DOCUMENT
GSM-G-CPL.026

DOCUMENT TITLE

NAVIGATION 1

CHAPTER 6 – NAVIGATION COMPUTER (WIND SIDE)

Version 2.0
October 2017

CONTENTS

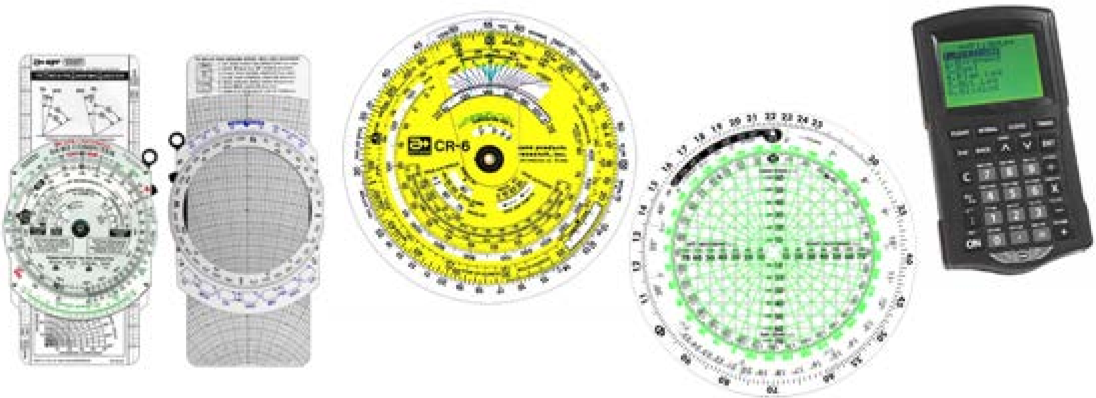
NAVIGATION COMPUTER (WIND SIDE)

6.1 Introduction

Triangle of velocities consists of:

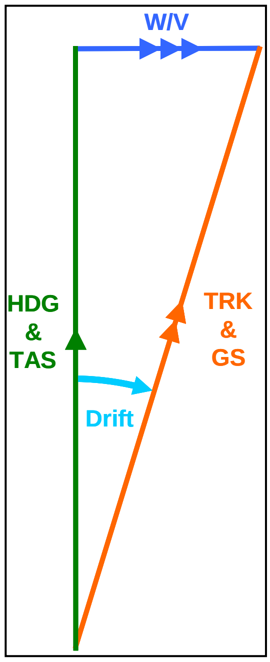
- A wind velocity (wind vector)
- Track and groundspeed (ground vector)
- Heading and true airspeed (air vector).

To solve the triangle of velocities there are various types of navigation computers available for aviation use, one such computer is the Jeppesen CR-3 navigation computer.

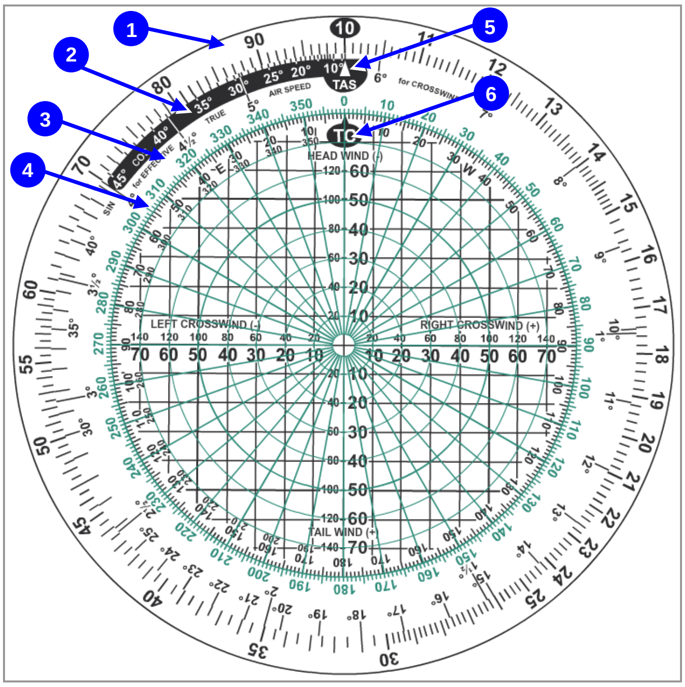


The wind side of the CR-3 circular navigation computer is used to solve:

- Sine and Cosine of angles up to 45°
- Velocity triangle for heading and groundspeed with given values for track, true airspeed and wind velocity
- Velocity triangle for track and groundspeed with given values for heading, true airspeed and wind velocity
- Velocity triangle for wind velocity for given values for track, heading, true airspeed and groundspeed
- Runway wind components for take-off or landing.



6.2 Overview



1 Outer disc containing a logarithmic scale

2 Black portion of middle disc containing a logarithmic Cosine scale

3 White portion of middle disc containing a logarithmic Sine scale

4 Inner disc containing a compass rose in green

5 True airspeed index marker on the middle disc

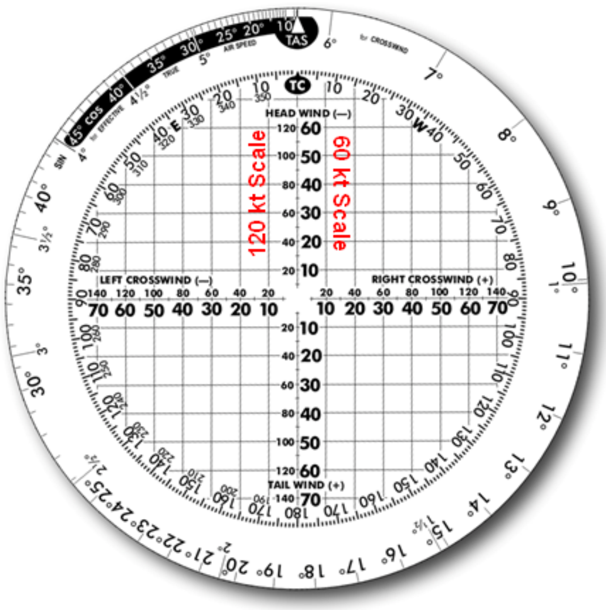
6 True course (track) marker on the middle disc.

