Trigonometric functions — الدوال المثلثية

There are six trigonometric functions; they are;

1- $\sin\theta = \frac{y}{1} = y$

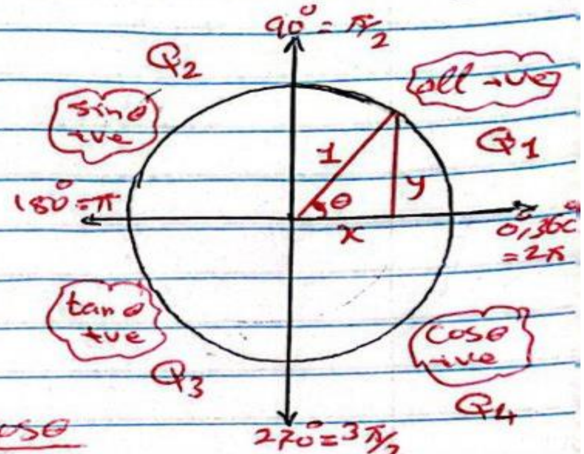
2- $\cos\theta = \frac{x}{1} = x$

3- $\tan\theta = \frac{y}{x} = \frac{\sin\theta}{\cos\theta}$

4- $\csc\theta = \frac{1}{y} = \frac{1}{\sin\theta}$

5- $\sec\theta = \frac{1}{x} = \frac{1}{\cos\theta}$

6- $\cot\theta = \frac{x}{y} = \frac{1}{\tan\theta} = \frac{\cos\theta}{\sin\theta}$



"unit circle"

We have two angle representatives;

1- Degree.
2- Radian.

Degree	Radian	Degree	Radian
30°	$\pi/6$	300°	$5\pi/3$
45°	$\pi/4$	315°	$7\pi/4$
60°	$\pi/3$	330°	$11\pi/6$
90°	$\pi/2$	360°	2π
120°	$2\pi/3$	0°	$0\pi = 0$
135°	$3\pi/4$		
150°	$5\pi/6$		
180°	π		
210°	$7\pi/6$		
225°	$5\pi/4$		
240°	$4\pi/3$		
270°	$3\pi/2$		

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The unit circle has four quarters, The sine & cosine funs in these quarters are:

① Q_1

Angle	sine	Cosine
0	0	1
30°	$\frac{1}{2}$	$\frac{\sqrt{3}}{2}$
45°	$\frac{1}{\sqrt{2}}$	$\frac{1}{\sqrt{2}}$
60°	$\sqrt{3}/2$	$1/2$
90°	1	0

② Q_2

Angle	sine	Cosine
180°	0	-1
150°	$\frac{1}{2}$	$-\sqrt{3}/2$
135°	$\frac{1}{\sqrt{2}}$	$-\frac{1}{\sqrt{2}}$
120°	$\sqrt{3}/2$	$-\frac{1}{2}$

③ Q_3

Angle	sine	cosine
210°	$-\frac{1}{2}$	$-\sqrt{3}/2$
225°	$-\frac{1}{\sqrt{2}}$	$-1/\sqrt{2}$
240°	$-\sqrt{3}/2$	$-\frac{1}{2}$
220°	-1	0

④ Q_4

Angle	sine	Cosine
300°	$-\sqrt{3}/2$	$\frac{1}{2}$
315°	$-\frac{1}{\sqrt{2}}$	$1/\sqrt{2}$
330°	$-\frac{1}{2}$	$\sqrt{3}/2$

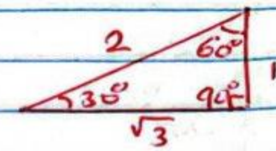
How To Evaluate The Trigonometric Func.

