V
TRIANGLE OF VELOCITY

The aircraft orientation in space is defined as **HEADING (HDG)**
Where the aircraft is going, is called the **TRACK (TRK)**, or ROUTE (RTE) or COURSE (CRS)

In the presence of **wind**, the aircraft isn't necessary **tracking** where it is **heading**

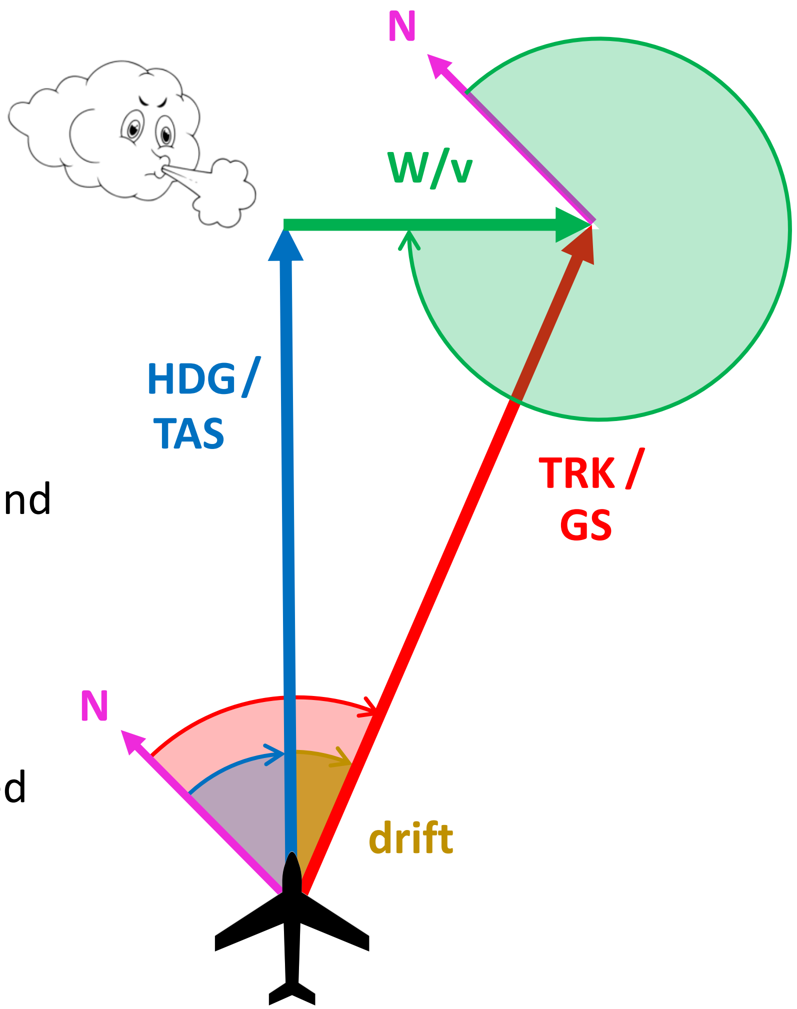
[…] Heading / HDG
Angle measured clockwise from the […] **North** to the longitudinal axis of the aircraft
We associate the **TAS** to the **HDG**

[…] Track/ TRK – Route/ RTE – Course/ CRS
Angle measured clockwise from the […] **North** to the aircraft flight path over the ground
We associate the **GS** to the **TRK**

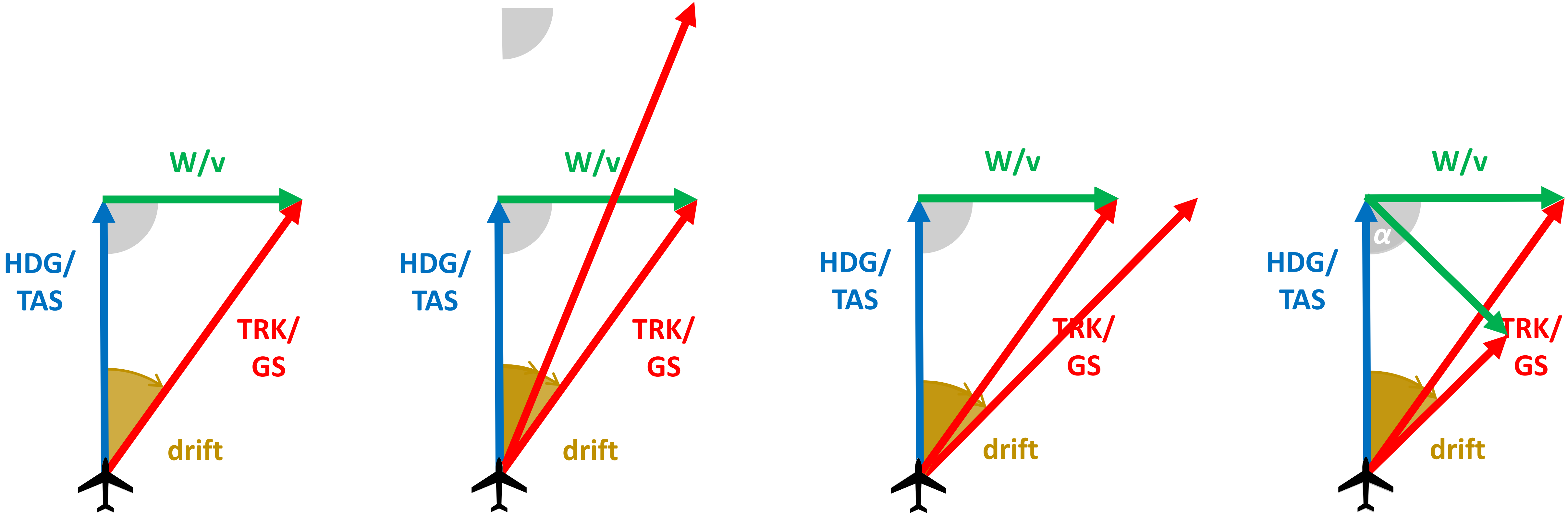
The **wind** is **drifting** the aircraft **from the HDG to the TRK**

The wind has a **direction (W)** and a **magnitude (v),** sometimes called velocity or speed

Note that the wind direction is **FROM** where the wind is blowing,
(and not TO where the wind is blowing, and it's much more convenient