6.2.1 Wind Scales

Two wind scales either side of the horizontal and vertical lines represent wind speeds and measured from the centre of the computer:

- Low speed scales (larger), wind speed less than 60 knots.
- High speed scales (smaller), wind speed greater than 60 knots.

Use the same scale throughout the calculations



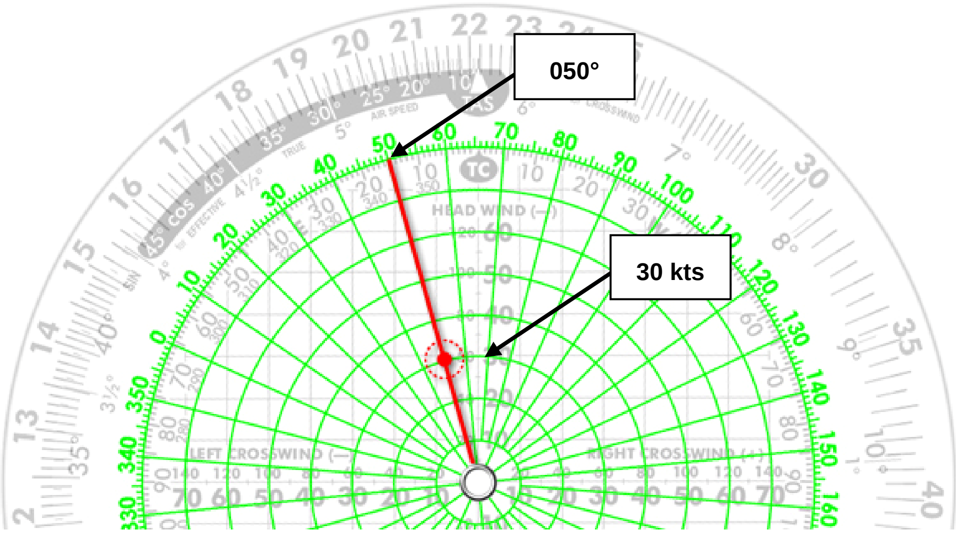
6.2.2 Wind Velocity

With wind velocity given, mark it first on the computer before any other values.

Plot a wind originating from 050° at 30 knots:

- Find the 050° line on the green circular scale of the inner disc.
- From the centre, measure to a point where the 30 circle, on the low speed scale, intersects the 050° line.
- Place a **small dot** with a sharp pencil at the intersection.
- Surround the dot with a circle.

The dot placement and circle size are illustrated below.



6.2.3 North Reference

The most common task during flight planning is calculating heading and groundspeed, with the values for TAS, track and wind velocity known.

It is important that the same north reference is used for **all vectors** of the triangle of velocities:

- If the track is in degrees true, the wind velocity must be in degrees true, resulting in heading degrees true.
- If the track is in degrees magnetic, the wind velocity must be in degrees magnetic, resulting in heading degrees magnetic.

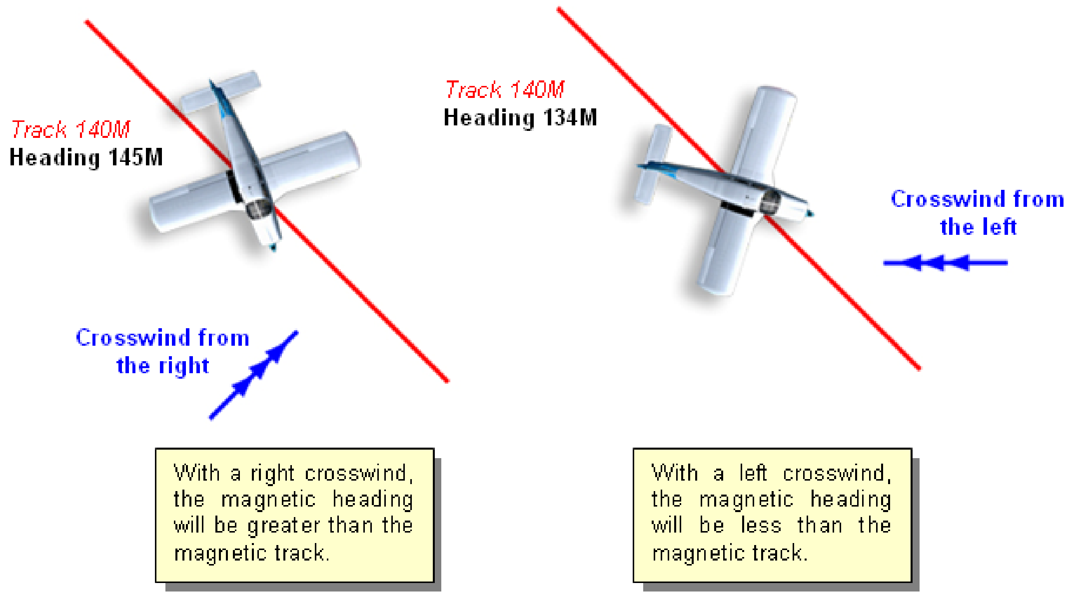
If a flight plan log is designed for magnetic directions, all calculations are done in degrees magnetic.

