k) = (0,0)$

$\sqrt{r^2-(x-h)^2+k^2}$

A. $\left(x, \sqrt{1-x^2}\right)$

B. $\left(x, \pm\sqrt{1-x^2}\right)$

C. $\left(\sqrt{1-x^2}, x\right)$

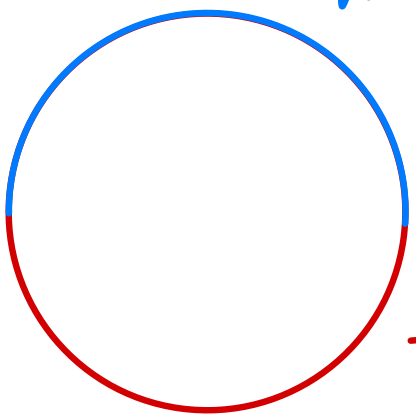
D. $\left(\sqrt{1-x^2}, -\sqrt{1-x^2}\right)$

1

$x^2+y^2 = 1$

$y^2 = 1-x^2$

$y = \pm\sqrt{1-x^2}$



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Question 11 (1 mark)

The following equation has no real solutions:

$$\sin(n^2x) = \frac{\sqrt{5}}{2}, \qquad 0 < x < 2\pi$$

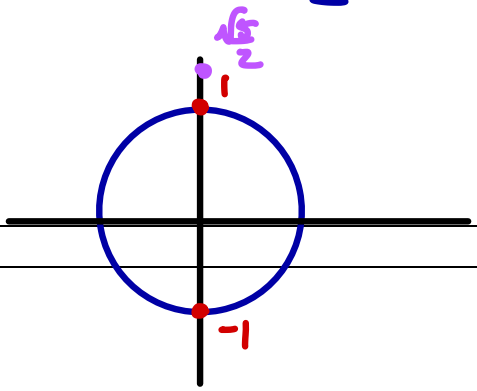
Which of the following is the best explanation for why this is the case?

A. We are not given the value of n.

B. There are real solutions but they are not in the domain $x \in (0, 2\pi)$.

C. The range of the sine function is $[-1, 1]$ but $\frac{\sqrt{5}}{2} > 1$.

D. $\frac{\sqrt{5}}{2}$ is inside the domain $x \in (0, 2\pi)$.



Question 12 (1 mark)

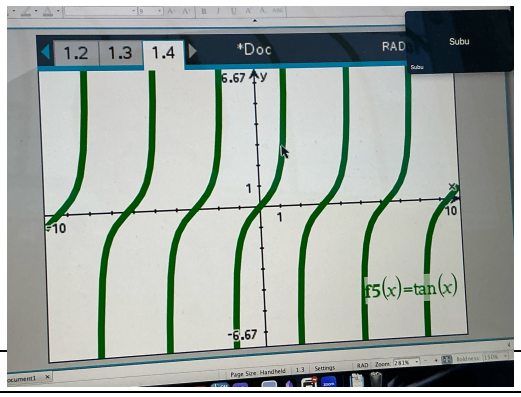
What is the range of $y = \tan(x)$?

A. R

B. R^+

C. $[-1,1]$

D. $R \setminus \left\{\frac{n\pi}{2}\right\}$



Question 13 (1 mark)

Solve the following equation for the given domain:

$$\sqrt{3}\tan\left(x - \frac{\pi}{2}\right) = 1, \qquad x \in [0, \pi]$$

A. $\frac{\pi}{3}$

B. $\frac{\pi}{6}$

C. $\frac{5\pi}{6}$

D. $\frac{2\pi}{3}$

Question 14 (1 mark)

Why does $\tan(x)$ have a period of π?

A. It is asymptotic.

B. Its values repeat every π radians.

C. $\cos(x)$ and $\sin(x)$ has a period of π.

D. Its period is not π.

Question 15 (1 mark)

Which of the following equations is true?