The drift angle depends on the following factors:



The aircraft's TAS

- The faster, the smaller the drift
- The slower, the bigger the drift

The wind magnitude

- The weaker, the smaller the drift
- The stronger, the bigger the drift

The angle α between the

- Aircraft's HDG

- Wind direction

The **wind affects** 2 parameters of the aircraft:

- **Groundspeed (GS)**
- **Drift angle**

The wind can be:

Fully headwind

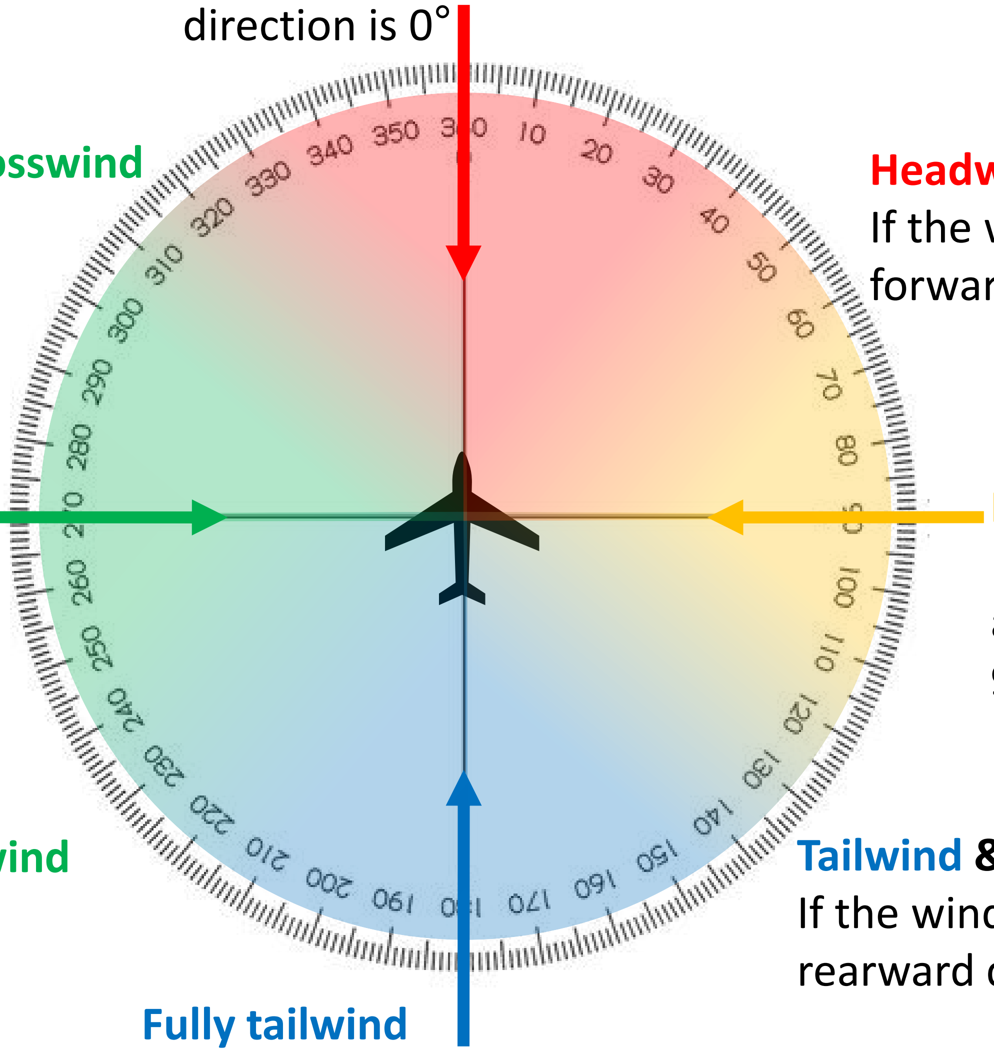
If the angle between the heading and the wind direction is 0°

Headwind & left crosswind

If the wind is from the left forward quadrant

Headwind & right crosswind

If the wind is from the right forward quadrant



Fully left crosswind

If the angle between the heading and the wind direction is 270° or 90° from the left

Fully right crosswind

If the angle between the heading and the wind direction is 90° or 90° from the right