PSN	LSALT	FL or ALT	TAS	TR(M)	WIND	HDG (M)	G/S	DIST	ETI	EET	PLN EST	REV EST	ATA ATD

<u>Note:</u> Wind velocity (W/V) forecast is given in degrees true. Convert wind direction to degrees magnetic before adding wind velocity to the flight plan log.

6.2.4 Magnetic Track

- The CR-3 computer has a True Course (TC) index (**course** is the American term for **track**)
- Either degrees true or degrees magnetic can be used. To conform to the flight plan log **TR(M)** the TC index will be used to plot the track in degrees magnetic using the inner disc and green numbers.



6.2.5 Application

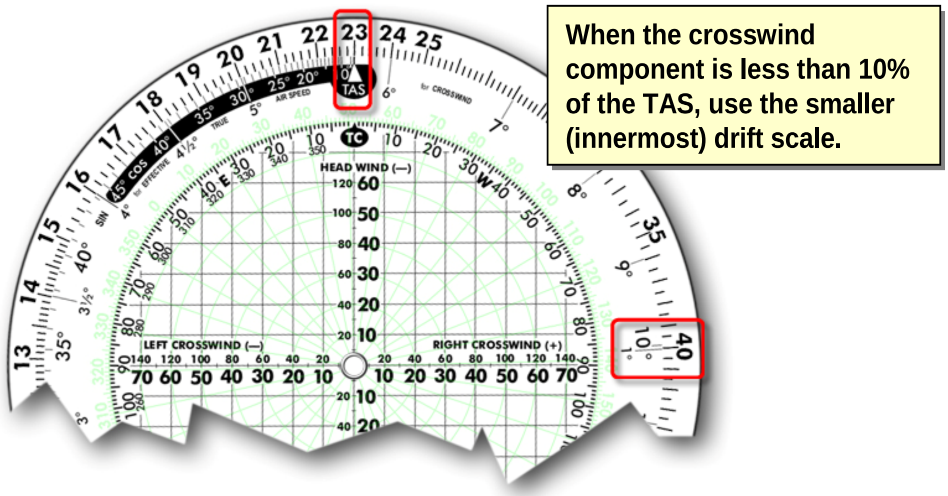
Three steps are required to set up a triangle of velocities:

- Mark the **magnetic wind velocity** on the inner disk.
- Place **True Airspeed** on the outer disk above the **TAS index**.
- Place **Magnetic Track** on the inner disk above the **TC index**.

6.2.6 Drift Angle Scale

- When reading the drift angle on the middle disc opposite crosswind component on the outside scale, when going from 10° clockwise to the TAS index on the middle disc there are two scales, the outside scale with large angles (10°, 11°, 12°, etc.) and inside scale with small angles (1°, 1½°, 2°, 2½°, etc.).
- If the crosswind component is less than 10% of the TAS, the drift angle is read on the inside angle scale (generally less than 6°). I.e. TAS is 230kts (TAS index set to 230) and the crosswind component is 4kts, the crosswind component is less than 23, 10% of TAS, therefore the drift angle is 1° on the inside angle opposite 4.0 kts crosswind (as 40 represent 4.0).
- If the crosswind component is greater than 10% of the TAS, the drift angle is read on the outside angle scale (6° or greater). I.e. TAS is 230kts, if the crosswind component is 40kts, therefore greater than 10% of the TAS, the angle will be 10° on the outer scale.

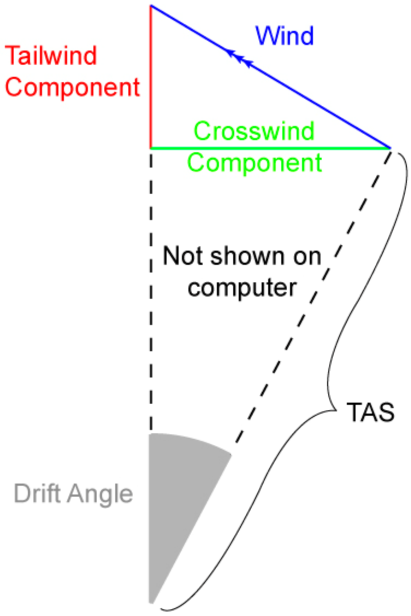
.



6.2.7 Basis for Wind Problem Solution

The circular navigation computer shows part of the triangle of velocities graphically and solves the remainder of the problem trigonometrically.

This is the portion of the triangle of velocities that the CR-3 Computer solves:



With the track and wind velocity known, the small triangle is used to calculate the tailwind- and crosswind components by reading it directly from the computer.

With the track set and the tailwind- and crosswind components known, it is possible to find the wind velocity.

The relationship between TAS, groundspeed and drift angle is calculated by using the Sine of the drift angle in the lower part of the triangle (dashed outline).

$$\text{Sin Drift Angle} = \frac{\text{Crosswind Component}}{\text{True Airspeed}}$$

$$\therefore \quad \text{True Airspeed} = \frac{\text{Crosswind Component}}{\text{Sin Drift Angle}}$$

The **TAS index** on the Sine scale is the **starting point** on the outside scale.

We know the crosswind component by plotting the TAS, forecast wind and flight planned track on the computer.