① $\underline{30^\circ} \Longrightarrow (Q_1)$

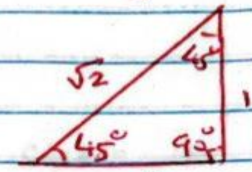
$\sin 30 = \frac{1}{2}$

$\cos 30 = \frac{\sqrt{3}}{2}$

$\tan 30 = \frac{1}{\sqrt{3}}$



② $\underline{45^\circ} \Longrightarrow (Q_1)$

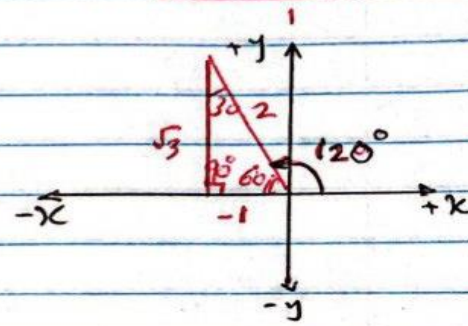


$\sin 45 = \frac{1}{\sqrt{2}}$

$\cos 45 = \frac{1}{\sqrt{2}}$

$\tan 45 = 1$

③ $\underline{120^\circ} \longrightarrow (Q_2)$

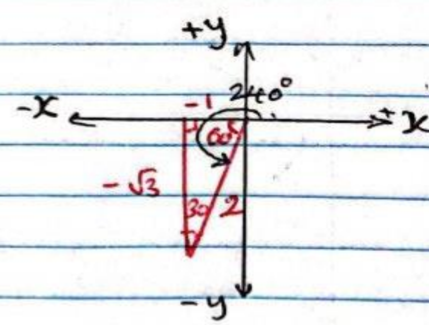


$\sin 120 = \frac{\sqrt{3}}{2}$

$\cos 120 = -1/2$

$\tan 120 = \sqrt{3}/_{-1} = -\sqrt{3}$

④ $\underline{240^\circ} \longrightarrow (Q_3)$

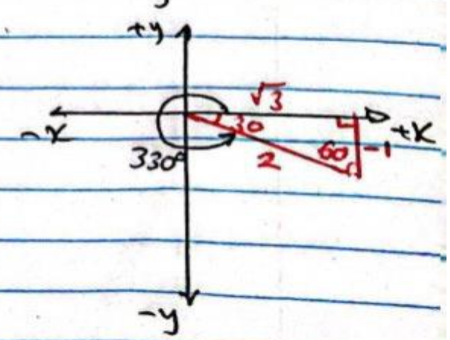


$\sin 240 = -\sqrt{3}/2$

$\cos 240 = -1/2$

$\tan 240 = -\sqrt{3}/_{-1} = \sqrt{3}$

⑤ $\underline{330^\circ} \longrightarrow (Q_4)$



$\sin 330 = -1/2$

$\cos 330 = \sqrt{3}/2$

$\tan 330 = -1/\sqrt{3}$

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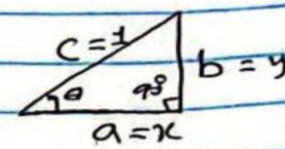
Trigonometric Relations :- العلاقات المثلثية

- Pythagorean Theorm نظرية فيثاغورس



$a^2 + b^2 = c^2$

If $a = x$, $b = y$, $c = 1$

$\therefore x^2 + y^2 = 1$

If we know from the unit circle that

$\sin\theta = y$

$\cos\theta = x$

$$\therefore \boxed{\sin^2\theta + \cos^2\theta = 1} \quad \text{— (1)}$$

- if we divided eq = 1 by $\sin^2\theta$; yields,

$$1 + \frac{\cos^2\theta}{\sin^2\theta} = \frac{1}{\sin^2\theta} \Rightarrow \boxed{1 + \cot^2\theta = \csc^2\theta} \quad \text{— (2)}$$

- If we divided eq = 1 by $\cos^2\theta$; yields,

$$\frac{\sin^2\theta}{\cos^2\theta} + 1 = \frac{1}{\cos^2\theta} \Rightarrow \boxed{1 + \tan^2\theta = \sec^2\theta} \quad \text{— (3)}$$

Even & Odd Trigonometric Functions :

الدوال المثلثية الزوجية والفردية

Even Funs	Odd Funs
$\cos(-\theta) = \cos\theta$	$\sin(-\theta) = -\sin\theta$
$\sec(-\theta) = \sec\theta$	$\csc(-\theta) = -\csc\theta$
	$\tan(-\theta) = -\tan\theta$
	$\cot(-\theta) = -\cot\theta$

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Trigonometric Functions are equal at:-

الدوال المثلثية تتساوي عند الزوايا التالية :-

$\cos\theta = \sin(90-\theta)$

$\sin\theta = \cos(90-\theta)$

$\csc\theta = \sec(90-\theta)$

$\cot\theta = \tan(90-\theta)$

Ex)

$\cos 0 = \sin 90 = 1$

$\cos 10 = \sin 80 =$

$\cos 20 = \sin 70$

$\cos 30 = \sin 60 = \sqrt{3}/2$

$\cos 45 = \sin 45 = \frac{1}{\sqrt{2}}$

$\cos 60 = \sin 30 = \frac{1}{2}$

$\cos 90 = \sin 0 = 0$

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⊕ Identity of the Trigonometric Functions:-

هوية الدوال المثلثية

① Double Angle Identity:-

* $\sin 2\theta = 2\sin\theta\cos\theta$
* $\cos 2\theta = \cos^2\theta - \sin^2\theta = 2\cos^2\theta - 1 = 1 - 2\sin^2\theta$
* $\tan 2\theta = \dfrac{2\tan\theta}{1-\tan^2\theta}$