Interval = $n\pi$

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

A. $\sin\left(\frac{\pi}{2}-x\right)=+\cos(x)$

B. $\sin\left(\frac{3\pi}{2}-x\right)=-\cos(x)$

C. $\cos\left(\frac{\pi}{2}+x\right)=-\sin(x)$

D. $\cos\left(\frac{\pi}{2}+x\right)=-\sin(x)$

No. of periods in interval = $\frac{\text{Interval}}{\text{Period}} = \frac{n\pi}{\left(\frac{2\pi}{n}\right)} = \frac{n^2}{2}$

Question 16 (1 mark)

$\sin(nx)=0$ in 1 period $\Rightarrow$ 2 times

How many x-intercepts will $\sin(nx)$ have over $(0, n\pi]$?

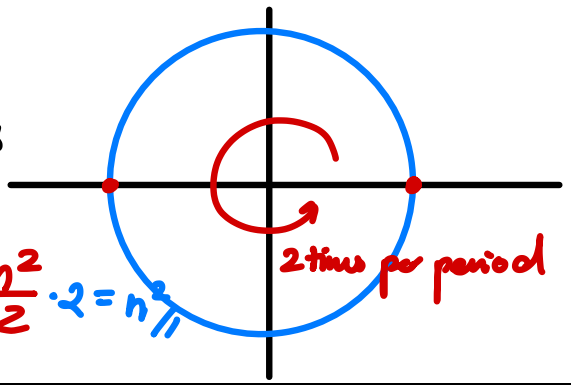
A. $\frac{2\pi}{n}n$

B. n^2

C. n

D. n^2+1

$P=\frac{2\pi}{n} \Rightarrow$ No. of solns



$\frac{n\pi}{\left(\frac{2\pi}{n}\right)} = \frac{n\pi}{1}\cdot\frac{n}{2\pi} = \frac{n^2}{2}\cdot 2 = n^2$

no. of periods

$n=1$:

$\sin(x)$ $x\in[0,\pi] \Rightarrow \therefore x=\pi$ (1)

$n=2$:

$\sin(2x)$ $x\in(0,2\pi] \Rightarrow$ 4 solutions

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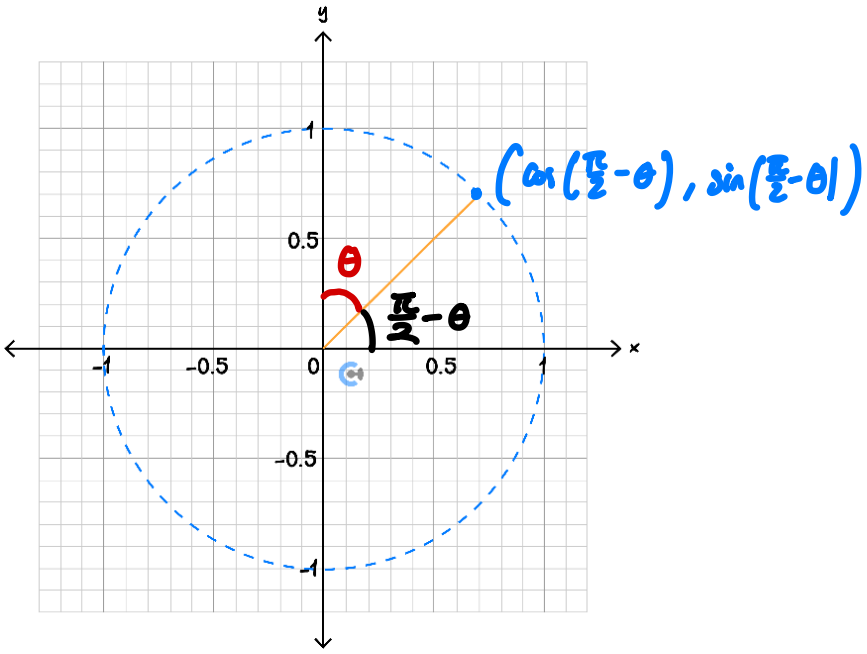
Question 17 (6 marks)