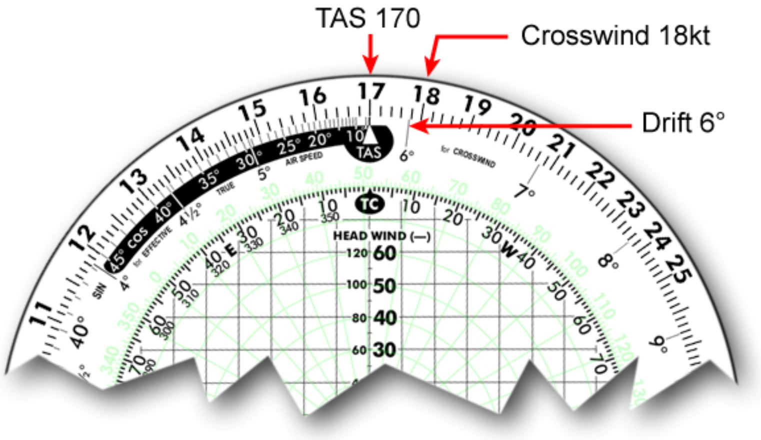
We need to know the drift angle to calculate the heading to steer for the forecast wind on the required track.

$$\text{True Airspeed} = \frac{\text{Crosswind Component}}{\text{Sin Drift Angle}}$$

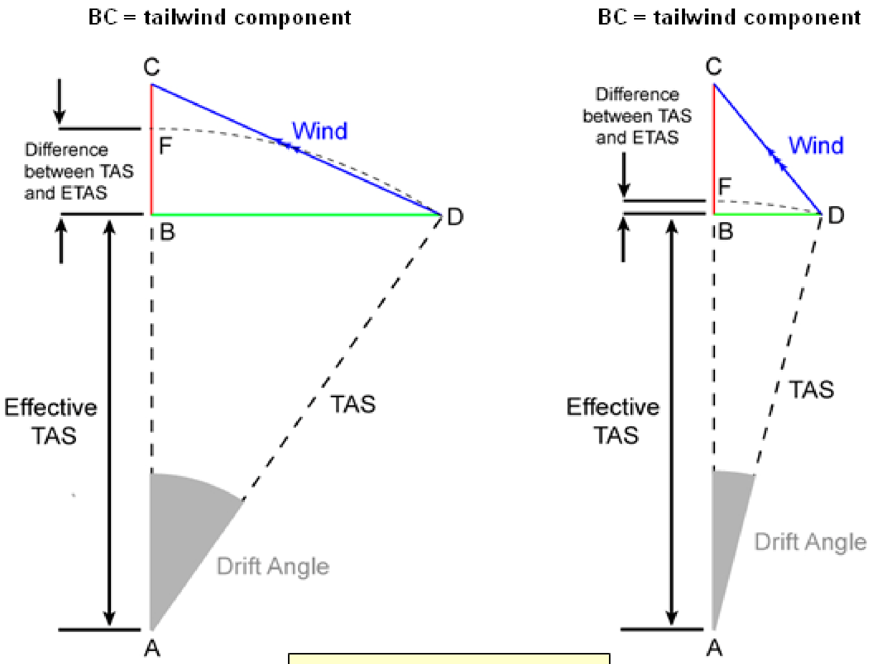
If the crosswind component is divided by (placed opposite) the drift angle on the inside scale, TAS is opposite the TAS index.

If the TAS is opposite the TAS index, the crosswind component on the outside scale is opposite the drift angle on the inside scale.

Drift applied to Track = Heading to Steer.

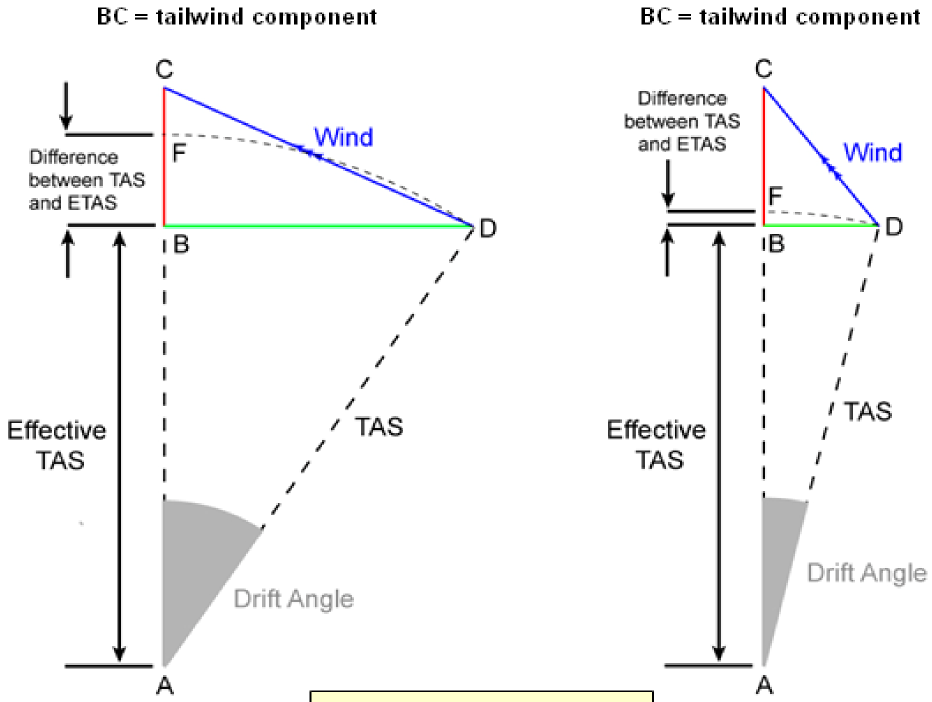


6.2.8 Effective True Airspeed



Note:
ETAS = TAS cos Drift angle

- **TAS** is the length of **AD**.
- **Groundspeed** is the length of **AC**.
- **Wind** velocity is the length of **DC**.
- **Tailwind** component is the length of **BC**.