② Half Angle Identity:-

$$\sin\frac{\theta}{2} = \mp\sqrt{\frac{1-\cos\theta}{2}}$$

$$\cos\frac{\theta}{2} = \mp\sqrt{\frac{1+\cos\theta}{2}}$$

$$\tan\frac{\theta}{2} = \sqrt{\frac{1-\cos\theta}{1+\cos\theta}} = \frac{1-\cos\theta}{\sin\theta} = \frac{\sin\theta}{1+\cos\theta}$$

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Ex) proof that $\tan\frac{\theta}{2} = \frac{1-\cos\theta}{\sin\theta}$

(Solution)

From the half angle identity,

$$\tan\frac{\theta}{2} = \sqrt{\frac{1-\cos\theta}{1+\cos\theta}} * \sqrt{\frac{1-\cos\theta}{1-\cos\theta}} = \sqrt{\frac{(1-\cos\theta)^2}{1-\cos^2\theta}}$$

From eq. ① $\Longrightarrow \sin^2\theta + \cos^2\theta = 1 \rightarrow 1-\cos^2\theta = \sin^2\theta$

$$\therefore \tan\frac{\theta}{2} = \sqrt{\frac{(1-\cos\theta)^2}{\sin^2\theta}} = \frac{1-\cos\theta}{\sin\theta} \qquad \text{O.K}$$

Ex) proof that $\tan\frac{\theta}{2} = \frac{\sin\theta}{1+\cos\theta}$

(solution)

From the half angle identity,

$$\tan\frac{\theta}{2} = \sqrt{\frac{1-\cos\theta}{1+\cos\theta}} * \sqrt{\frac{1+\cos\theta}{1+\cos\theta}} = \sqrt{\frac{1-\cos^2\theta}{(1+\cos\theta)^2}}$$

From previous ex. $\Longrightarrow 1-\cos^2\theta = \sin^2\theta$

$$\therefore \tan\frac{\theta}{2} = \sqrt{\frac{\sin^2\theta}{(1+\cos\theta)^2}} = \frac{\sin\theta}{1+\cos\theta} \qquad \text{O.K}$$

③ Sum & Difference Identity :- هوية الجمع والطرح

* $\sin(\alpha \mp \beta) = \sin\alpha\cos\beta \mp \cos\alpha\sin\beta$
* $\cos(\alpha \mp \beta) = \cos\alpha\cos\beta \pm \sin\alpha\sin\beta$
* $\tan(\alpha \mp \beta) = \dfrac{\tan\alpha \mp \tan\beta}{1 \pm \tan\alpha\tan\beta}$

i.e;

$$\tan(\alpha - \beta) = \frac{\tan\alpha - \tan\beta}{1 + \tan\alpha\tan\beta}$$

④ The Power Reducing Formulas: علاقات تخفيض القوة (الأس)

* $\sin^2\theta = \dfrac{1-\cos(2\theta)}{2}$

* $\cos^2\theta = \dfrac{1+\cos(2\theta)}{2}$

* $\tan^2\theta = \dfrac{1-\cos(2\theta)}{1+\cos(2\theta)}$

⑤ The Product To Sum Formulas: علاقات الضرب إلى الجمع

* $\sin\alpha\,\sin\beta = \frac{1}{2}\left[\cos(\alpha-\beta) - \cos(\alpha+\beta)\right]$

* $\cos\alpha\,\cos\beta = \frac{1}{2}\left[\cos(\alpha-\beta) + \cos(\alpha+\beta)\right]$

* $\sin\alpha\,\cos\beta = \frac{1}{2}\left[\sin(\alpha+\beta) + \sin(\alpha-\beta)\right]$

* $\cos\alpha\,\sin\beta = \frac{1}{2}\left[\sin(\alpha+\beta) - \sin(\alpha-\beta)\right]$

⑥ Sum to Product Formulas:- علاقات الجمع الى الضرب

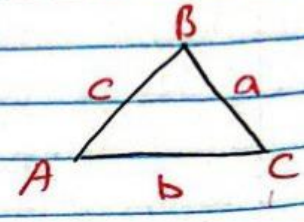
* $\sin\alpha + \sin\beta = 2\sin\left(\frac{\alpha+\beta}{2}\right)\cos\left(\frac{\alpha-\beta}{2}\right)$

* $\sin\alpha - \sin\beta = 2\sin\left(\frac{\alpha-\beta}{2}\right)\cos\left(\frac{\alpha+\beta}{2}\right)$