Consider the following unit circle:



a. If the line makes an angle of, θ, with the ***y*-axis**. Express the coordinates of the unit circle in terms of θ. (2 marks)

$x = \cos\left(\frac{\pi}{2} - \theta\right) = \sin\theta$

$y = \sin\left(\frac{\pi}{2} - \theta\right) = \cos\theta$

$\therefore (x, y) = (\sin\theta, \cos\theta)$ ∎

b. Find the coordinates in terms of y, for $x > 0$. (2 marks)

$y = \cos\theta$

Unit Circle

$x^2 + y^2 = 1$

$x^2 = 1 - y^2$

$x = \pm\sqrt{1 - y^2} \Rightarrow \therefore x = +\sqrt{1 - y^2}$

$\therefore (x, y) = (\sqrt{1 - y^2}, y)$

c. Express $\tan(\theta)$ in terms of y, for $x > 0$. (2 marks)

$\tan\theta = \frac{y}{x}$

$\therefore \tan\theta = \frac{\sqrt{1-y^2}}{y}$ //

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Question 18 (10 marks)

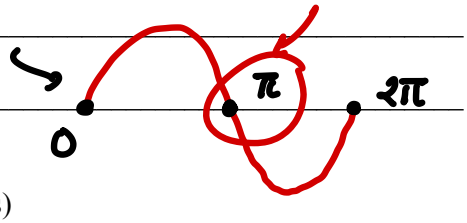
The height of a point on the pump of an oil rig relative to the ground can be modelled using the following function:

$$f(t) = 2\sin(t) - \sqrt{2}, \text{ for } t \geq 0$$

where $y = 0$ is the ground level and t is measured in seconds.

a. How long does it take for the point to first return to its starting height? (1 mark)

$\therefore t = \pi$ seconds



b. What is the maximum, and minimum height of the point? (2 marks)
Hint: sin and cos can only be between -1 and 1.

Max height occurs when $\sin(t) = 1$: Max height $= 2-\sqrt{2}$ units //

Min height occurs when $\sin(t) = -1$: Min height $= -2-\sqrt{2}$ units //

c.

i. For what values of $t \in [0,4\pi]$, will the point be level with the ground? (3 marks)

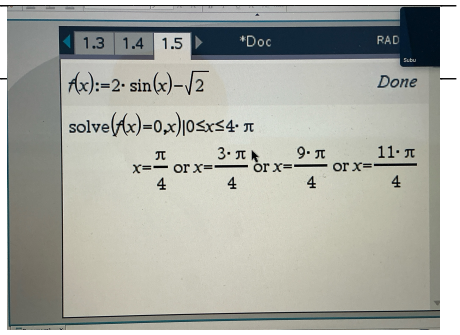
$y = 0$

Let $f(t) = 0$:

$2\sin(t) - \sqrt{2} = 0$

$\sin(t) = \frac{\sqrt{2}}{2}$

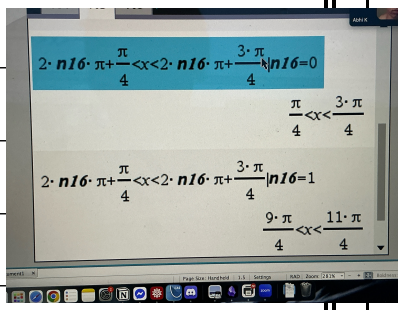
$\therefore t = \frac{\pi}{4}, \frac{3\pi}{4}, \frac{9\pi}{4}, \frac{11\pi}{4}$ seconds //



ii. Hence, state the values of $t \in [0, 4\pi]$ for which the point is above the ground level. (2 marks)

Solve $f(t) > 0$:

$\therefore t \in \left(\frac{\pi}{4}, \frac{3\pi}{4}\right) \cup \left(\frac{9\pi}{4}, \frac{11\pi}{4}\right)$



d. The height of another point on the pump is modelled by $g(t) = \sin(t) - \sqrt{2}$ instead. Can this point reach the ground level? Justify. (2 marks)