Note:
ETAS = TAS cos Drift angle

If AD is equal to the component AB (zero drift angle), the tailwind component BC is added to the TAS to calculate groundspeed.

If AB and AD are similar in length (difference being BF), it can be assumed as equal and the tailwind component can still be applied to the TAS. The margin of error in the calculated groundspeed would be insignificant.

When the drift angle is large, AB is too different from AD in length (difference illustrated by BF) and a significant margin of error would be present in the groundspeed so derived.

The wind component (BC) and groundspeed acts along the track, TAS (AD) acts along the heading

The circular navigation computer solves the wind vector about the track, therefore if the drift angle is greater. The TAS vector must be resolved about the track before the wind component is added to obtain groundspeed. To find the groundspeed (AC) add the tailwind component (BC) to that portion of the TAS acting along track, i.e. add AC to the ETAS (AB).

Groundspeed = ETAS + Tailwind component

or in a headwind scenario:

Groundspeed = ETAS - Headwind component

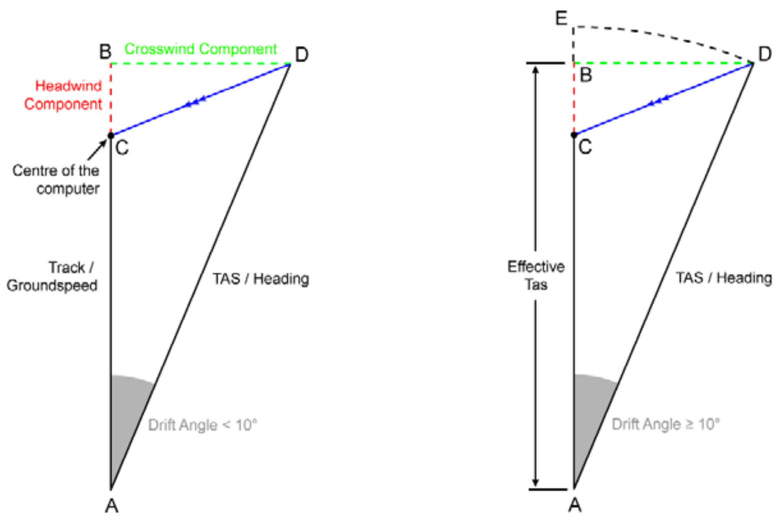
In the diagrams above, ETAS is calculated with the equation:

ETAS = TAS Cos Drift Angle

When the drift angle is less than 10º, Cos drift will be approximately 1º, and the wind component is added to the TAS. When the drift angle is 10º or greater, effective TAS (ETAS) is used to calculate groundspeed.

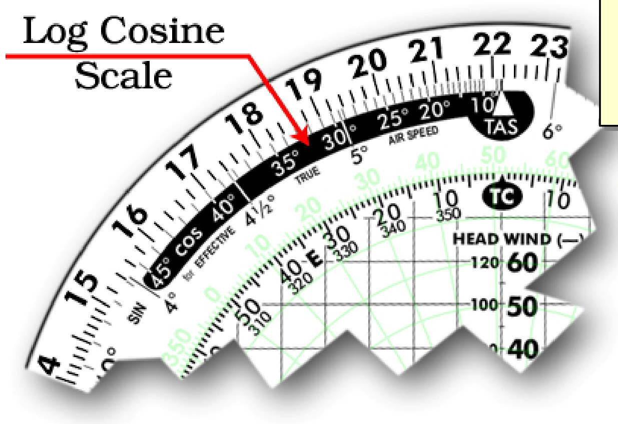
When ETAS is <u>not</u> considered with 9º drift angle there is a 1% error in the groundspeed calculation, for speeds up to 200kts the error margin is negligible.

Therefore, **ETAS** is used to calculate groundspeed for a **drift angle greater than 10º** and a variation of method is introduced.



$$\text{Cos A} = \frac{\text{AB}}{\text{AD}} = \frac{\text{Effective True Airspeed}}{\text{True Airspeed}}$$

$$\therefore \ \text{True Airspeed} = \frac{\text{Effective True Airspeed}}{\text{Cos Drift Angle}}$$