* $\cos\alpha + \cos\beta = 2\cos\left(\frac{\alpha+\beta}{2}\right)\cos\left(\frac{\alpha-\beta}{2}\right)$

* $\cos\alpha - \cos\beta = 2\sin\left(\frac{\alpha+\beta}{2}\right)\sin\left(\frac{\alpha-\beta}{2}\right)$

(7) Law of Sines :- قانون الجيوب



$$\frac{\sin A}{a} = \frac{\sin B}{b} = \frac{\sin C}{c}$$

(8) Law of Cosines :- قانون الجيوب تمام

$$c^2 = a^2 + b^2 - 2ab\cos C$$

To calalate the area of the triangle

$$\text{Area} = A = \frac{1}{2} ab \sin C$$

or

$$\text{Area} = \sqrt{s(s-a)(s-b)(s-c)}$$

$$s = \frac{a+b+c}{2}$$

(9) Law of Tangents :- قانون الظلال

It's no longer using, due to its complication;

$$\frac{a-b}{a+b} = \frac{\tan\left[\frac{1}{2}(A-B)\right]}{\tan\left[\frac{1}{2}(A+B)\right]}$$

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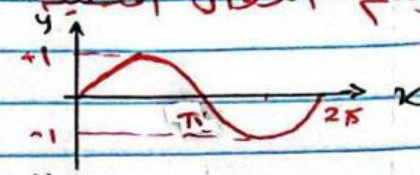
Graphing the Trigonometric Functions :-

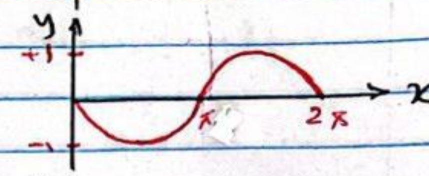
رسم الدوال المثلثية

(موضوع رسم الدوال للأطلاع)

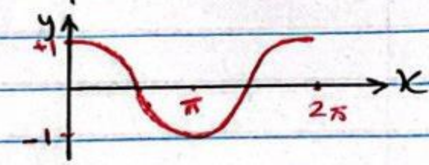
① $y = +\sin x \longrightarrow$



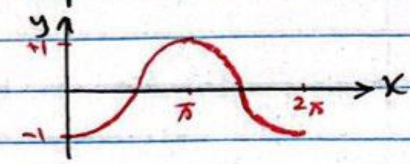
② $y = -\sin x \longrightarrow$



③ $y = +\cos x \longrightarrow$



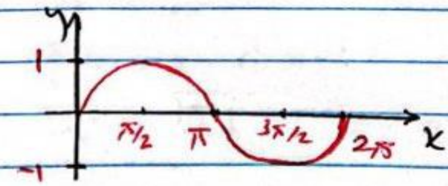
④ $y = -\cos x \longrightarrow$



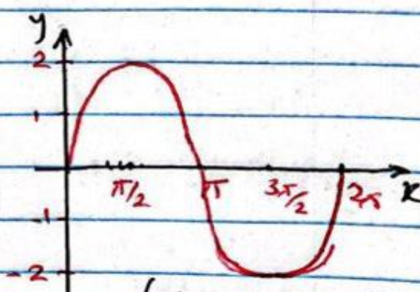
Note:
From $0 \sim 2\pi$ "one cycle"

Q: what is the difference between
$y = \sin x$ and,
$y = 2\sin x$

Answer



$(y = \sin x)$



$(y = 2\sin x)$

* The amplitude of $y = 2\sin x$ is twice that of $y = \sin x$.

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* The general Form of a sine wave is;

$$y = A \sin(Bx + C) + D$$

A --- Amplitude
B --- used to Calculate the period
C --- phase shifting
D --- Vertical shifting

$$\text{period} = p = \frac{2\pi}{B}$$

- If $D = 3 \longrightarrow$ this means shift 3 units up.
- If $D = -2 \longrightarrow$ " " " 2 " down.

To calculate a phase shift $\rightarrow Bx + C = 0$

$\therefore x = \frac{-C}{B}$

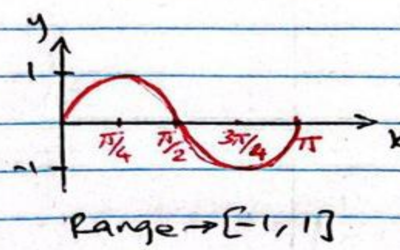
Ex) Graph $y = \sin 2x$?