$\sin(t) \in [-1, 1]$

$\because$ ground level $\Rightarrow y = 0$

Range $g(t) \in [-1-\sqrt{2}, 1-\sqrt{2}]$

$1-\sqrt{2} < 0$

$\therefore$ y-value is ALWAYS negative

it NEVER reaches ground level //

Space for Personal Notes

Section F: Extension Exam 1 (9 Marks)

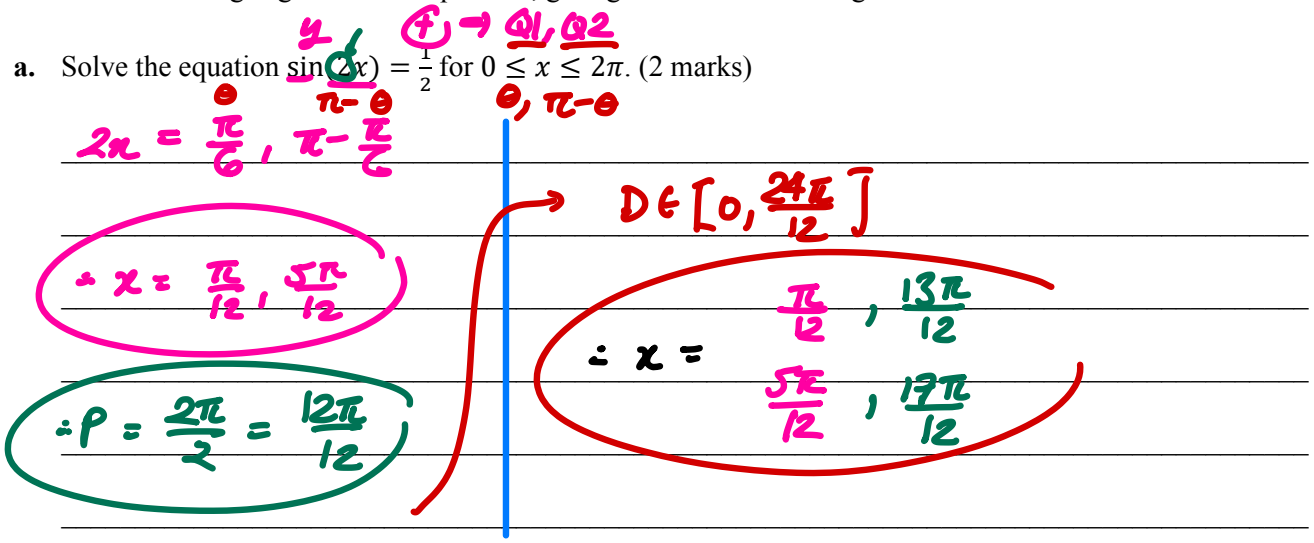
INSTRUCTION:

- Regular: Skip.
- Extension: 9 Marks. 10 Minutes Writing.