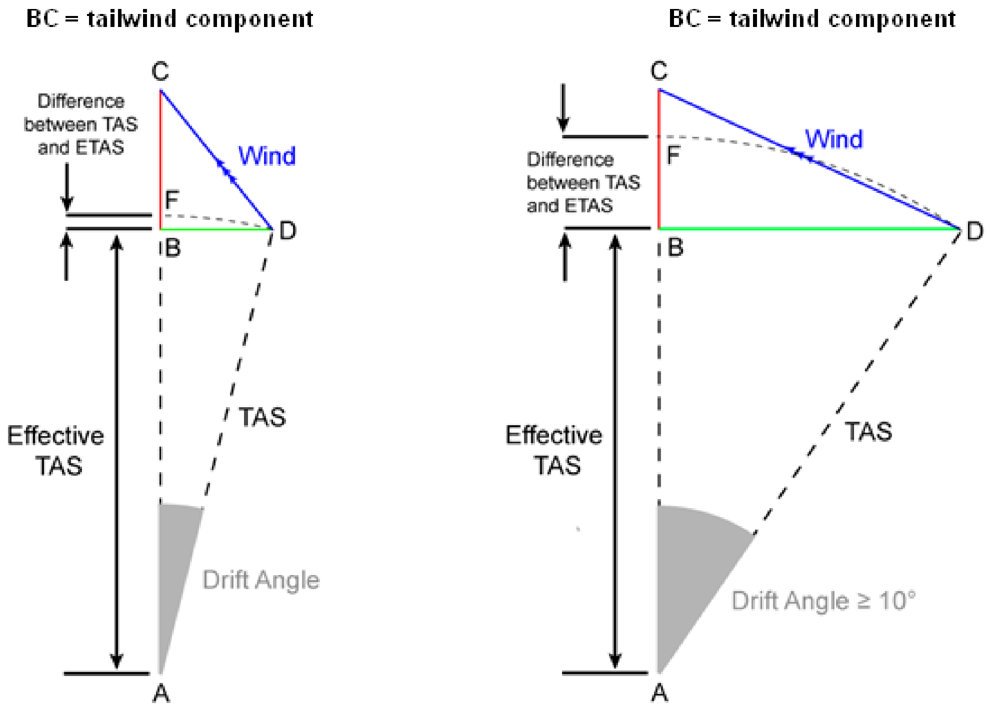


On the middle disc, the black section to the left of the TAS index, is a log cosine scale, used for deriving ETAS.

With TAS opposite the TAS Index, ETAS is opposite the drift angle on the black cosine scale.

With a drift angle of 10° the use of TAS, instead of ETAS, will result in an error of approximately 1½%. With a 5° drift angle, the error is less than one half of 1%.

An error less than 1½% is not significant in actual flight conditions, therefore it is recommended that ETAS be used only if the drift angle is 10° or greater.



Note:
ETAS = TAS cos Drift angle

Drift angle less than 10º	GS = TAS + tailwind component GS = TAS - headwind component
Drift angle ≥ 10°	GS = ETAS + tailwind component GS = ETAS - headwind component

6.3 Wind Side

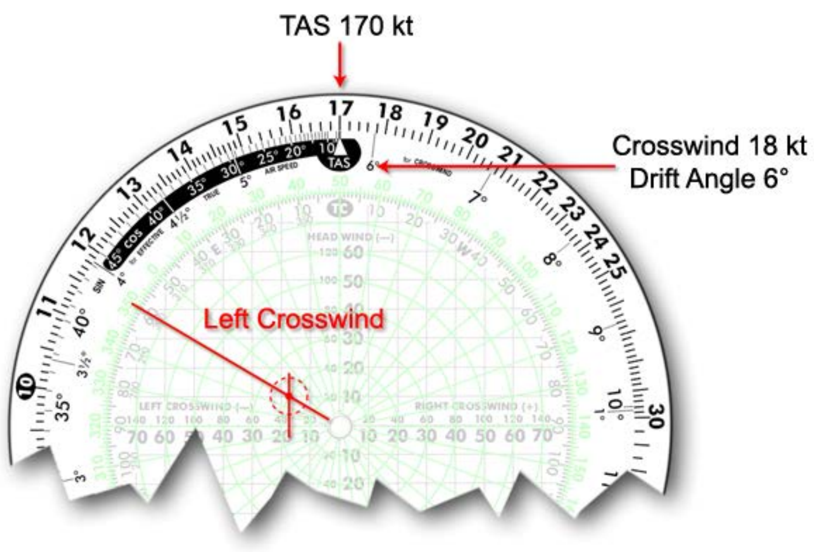
6.3.1 Heading and Groundspeed (Without ETAS)

The following two examples both solve the velocity triangle during flight planning:

- In the first example the drift is less than 10° and the steps to solve ETAS have been omitted, since in this case it is not necessary to solve ETAS in order to find accurate groundspeed.
- In the second example the drift is greater than 10° and the additional steps required to solve groundspeed by means of ETAS can be found in the solution.

Example 1	Wind	350°M at 20kts
	TAS	170kts
	Magnetic Track	050°M

Solution



- Set the TAS index opposite **170kts** on the outside scale.
- **Plot the wind velocity** on the **green** (inner) disc, find the direction of **350°M** and plot the wind speed on the intersection of the 350° green line and the green **20kts** line.
- Draw a dot and circle it as illustrated previously, using the low speed scale.
- **Align the track**, rotate the inner disc until the track **050°M** is opposite the TC index.
- The computer is now set and no further movement of discs should be made.

- From the wind dot, proceed vertically (down) to intersect the crosswind scale, the point represents a value of 18 on the low speed scale. **T**he crosswind component is **18kts <u>from</u>** the **left.**
- Locate **18kts** on the outside scale and read the drift angle on the middle disk opposite the crosswind value, **6°** (as the drift angle is **less than** 10° ETAS is not required). Since the crosswind is **<u>from</u>** the **left**, drift angle is 6° **<u>towards</u>** the **right, 6°R**.
- The minus sign (-) next to the crosswind from the left indicates that a subtraction is required to obtain the heading. i.e subtract drift angle from the track to obtain heading.

Heading = 050°M – 6° = **044°M**

- Read the headwind component horizontally across from the wind dot towards the vertical wind component axis.