Answer

Amplitude $= A = \boxed{1}$,

Period $= \frac{2\pi}{B}$, $B = 2$

$\therefore$ period $= \frac{2\pi}{2} = \boxed{\pi}$



Range $\rightarrow [-1, 1]$

Ex) Graph $y = \sin x + 1$

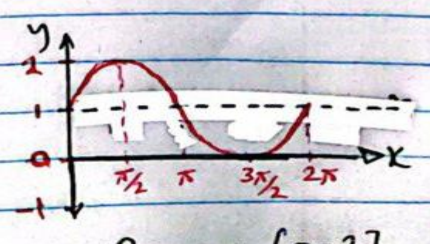
Answer

- Amplitude $= A = \boxed{1}$
- period $= p = \frac{2\pi}{B}$, $B = 1$

$\therefore p = \boxed{2\pi}$

- vertical shifting $= D = \boxed{1}$

(1 unit shifting up)



Range $\rightarrow [0, 2]$

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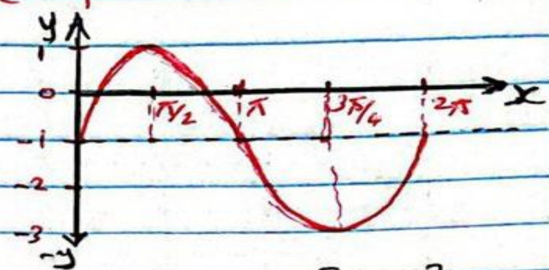
Ex) Graph $y = 2\sin x - 1$

Answer

- Amplitude $= A = \boxed{2}$
- Period $= \frac{2\pi}{B}$, $B = 1$
- $\therefore$ period $= \boxed{2\pi}$
- vertical shifting $= D = \boxed{-1}$

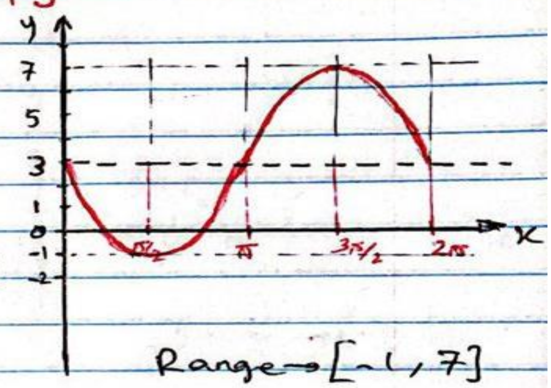


Range $\to [-3, 1]$

Ex) Graph $y = -4\sin x + 3$

Answer

- Amplitude $= A = \boxed{4}$
- period $= \frac{2\pi}{B}$, $B = 1$
- $\therefore$ period $= \boxed{2\pi}$
- vertical shifting $= D = \boxed{3}$

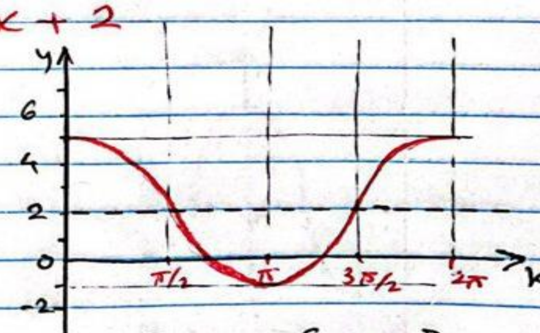


Range $\to [-1, 7]$

Ex) Graph $y = 3\cos x + 2$

Answer

- Amplitude $= A = \boxed{3}$
- Period $= \frac{2\pi}{B}$, $B = 1$
- $\therefore$ period $= \boxed{2\pi}$
- vertical shifting $= D = 2$

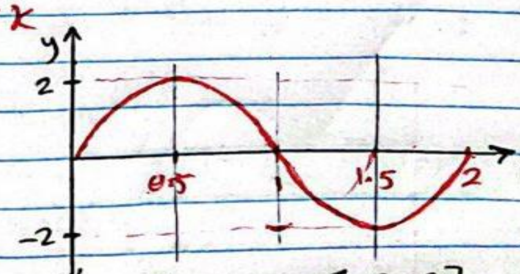


Range $\to [-1, 5]$

Ex) Graph $y = 2\sin \pi x$

Answer

- Amplitude $= \boxed{2}$
- Period $= P = \frac{2\pi}{B} = \frac{2\pi}{\pi} = \boxed{2}$
- No vertical shifting