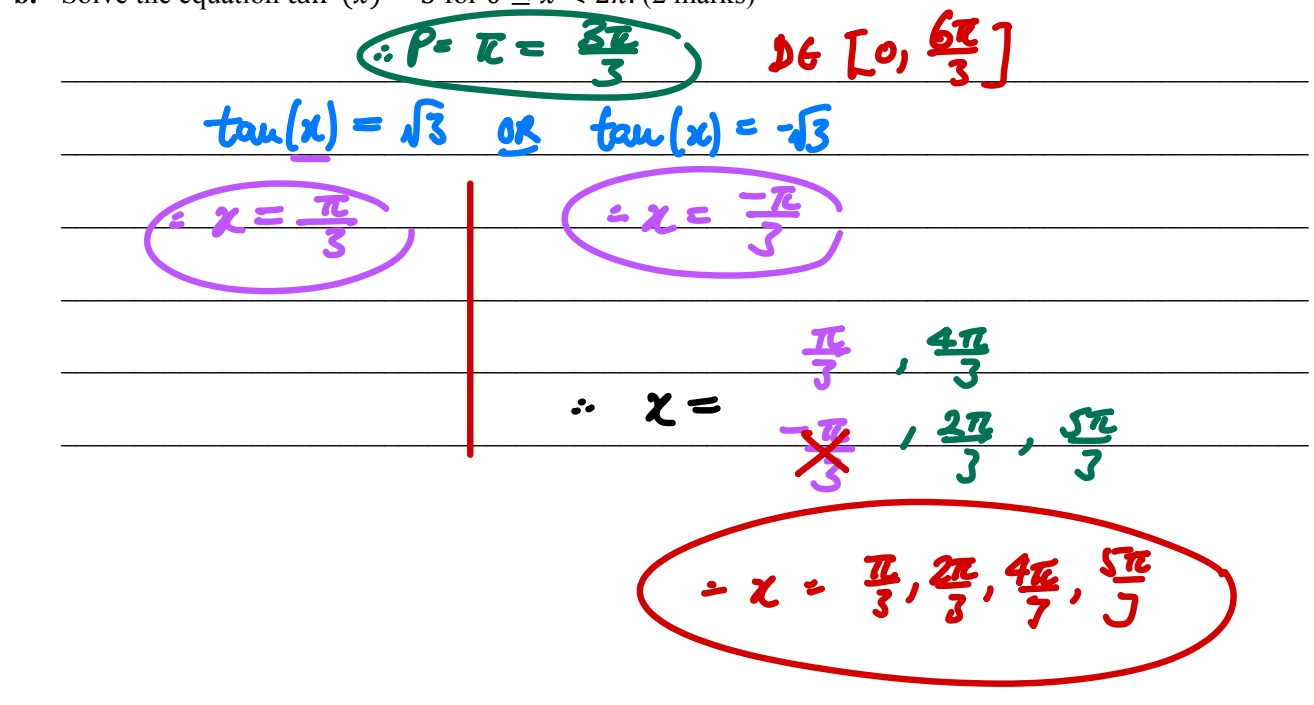
Question 19 (9 marks)

Solve the following trigonometric equations, giving all solutions in the given domain.

a. Solve the equation $\sin(2x) = \frac{1}{2}$ for $0 \leq x \leq 2\pi$. (2 marks)



b. Solve the equation $\tan^2(x) = 3$ for $0 \leq x < 2\pi$. (2 marks)



c. Solve the equation $\sin(x) = \cos(x)$ for $0 \leq x < 2\pi$. (2 marks)

$\frac{\sin(x)}{\cos(x)} = \frac{\cos(x)}{\cos(x)}$

$\tan(x) = 1$

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

$\therefore P = \frac{\pi}{1} = \frac{4\pi}{4}$

DG $[0, \frac{8\pi}{4})$

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

d. Solve the equation $2\cos^2(x) - 3\cos(x) + 1 = 0$ for $-\pi \leq x \leq \pi$. (3 marks)

let $a = \cos(x)$:

$2a^2 - 3a + 1 = 0$

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

$\therefore a = \frac{1}{2}$ OR $a = 1$

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

Q1 Q4

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

$\therefore P = \frac{2\pi}{1} = \frac{6\pi}{3}$

DG $[-\frac{3\pi}{3}, \frac{3\pi}{3}]$

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

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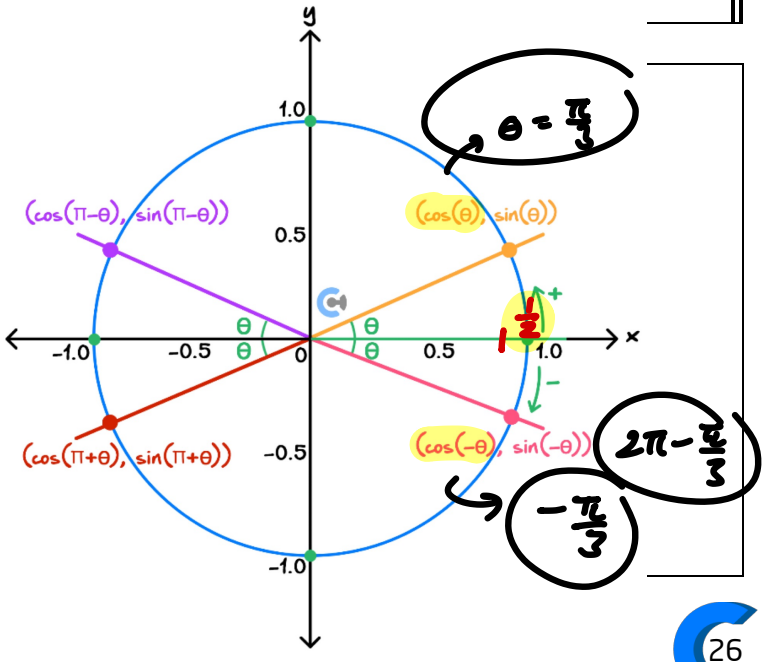


Section G: Extension Exam 2 (12 Marks)

INSTRUCTION:

- Regular: Skip.
- Extension: 12 Marks. 15 Minutes Writing.

Question 20 (5 marks)

Consider the following two functions:

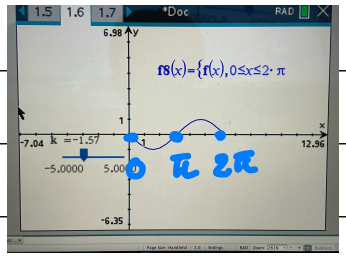
$$g(x) = \sin(x) \text{ and } f(x) = \cos(x - k), 0 \leq x \leq 2\pi$$

a. For what value of k will $f(x)$ have three x-intercepts? For this value of k state the value(s) of x where $f(x)$ crosses the x-axis. Just provide one possible value for k. (2 marks)

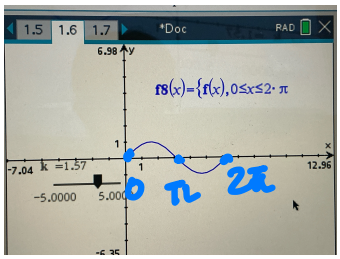
$\cos(x-k) = 0$

$\therefore k = -\frac{\pi}{2}$

$\therefore x = 0, \pi, 2\pi$



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

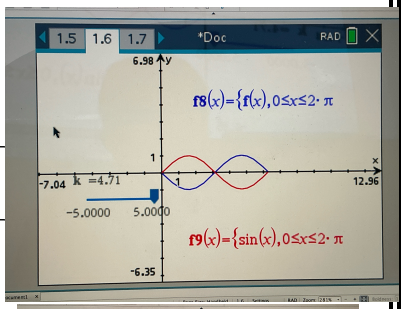


b. Suppose $k \in [0, 2\pi]$. Provide a value of k for which $f(x) = g(x)$ has:

$\cos(x-k) = \sin(x)$

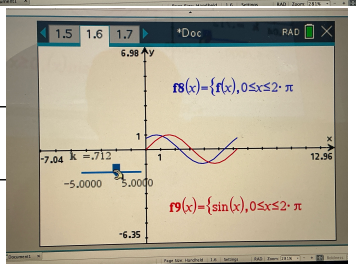
i. 3 solutions. (1 mark)

$k = -\frac{\pi}{2} \xrightarrow{+P}$ $\therefore k = \frac{3\pi}{2}$



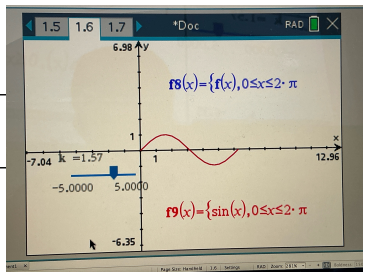
ii. 2 solutions. (1 mark)

$\therefore k \in [0, 2\pi] \setminus \{\frac{\pi}{2}, \frac{3\pi}{2}\}$



iii. Infinitely many solutions. (1 mark)