Tailwind & left crosswind

If the wind is from the left rearward quadrant

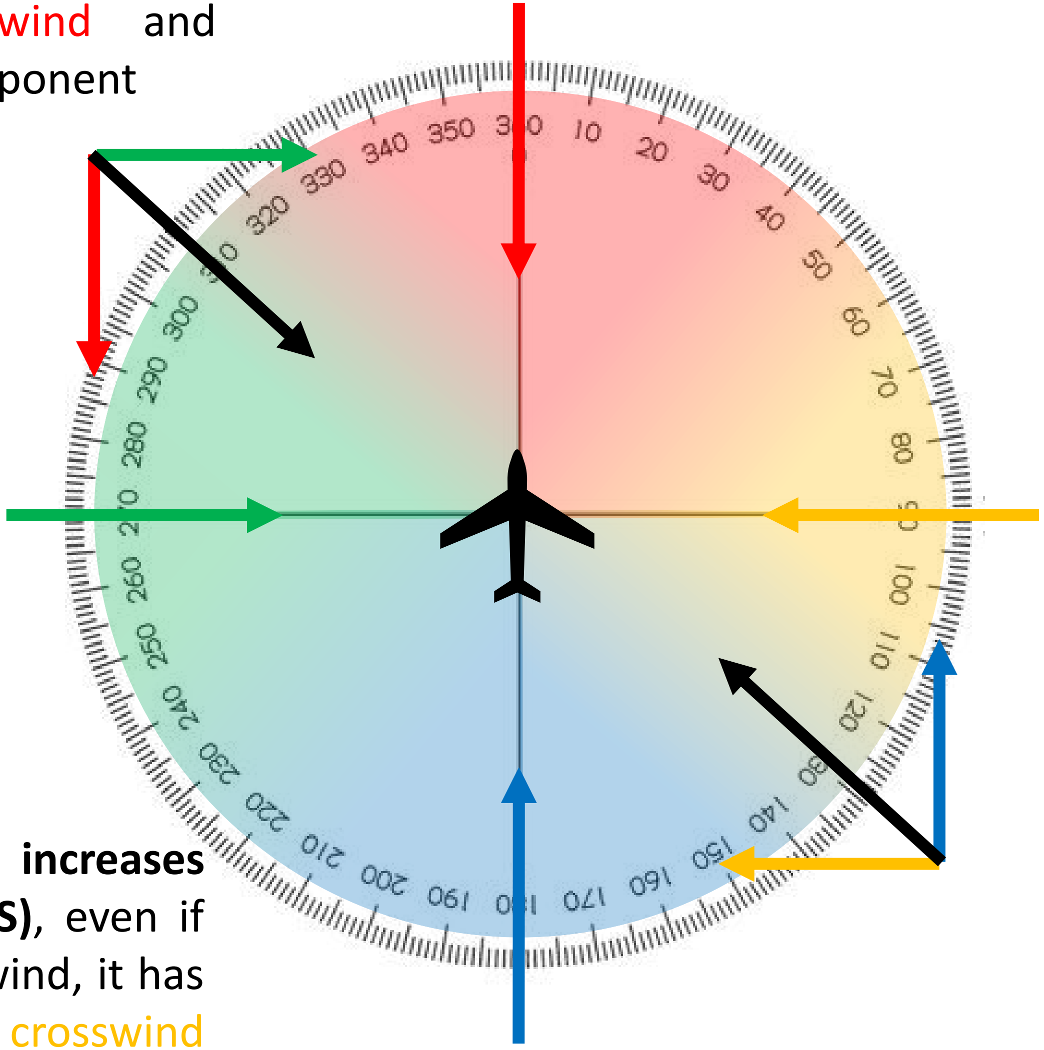
Tailwind & right crosswind

If the wind is from the right rearward quadrant

Fully tailwind

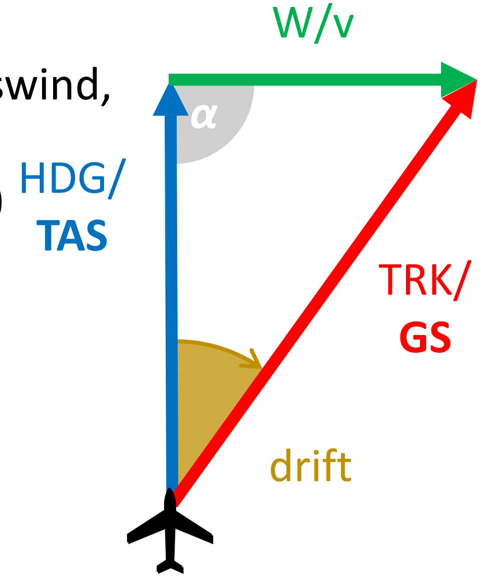
If the angle between the heading and the wind direction is 180°

The headwind decreases the GS (TAS>GS), even if is not fully headwind, it has a headwind and crosswind component



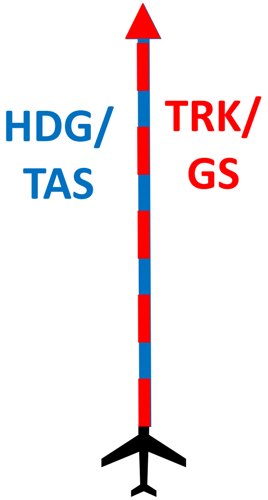
The tailwind increases the GS (TAS<GS), even if is not fully tailwind, it has a tailwind and crosswind component

Note that a fully crosswind, also affect the GS.
GS increases (TAS<GS)

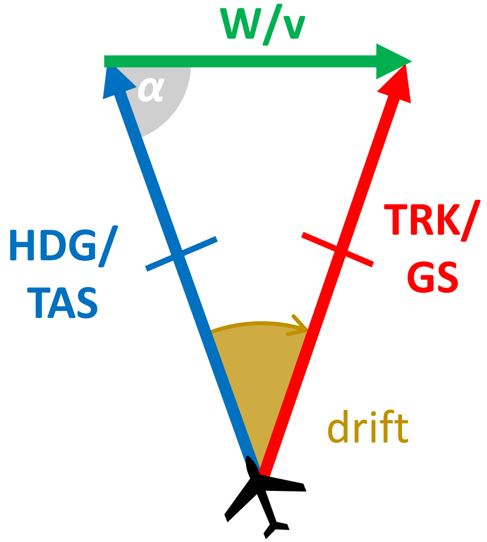


The GS isn't affected **(TAS=GS)** only:

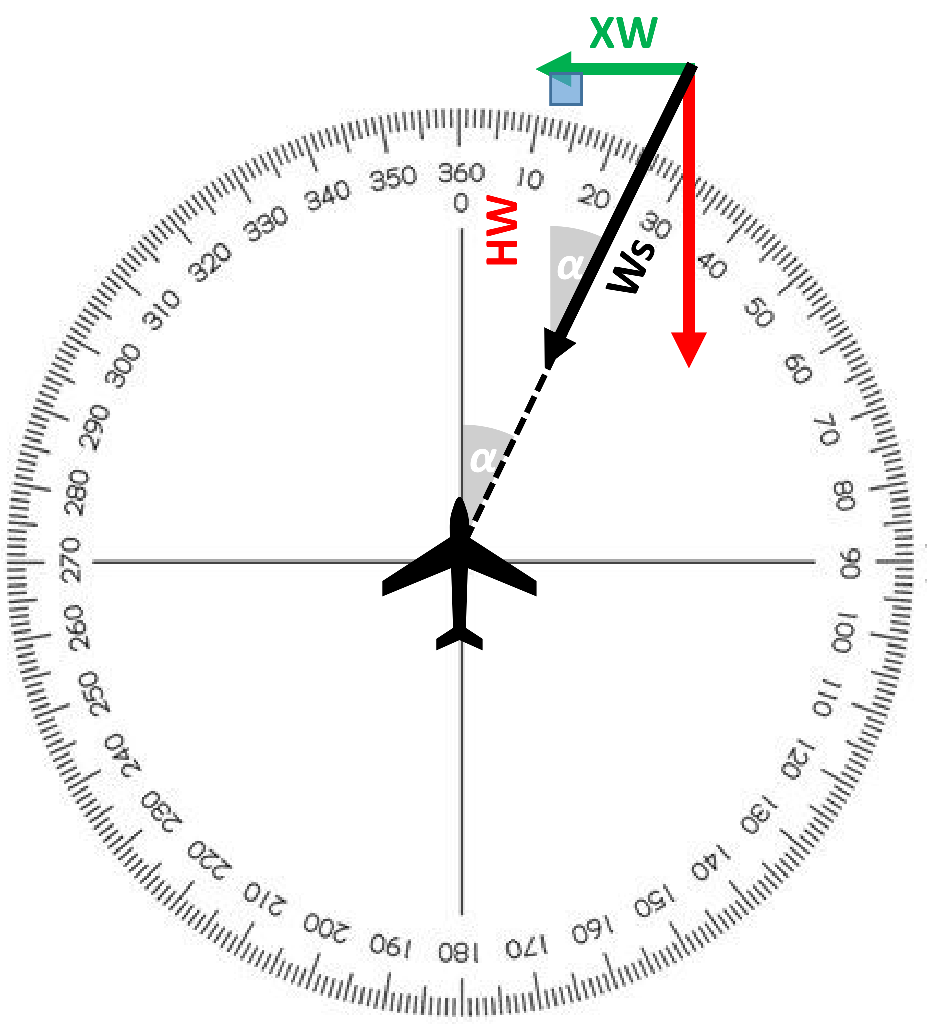
- In no or variable wind condition **(HDG=TRK)**