Range $\to [-2, 2]$

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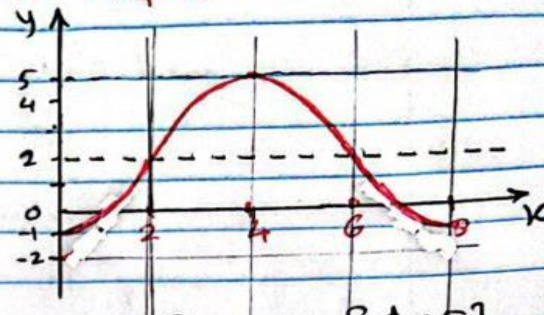
Ex) Graph $y = -3\cos(\frac{\pi}{4}x) + 2$

Answer

- Amplitude $= \boxed{3}$
- period $= \frac{2\pi}{B}$, $B = \pi/4$
- $\therefore$ period $= \frac{2\pi}{\pi/4} = \boxed{8}$
- Vertical shifting $= D = \boxed{2}$

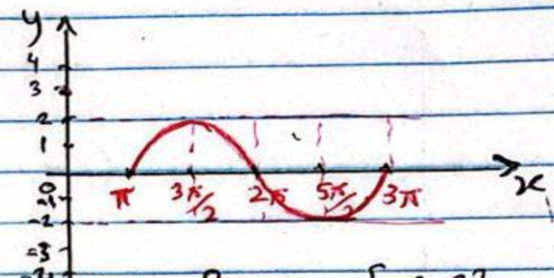


Range → $[-1, 5]$

Ex) Graph $y = 2\sin(x - \pi)$

Answer

- Amplitude $= A = \boxed{2}$
- period $= \frac{2\pi}{B}$, $B = 1$
- $\therefore$ period $= \boxed{2\pi}$
- No vertical shifting, $D = 0$
- phase shifting:
  $x - \pi = 0 \longrightarrow \boxed{x = \pi}$

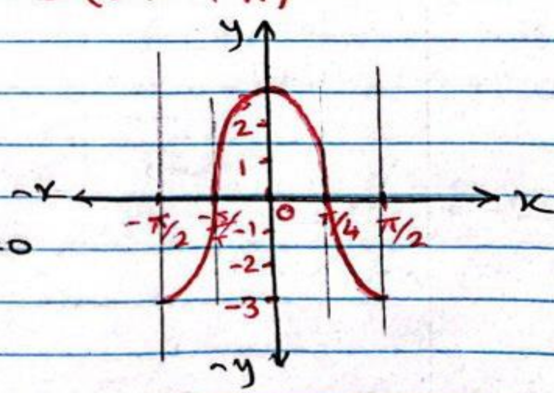


Range → $[-2, 2]$

Ex) Graph $y = -3\cos(2x + \pi)$

Answer

- Amplitude $= A = \boxed{3}$
- period $= \frac{2\pi}{B}$, $B = 2$
- $\therefore$ period $= \boxed{\pi}$
- No vertical shifting, $D = 0$
- phase shifting
  $2x + \pi = 0 \longrightarrow \boxed{x = -\frac{\pi}{2}}$



Range → $[-3, 3]$

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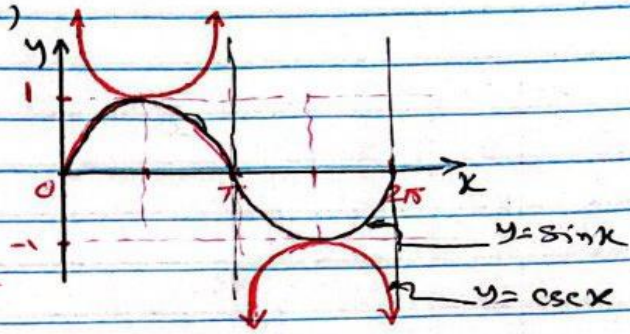
Ex) Graph $y = \csc x = \frac{1}{\sin x}$

Answer

It's same for $y = \sin x$, but here we have asymptotes (محاذيات)



* The domain of $\csc x$ is all x except

$x = 0, \mp\pi, \mp 2\pi, \mp 3\pi, \ldots$

or $x \neq n\pi$, $n = 0, \mp 1, \mp 2, \ldots$

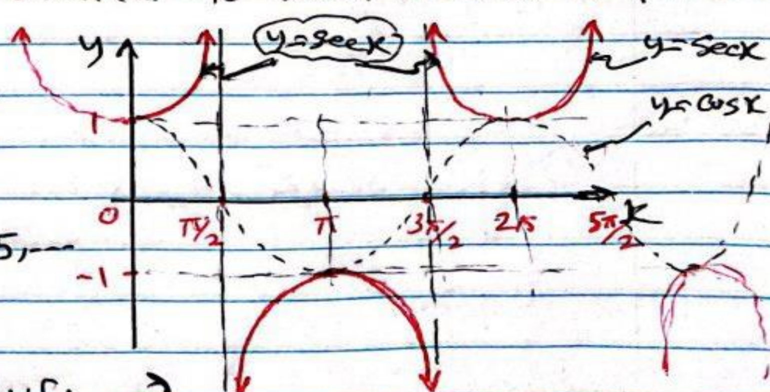
Range $\rightarrow (-\infty, -1] \cup [1, \infty)$

$\cup$ --- Union

Ex) Graph $y = \sec x = \frac{1}{\cos x}$

Answer

Here we need to graph $\cos x$ first, then we can graph $\sec x$, similar to what we did in previous example.