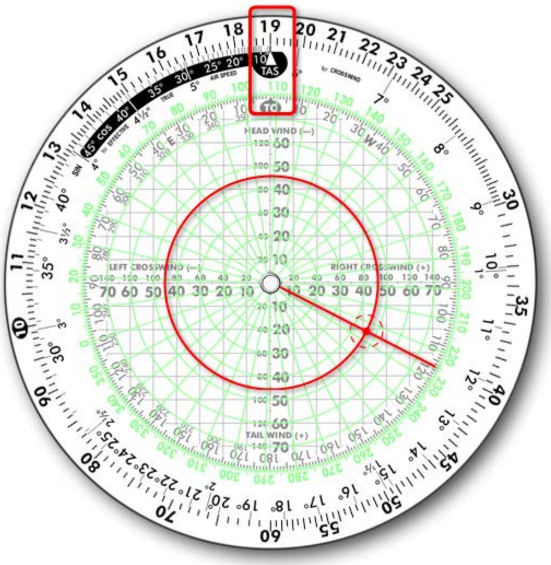
Headwind component = **11kts**

- Subtract the headwind component from the TAS to calculate the groundspeed.

Groundspeed = 170 – 11 = **159kts**

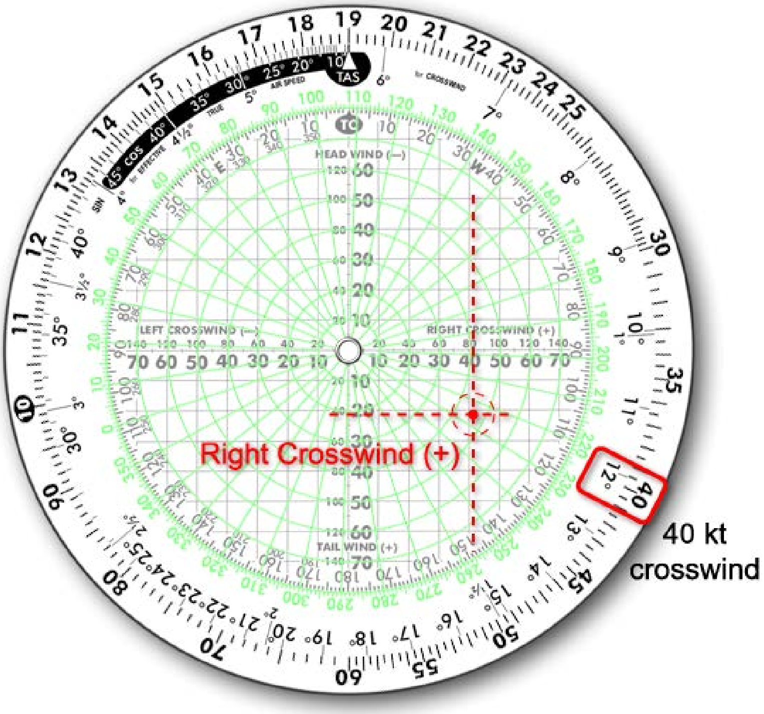
6.3.2 Heading and Groundspeed (ETAS required)

<u>Example 2</u>	Wind	225°M at 45kts
	TAS	190kts
	Magnetic Track	108°M



Solution:

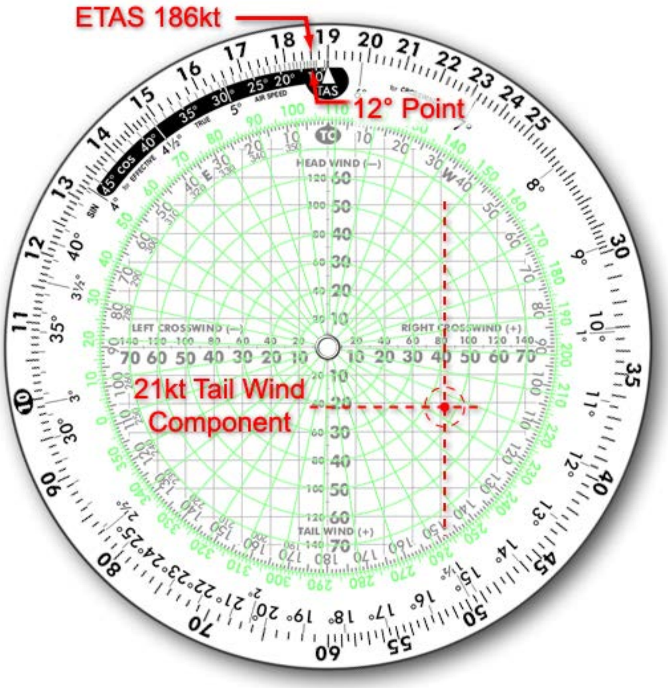
- Set the TAS index opposite 190 kts on the outside scale.
- **Plot the wind velocity**, on the **green** (inner) disc find the direction of **108°M** and plot the wind speed at the intersect of the 108° green line and the green **45kts** arc.
- **Set the track** opposite the TC Index using the inner (green) scale.
- From wind dot, read the crosswind component by going vertically up towards the right crosswind scale. The crosswind component is **40 knots** **from** the **right**.
- Locate **40kts** on the outside scale and read the drift angle opposite the value on the middle disk, drift angle is **12°**. (Drift is **more than** 10°, therefore ETAS **must be** used to calculate groundspeed). Due to the crosswind **from** the right, the aircraft will experience drift **towards** the left, i.e. 12°L drift angle.



- It is a **right** crosswind, add the drift angle to the track to obtain the heading.

Calculate Heading: Heading = 108° + 12° = **120°M**

- Refer to the picture below. Read the tailwind component from the computer by proceeding horizontally to the left from the wind dot, the tailwind component is **21kts**.
- Since the drift angle is 10° or greater use **an Effective True Airspeed (ETAS)** instead of TAS to calculate the groundspeed.