- Or if the triangle of velocity is isosceles (rare)



It is simple to calculate the crosswind and the headwind/tailwind component



If we take angle **α** between the HDG and the wind direction (**W_D**)

The wind speed (**W_S**) being the hypotenuse

The crosswind (**XW**) is the opposite side

The headwind (**HW**) or tailwind (**TW**) is the adjacent side

We obtain:

XW = Ws x sin(HDG– W_D)

SINE is SIDE (SIDEWIND for CROSSWIND)

HW or TW = Ws x cos(HDG– W_D)

COS is not CROSS(WIND)

If the result is positive, so it's HW
If the result is negative, so it's TW

XW = Ws x sin(HDG– W_D)
SINE is SIDE (SIDEWIND for CROSWIND)

HW or TW = Ws x cos(HDG– W_D)
COS is not CROSS(WIND)
If the result is positive, so it's HW
If the result is negative, so it's TW

Example:
The direction of the runway is use is 23 (232), when the W/v is 270°/25 kt, calculate the HW or TW and XW component.

HW or TW *= Ws x cos(HDG– W_D) = 25 x cos(232-270)*
= 25 x cos(-38) ≈ ***+20 kt HW***

XW *= Ws x sin(HDG– W_D) = 25 x sin(232-270)*
= 25 x sin(-38) ≈ ***-15 kt***

Example:
The runway in use is 30 (303), when the W/v is from 160°, what is the maximum allowable wind speed for take-off when the aircraft is limited to 10 kt tailwind and 15 crosswind during take-off ?

HW or TW *= Ws x cos(HDG– W_D) ↔*
Ws *= TW/cos(HDG– W_D) = 10/cos(303-160)*
Ws *= 10/cos(143) ≈* ***12.5 kt → 12 kt***

XW *= Ws x sin(HDG– W_D) ↔*
Ws *= XW/sin(HDG– W_D) = 15/sin(303-160)*
Ws *= 15/sin(143) ≈* ***24.9 kt → 24 kt***

The tailwind is more limiting, so the ***maximum wind magnitude*** *to allow the take-off is* ***12 kt or less***

We saw that the angle between the **HDG** and the ***W_D*** is important to obtain the HW-TW or the XW, therefore when the **HDG** and the ***W_D*** are compared, it is very important that both are measured from the same reference.

Example:

MH=240, VAR=30°W, and W/v=220/15, what is the crosswind component?

*In this example it looks like the wind is 20° from the left of the aircraft's heading, however if we compare the **W_D** with the **TH**, (TH = MH+VAR = 240+(-30) = 210), it seems that the wind is now 10° from the right, which will give us another XW value.*

So it is important that **HDG** and the **W_D** are measured from the same reference, and to know if the provided wind is TRUE or MAGNETIC.

If the wind is only mentioned as **W/v**, so it is **TRUE**,
if it mentioned as **Mg W/v** or mentioned from **ATIS** or **TOWER**, so it's **MAGNETIC**

*In our example, the wind is TRUE, so either remove the VAR from the **W_D** to convert it MAGNETIC, or we add the VAR to MH to convert it to TT*

Mg W_D = 220 – (-30) = 250°
→ Mg W_D = 250°
→ MH = 240
The wind is 10° from the right

OR

TH = 240 + (-30) = 210°
→ W_D = 220
→ TH = 210
The wind is 10° from the right

XW = Ws x sin(HDG– W_D)
*XW = 15 x sin10 ≈ **3 kt***

What you **read**, it is **TRUE** (W/v) eg, wind chart, GAMET, synoptic chart
What you **hear**, it is **MAGNETIC** (Mg W/v) eg. ATIS or TOWER (TWR) when taking-off or landing

When you are flying, the directions are stated from the Magnetic North, since our compass is pointing to the latter. So when you hear the wind provided from the TOWER or the ATIS, you can look at your heading indicator to see the direction of the wind and have an idea if it headwind, tailwind or crosswind, without thinking about VARIATION.

Example:

Imagine you are landing on runway 30 (302), and the TOWER says:

"cleared to land runway 30, wind 240 degrees, 10 kt"

So by a quick look at the heading indicator, 240° is in the left forward quadrant, so you will land in headwind and crosswind from the left

Remember:

What you **read**, it is **TRUE**

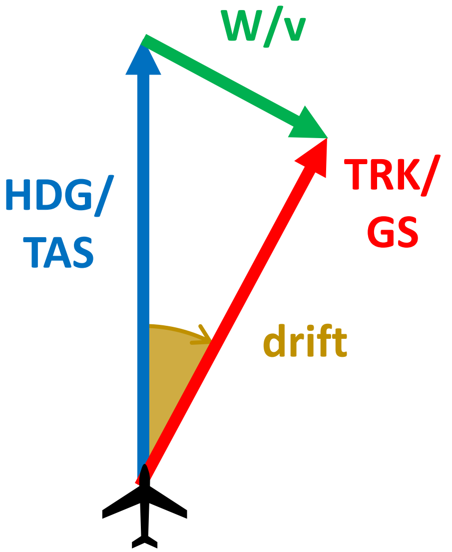
What you **hear**, it is **MAGNETIC**

*There is one exception of a TRUE WIND that you hear, it's when you ask ATC, other than TOWER, to report the wind at your current position. Actually ATC will provide you the wind from the publications that you consult on the ground, basically **ATC will read the wind for you**. While the TOWER, they have a monitor displaying the magnetic direction of the wind.*

In windy conditions, when you are **HEADING** to your target point (next point on your plan), you will not reach the latter, you will **drift** and **TRACK** elsewhere.