Domain

$x \neq n\frac{\pi}{2}$,

$n = \mp 1, \mp 3, \mp 5, \ldots$

Range $\rightarrow (-\infty, -1] \cup [1, \infty)$

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Ex) Graph $y = \tan x$

Answer

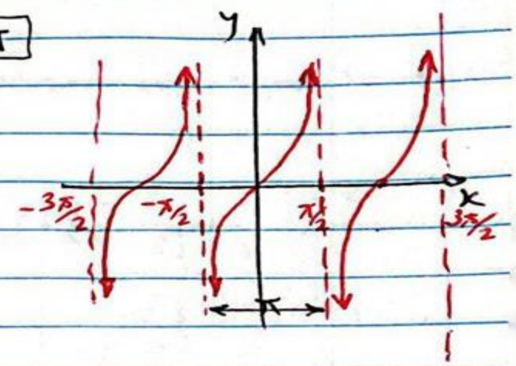
The period of tan is different from sine & Cosine's once; it is,

$$P = \frac{\pi}{B} \Longrightarrow P = \frac{\pi}{1} = \boxed{\pi}$$

Range → $(-\infty, \infty)$

Domain → $x \neq n\frac{\pi}{2}$

$n = \mp 1, \mp 3, \ldots$



Ex) Graph $y = -\tan x$

Answer

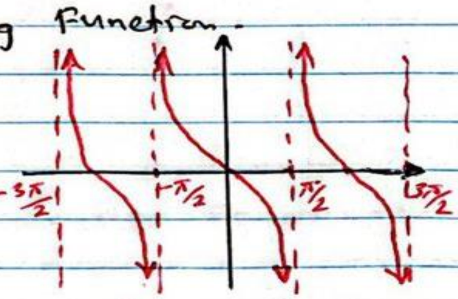
It is exactly, similar to the previous example, but $-$ve tan fun is decreasing function.

- Period $= P = \frac{\pi}{B} = \boxed{\pi}$

Range → $(-\infty, \infty)$

Domain → $x \neq n\frac{\pi}{2}$

$n = \mp 1, \mp 3, \ldots$



Note)

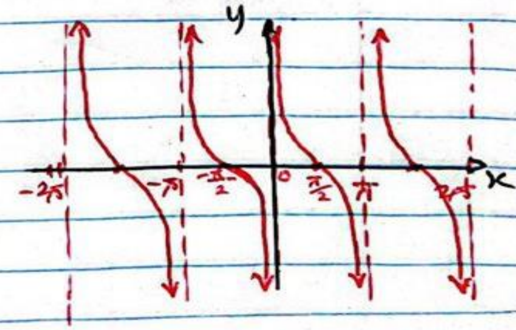
To graph $\cot x$, it is similar to $-\tan x$, & to graph $-\cot x$, it is similar to $\tan x$.

Ex) Graph $y = \cot x$

Answer

- period $= P = \frac{\pi}{B} = \boxed{\pi}$
- Range → $(-\infty, \infty)$
- Domain → $x \neq n\pi$

$n = 0, \mp 1, \mp 2, \ldots$



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Ex) Graph $y = -2\cot(\frac{1}{2}x - \pi) + 3$

Answer

- First of all, we need to find the period,

period $= p = \frac{\pi}{\beta}$, $\beta = \frac{1}{2}$

$\therefore p = \frac{\pi}{1/2} = \boxed{2\pi}$

- To find the vertical asymptote, we need to set

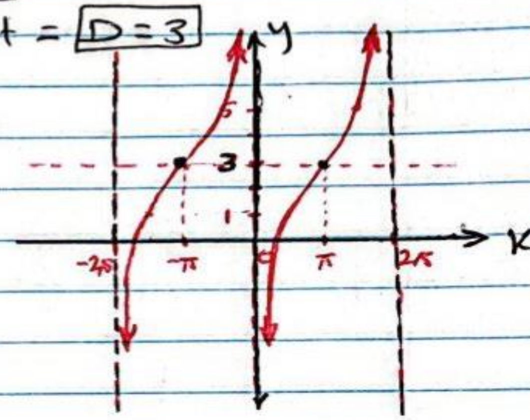
$\frac{1}{2}x - \pi = 0 \longrightarrow \boxed{x = 2\pi}$