$\therefore k = \frac{\pi}{2}$ →



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Question 21 (7 marks)

The temperature $T(t)$ in degrees Celsius inside an office at time t hours after midnight is modelled by:

$$T(t) = 21 + 3\cos\left(\frac{\pi}{6}(t - 4)\right),$$

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

where $0 \leq t \leq 24$.

a. State the maximum and minimum temperatures in the office, and the times at which they occur. (2 marks)

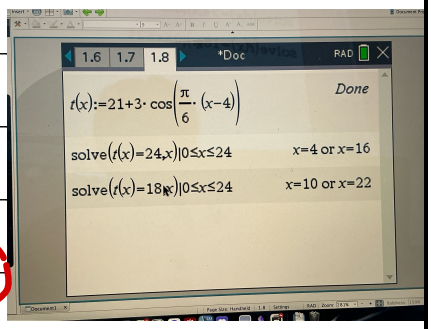
Max Temp = 24 $\Rightarrow \therefore T(t) = 24$

Min Temp = 18 $\therefore t = 4$ OR 16 //

OR

$\therefore T(t) = 18$

$\therefore t = 10$ OR 22 //



earliest

b. Find the **exact** value of t for which the temperature is first 23 °C. What time of day, to the nearest minute, does this t correspond to? (3 marks)

Let $T(t) = 23$:

$21 + 3\cos\left(\frac{\pi}{6}(t-4)\right) = 23$

$\therefore \cos\left(\frac{\pi}{6}(t-4)\right) = \frac{2}{3}$

(+) $\Rightarrow$ Q1, Q4

θ $-\theta$

Q1 Q4

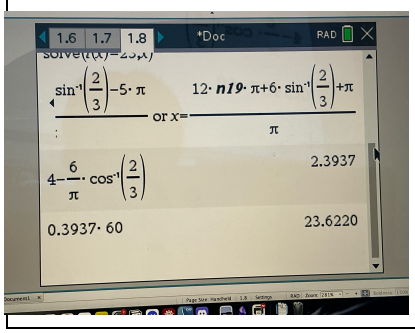
$\frac{\pi}{6}(t-4) = \cos^{-1}\left(\frac{2}{3}\right)$ OR $\frac{\pi}{6}(t-4) = -\cos^{-1}\left(\frac{2}{3}\right)$

$\frac{\pi}{6}(t-4) = \pm\cos^{-1}\left(\frac{2}{3}\right)$

$t - 4 = \pm\frac{6}{\pi}\cos^{-1}\left(\frac{2}{3}\right)$

$t = 4 \pm \frac{6}{\pi}\cos^{-1}\left(\frac{2}{3}\right)$

$\Rightarrow \therefore t = 4 - \frac{6}{\pi}\cos^{-1}\left(\frac{2}{3}\right)$ (earliest)



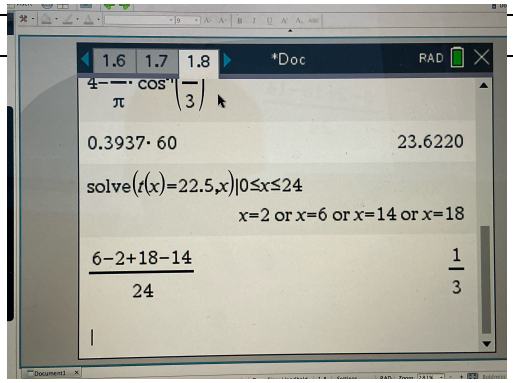
$\Rightarrow \approx$ 2:24 AM //

c. What fraction of the day is the temperature above 22.5°C? (A day starts at midnight and ends at midnight 24 hours later.) (2 marks)

Fraction of Day $= \dfrac{(t_2 - t_1) + (t_4 - t_3)}{24}$

$= \dfrac{1}{3}$

$= \dfrac{t_2 - t_1}{12} = \dfrac{1}{3}$



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fraction over 1 period = fraction over any period

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