The **actual TRACK** is the result of where you are **HEADING** and the amount of your **drift**.

TRK = HDG + drift
HDG = TRK – drift
drift = TRK – HDG

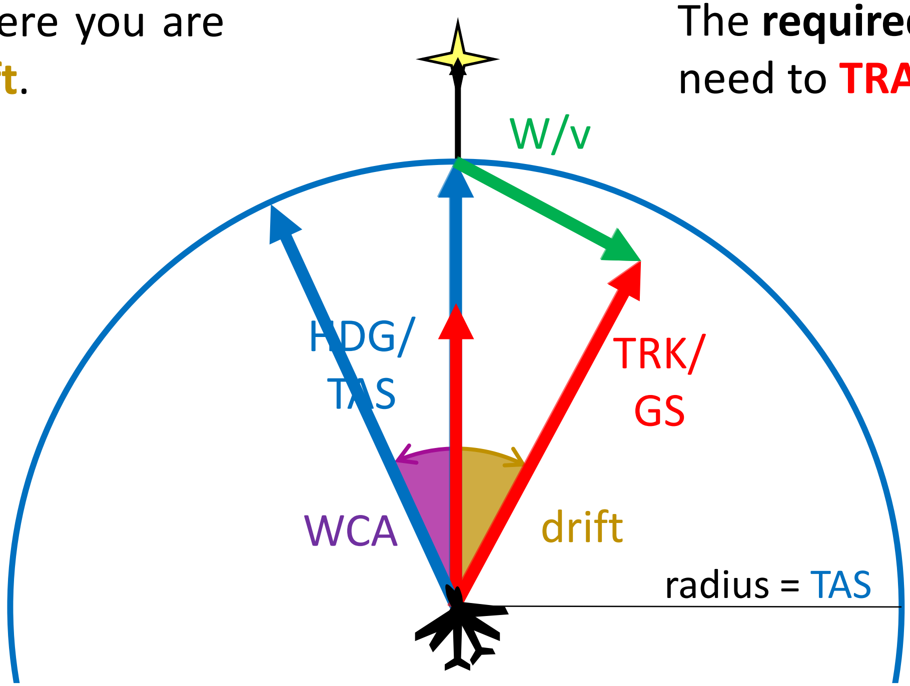


HDG Reference

So if you need to **TRACK** your target point, you need to use the **drift** to remain on that **TRACK**. Therefore you will set your **HEADING** toward the **wind** by an angle, called **Wind Correction Angle (WCA)**.

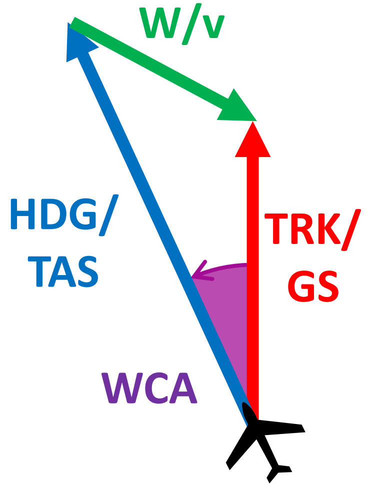
The **required HEADING** is the result of where you need to **TRACK** and the amount of your **WCA**.

HDG = TRK + WCA
TRK = HDG – WCA
WCA = HDG –TRK



Note:
<u>Right</u> or <u>Starboard</u> angles are **positive** (+)
<u>Left</u> or <u>Port</u> angles are **negative** (–)

L	R
P	S
–	+



TRK Reference

Note:
Right or Starboard angles are **positive** (+)
Left or Port angles are **negative** (–)

L	R
P	S
–	+

HDG = 230	TRK = 065	HDG 355	TRK = 236	HDG = 302	TRK = 074
DRIFT = 15°L	WCA = 8°R	WCA = 13°L	DRIFT = 11°R	TRK = 293	HDG = 086
TRK = 215	**HDG = 073**	**TRK = 008**	**HDG = 225**	**DRIFT = 9°L**	**WCA = 12°R**

When the **HDG** and the **TRK** are compared, it is very important that both are measured from the same reference

What you **read**, it is **TRUE** (W/v)
What you **hear**, it is **MAGNETIC** (Mg W/v) eg. ATIS or TOWER (TWR)

	→	-	→	-	→	
↑	TT	V	MT	d	CT	↓
+drift						+ WCA
↑	TH	V	MH	d	CH	↓
	←	+	←	+	←	

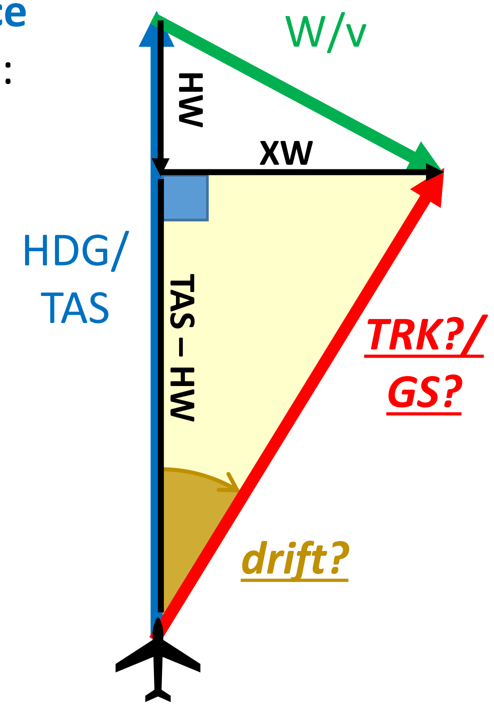
TT = 120
WCA = 9°R
VAR = 15°W
MH = 144

MH = 280
drift = 5°R
VAR = 7°W
TT = 278

HDG Reference

Unknown data:

- Drift
- TRK
- GS



$$\boldsymbol{Drift} = tan^{-1}\left(\frac{XW}{TAS - HW}\right) = tan^{-1}\left(\frac{Ws \text{ x } sin(HDG - WD)}{TAS - Ws \text{ x } cos(HDG - WD)}\right)$$

$$\boldsymbol{TRK = HDG + tan^{-1}\left(\frac{Ws \text{ x } sin(HDG - WD)}{TAS - Ws \text{ x } cos(HDG - WD)}\right)}$$

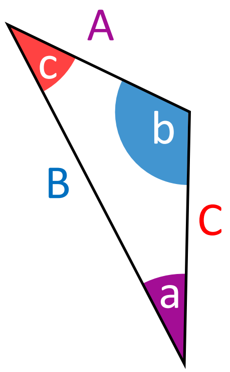
$$\boldsymbol{GS} = \frac{TAS - HW}{\cos(TRK - HDG)}$$

$$\boldsymbol{GS = \frac{TAS - Ws \text{ x } cos(HDG - WD)}{cos(TRK - HDG)}}$$

TRK Reference

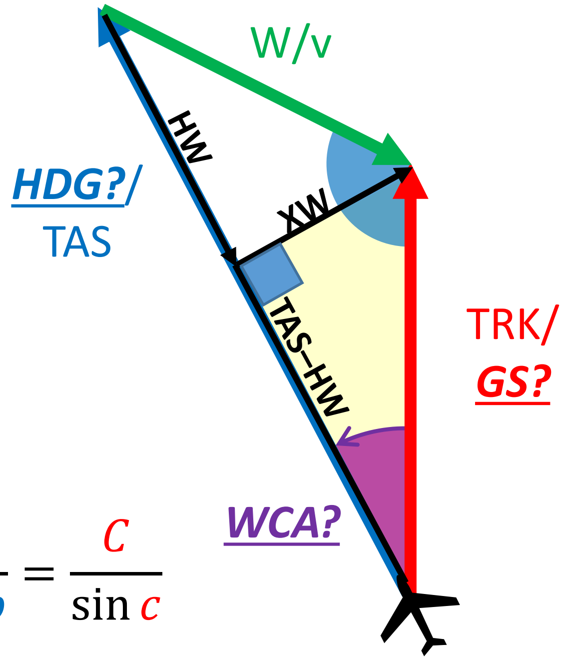
Unknown data:

- WCA
- HDG
- GS



Sinus rule:

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



$$\frac{Ws}{\sin \boldsymbol{WCA}} = \frac{TAS}{\sin(TRK - WD)} \leftrightarrow \boldsymbol{WCA} = sin^{-1}\left(\frac{Ws \text{ x } \sin(TRK - WD)}{TAS}\right)$$

$$\boldsymbol{HDG = TRK + sin^{-1}\left(\frac{Ws \text{ x } sin(TRK - WD)}{TAS}\right)}$$

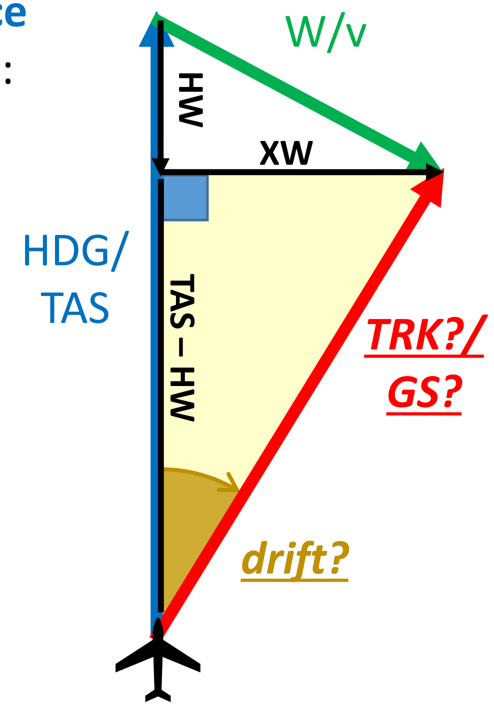
$$\boldsymbol{GS} = \frac{TAS - HW}{\cos(HDG - TRK)}$$

$$\boldsymbol{GS = \frac{TAS - Ws \text{ x } cos(HDG - WD)}{cos(HDG - TRK)}}$$

HDG Reference

Unknown data:

- Drift
- TRK
- GS



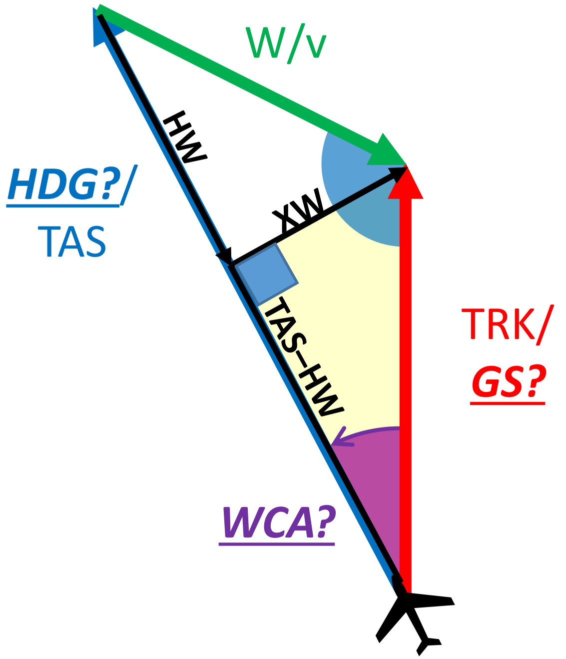
$$TRK = HDG + tan^{-1}\left(\frac{Ws\ x\ sin(HDG - WD)}{TAS\ - Ws\ x\ cos(HDG - WD)}\right)$$

$$GS = tan^{-1}\left(\frac{TAS - Ws\ x\ cos(HDG - WD)}{cos(TRK - HDG)}\right)$$

TRK Reference

Unknown data:

- WCA
- HDG
- GS



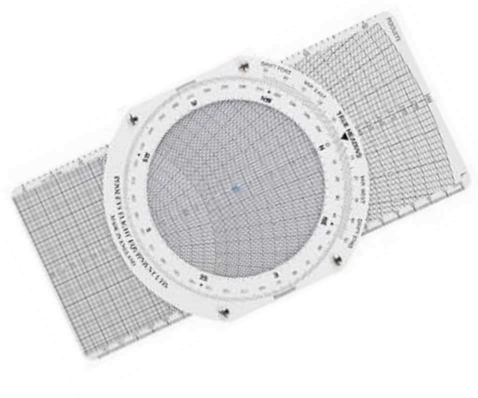
$$HDG = TRK + sin^{-1}\left(\frac{Ws\ x\ sin(TRK - WD)}{TAS}\right)$$

$$GS = tan^{-1}\left(\frac{TAS - Ws\ x\ cos(HDG - WD)}{cos(HDG - TRK)}\right)$$

The **absolute values** of the drift and the Wind Correction Angle are different in most of the cases, however the difference is very small. Therefore for convenience, in practice the pilots calculate the drift angle if they head to their desired track, then they use the opposite of the drift **value** as Wind Correction Angle in order to obtain the heading to adapt to maintain the desired track. Indeed it is easy to calculate the approximate drift in our mind (seen later with 1:60 rule).

Eg. **TRK 090°, if HDG 090° and drift 10°R, so they choose WCA 10°L, so they set HDG 080° to maintain TRK 090°.**

The same reasoning will be applied on the Flight Computer CRP-5



Remember: it is very important that all angles of direction (**HDG, TRK, W_D**) are measured from the same reference.

What you read, it is TRUE (W/v)
What you hear, it is MAGNETIC (Mg W/v) eg. ATIS or TOWER (TWR)

A) Searching the W/V when you have HDG, TRK, GS and TAS
→ HDG Reference

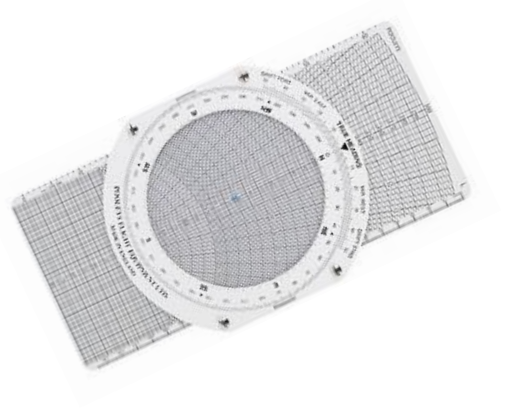
1) Set HDG on True Index
2) Scroll centre on TAS
3) Draw the line of same drift
4) Draw the GS arc
5) Mark the intersection of the DRIFT LINE and GS arc
6) Turn and set the MARK below the centre
7) Read **Wind direction** below True Index
8) Read **Wind velocity** on the MARK (down from the centre)

B) Searching the W/V when you have HDG, TRK, GS and TAS
→ TRK Reference

1) Set TRK on True Index
2) Scroll on GS
3) Draw the line of same WCA
4) Draw the TAS arc
5) Mark the intersection of the WCA LINE and TAS arc
6) Turn and set the MARK above the centre
7) Read **Wind direction** on True Index
8) Read **Wind velocity** on the MARK (up from the centre)

The same reasoning will be applied on the Flight Computer CRP-5

Remember: it is very important that all angles of direction (**HDG, TRK, W_D**) are measured from the same reference.



What you read, it is TRUE (W/v)
What you hear, it is MAGNETIC (Mg W/v) eg. ATIS or TOWER (TWR)

A) Find Drift and GS when you have HDG, TAS and W/v
→ HDG Reference

1) Set Wind direction on True Index
2) Mark the wind speed **DOWN** from the centre
3) Set HDG on True Index
4) Scroll TAS arc on the centre
5) Read **GS** on the MARK
6) Read **drift angle** between MARK and centreline

B) Find WCA and GS, when you have TRK, TAS and W/v
→ TRK Reference

1) Set Wind direction on True Index
2) Mark the wind speed **UP** from the centre
3) Set TRK on True Index
4) Scroll MARK on the TAS arc
5) Read **GS** on the centre
6) Read **WCA** between MARK and centreline

*As discussed earlier, since we can assume that the absolute **value** of the **drift** and of the **WCA** are the same, in practice and for convenience to find the **GS** and the **WCA**, you can use **method (A)** instead of **method (B)**, simply the **drift** found becomes the **WCA** by changing the sign,*
*→ **Eg.** If you find **drift 10°L**, so **WCA 10°R**, and the **GS** is will be wrong by few knots.*
*However in some exercises in the question bank, a very precise answer is needed and the difference between the options proposed is very small. So for the question bank, it is recommended to use **method (B)** to find the exact **WCA** and **GS**.*

(If 1:60 rule covered)

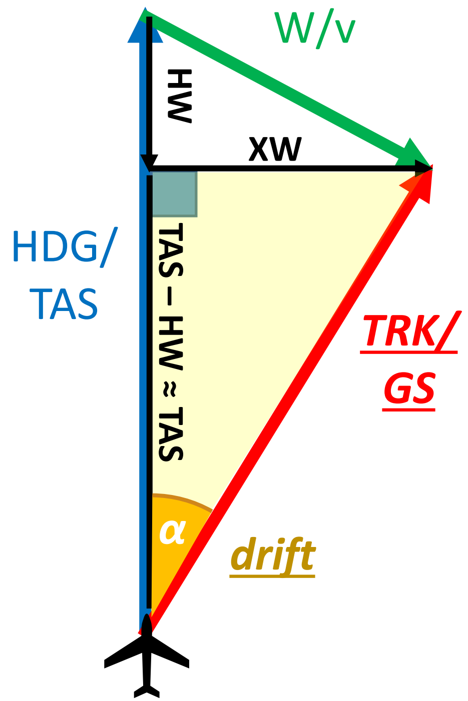
Quick calculation for the drift calculation by Rule of Thumb:

Since the accuracy will vary only by fractions of degrees, we can therefore calculate the approximate full degree of drift with the Rule of Thumb, and by assuming a triangle rectangle between the TAS and the XW

$$\boldsymbol{drift = \frac{XW}{TAS} \text{ x } 60}$$

$$drift = \frac{Ws \text{ x } \sin\alpha}{TAS} \text{ x } 60$$

$$\boldsymbol{drift = \frac{Ws}{TAS} \text{ x } 60 \text{ x } \sin\alpha}$$



To determine the approximate value of the sinus, we can use the clock angle:

sin 0° = 0 → 0

sin 15° ≈ 0.25 → ¼

sin 20° ≈ 0.33… → ⅓

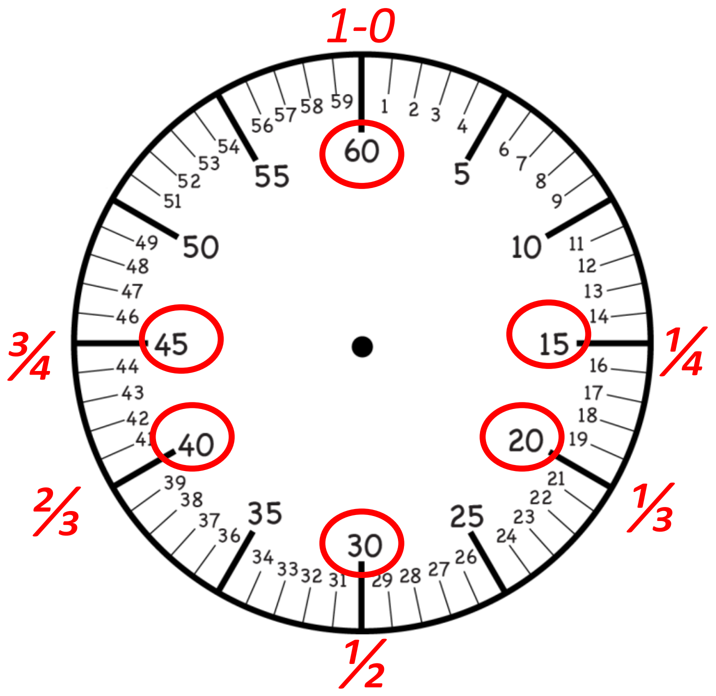
sin 30° = 0.5 → ½

sin 40° ≈ 0.66… → ⅔

sin 45° ≈ 0.75 → ¾

sin 60° ≈ 1 → 1

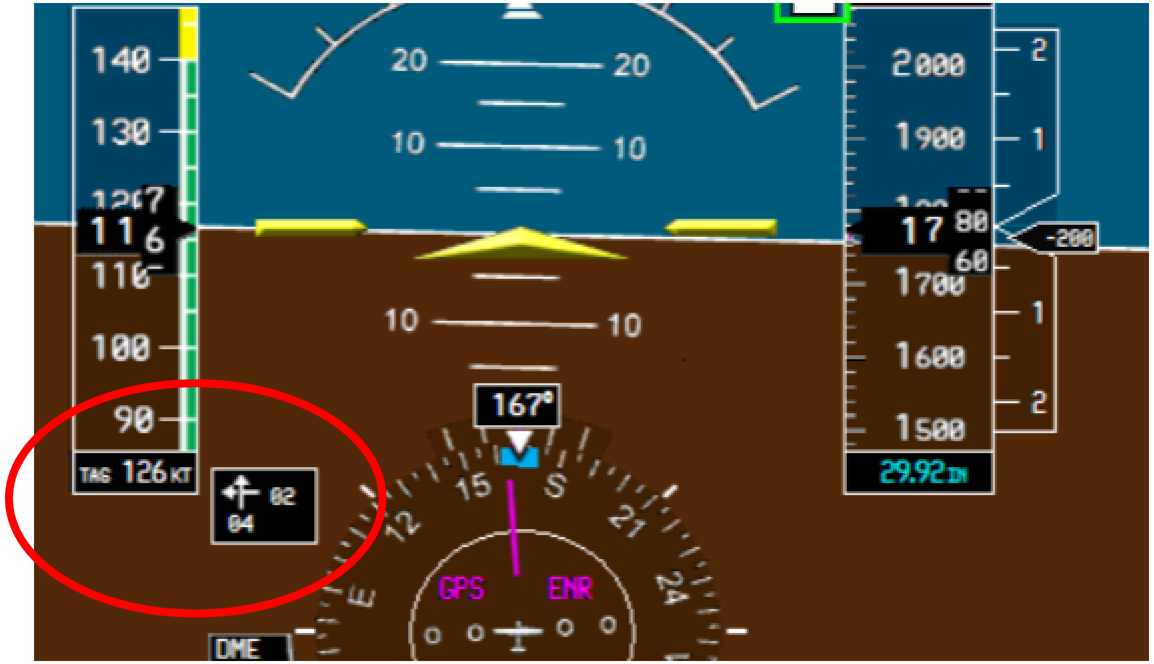
***Note**: If you can calculate SIN, you can also calculate COS:*
cos α = sin (90 – α)



Example: 20 x sin 40 = "20 x 40minutes" = "20 x 2/3 hour" ≈ 20 x 2/3 ≈ 13°

(If 1:60 rule covered)
Quick adaptation

On the G1000, it exists an option that could display the XW directly:



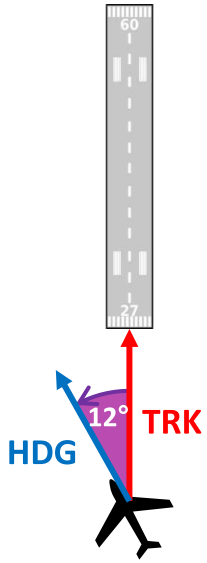
So the following equation can be used

$$drift = \frac{XW}{TAS} \text{ x } 60$$

In this example

$$drift = \frac{2}{126} \text{ x } 60 \approx \frac{60}{120} \text{ x } 2$$

$$drift \approx 1°L$$



You can always improve the calculation method when you know your aircraft

For example, the Tecnam P2006T (which is equipped with G1000), has typical approach speed of 90 KTAS:

$$drift\ during\ approach = \frac{XW}{90} \text{ x } 60 = \frac{60}{90} \text{ x } XW$$

$$drift\ during\ approach = 2/3\ of\ XW$$

*So for example during approach with a Tecnam 2006T, if you see XW=19 kt to the right, so the **WCA** to keep tracking the runway centerline will be 2/3 of 19 which is **approximately 12° to the left**.*