- We have a vertical shift $= \boxed{D = 3}$

Range $\to (-\infty, \infty)$

Domain $\to x \neq n\pi$

$n = 0, \mp 2, \mp 4, \mp 6, \ldots$



H.W # 3 :-

Graph the following Trigonometric Functions :-

1- $y = 2\csc(\frac{\pi}{4}x) + 1$

2- $y = -2\sec(2x - \pi) + 6$

3- $y = 3\tan x + 2$

4- $y = -2\tan(\frac{1}{4}x - \pi) + 3$

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Inverse Trigonometric Functions
الدوال المثلثية العكسية

Inverse trigonometric Functions are defined as the inverse functions of the basic trigonometric Funs, which are sine, Cosine, tangent, Cotangent, secant & cosecant.

① Evaluate $\sin^{-1}$ Fun

The Range of $\sin^{-1}$ Fun is between $-\frac{\pi}{2}$ & $+\frac{\pi}{2}$

$\therefore$ Range $\Rightarrow [-\frac{\pi}{2}, \frac{\pi}{2}]$

So, it is only exist in this range.

Ex)

- $\sin^{-1} 0 = 0$
- $\sin^{-1} 1 = \frac{\pi}{2}$
- $\sin^{-1}(-1) = -\frac{\pi}{2}$
- $\sin^{-1}\frac{1}{2} = \frac{\pi}{6}$
- $\sin^{-1}\frac{\sqrt{3}}{2} = \pi/3 = 60$
- $\sin^{-1}(-\frac{1}{2}) = -\frac{\pi}{6}$
- $\sin^{-1}(-\frac{1}{\sqrt{2}}) = -\pi/4$
- sin

② Evaluate $\cos^{-1}$ Fun:

The Range of $\cos^{-1}$ Fun is between zero & π

$\therefore$ Range $\Rightarrow [0, \pi]$, so $\cos^{-1}$ is only exist in this range

Ex)

$\cos^{-1}\frac{1}{2} = \frac{\pi}{3}$

$\cos^{-1}(-\frac{\sqrt{3}}{2}) = 150 = \frac{5\pi}{6}$

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- $\cos^{-1}(-\frac{1}{\sqrt{2}}) = 135 = \frac{3\pi}{4}$
- $\cos^{-1}(0) = \frac{\pi}{2}$
- $\cos^{-1}(1) = 0$
- $\cos(-1) = \pi$

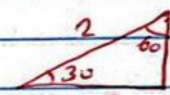
③ **Evaluate $\tan^{-1}$ Fun**

The Range of $\tan^{-1}$ Fun is similar to $\sin^{-1}$, which is between $-\pi/2$ to $\pi/2$

$\therefore$ Range $\longrightarrow [-\frac{\pi}{2}, \frac{\pi}{2}]$

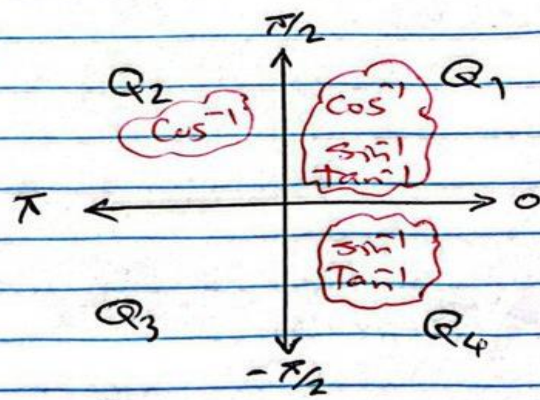
Ex)

- $\tan^{-1}(0) = 0$
- $\tan^{-1}(1) = \pi/4$
- $\tan^{-1}(-1) = -\pi/4$
- $\tan^{-1}(\sqrt{3}) = \frac{\pi}{3} = 60$
- $\tan^{-1}(-\frac{1}{\sqrt{3}}) = -\pi/6 = -30$



$\tan 60 = \frac{\sqrt{3}}{1} = \sqrt{3}$

Summary



Arc sine	Range
$\cos^{-1}x$ $\longrightarrow$	$[0, \pi]$
$\left.\begin{matrix}\sin^{-1}x \\ \tan^{-1}x\end{matrix}\right\}$ $\longrightarrow$	$[-\pi/2, \pi/2]$

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