- On the black scale (Cosine scale) to the left of the TAS index, locate the **12°** point. Opposite the **12°** read the ETAS on the outer scale, **186kts**.
- Add the tailwind component to the ETAS to obtain the groundspeed.

Groundspeed = 186 + 21 = **207kts**

6.3.3 Track and Groundspeed

The following example calculates the track and groundspeed that will result from a given wind velocity, while maintaining a specified heading and true airspeed.

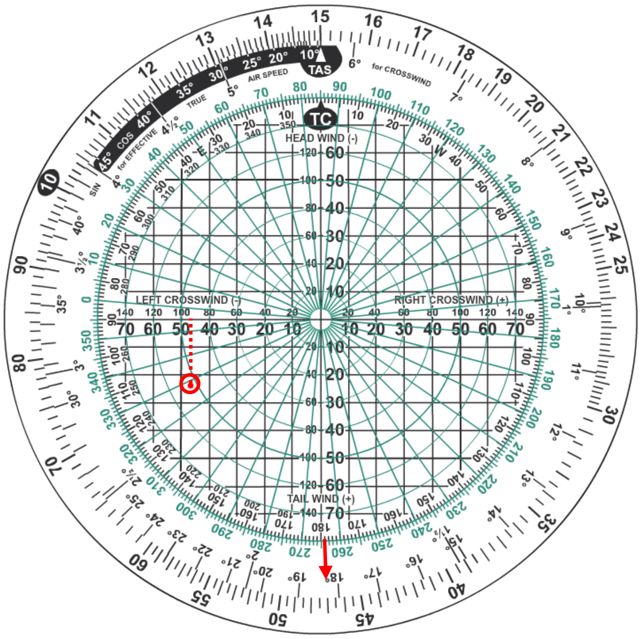
The steps required to solve the velocity triangle are similar as before, although additional steps are required to solve the track, before the groundspeed can be calculated. If the drift angle is greater than 10° then ETAS is used to solve groundspeed.

Example 3	Wind	328°M at 52kts
	TAS	150kts
	Magnetic Heading	085°M

Solution:

- **Align the TAS.** Set the TAS index opposite 150kts on the outside scale.
- **Plot the wind velocity.** On the **green** (inner) disc find the direction **085°M** and plot the wind speed on the intersection of the 85° green line and the green **45kts** arc.

- **Set the heading** (estimated track value) opposite the **TC Index** using the inner (green) scale. Track is normally set opposite the TC Index, as it is not a known value additional steps are required to solve the track before the groundspeed can be calculated.
- The wind dot is not in the correct position, as heading is set opposite the TC index, instead of track. The wind component values are treated as estimated values until the track is calculated and placed at the TC Index.
- From the wind dot vertically up towards the left crosswind scale **read the estimated crosswind component.** The crosswind component is **47 knots <u>from</u>** the **left**.
- Locate **47kts** on the outside scale and read the **estimated** drift opposite the value on the middle disk. The estimated drift angle is **18°** (drift angle is considered **estimated** since the crosswind component is an **estimated value**). Due to the crosswind being **<u>from</u>** the left, the aircraft will experience drift **<u>towards</u>** the right, i.e. 18° right drift angle (initially).



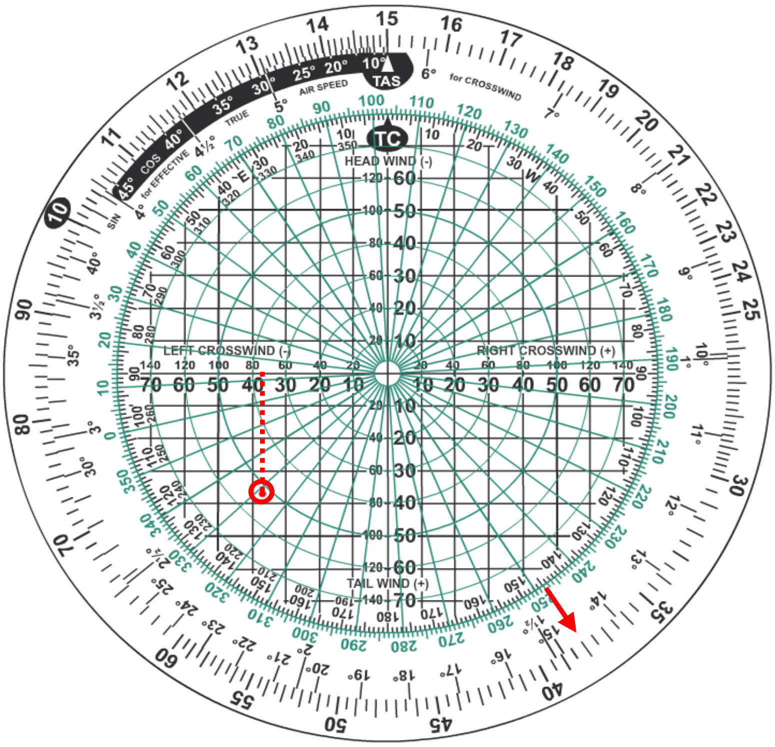
- **Calculate a revised track estimate** by applying the **estimated drift** to the **heading.** The aircraft's heading is given as 085°M and the drift angle 18° to the right, the aircraft will make good a track to the right of the heading.

Revised Track Estimate = 085° + 18° = **103°M**

- **Set the revised track estimate** opposite the **TC Index** on the inner scale. This process will move the wind dot's position and cause the wind components to change, which in turn could change the drift angle, which will then alter the track estimate.

  Note: The steps performed earlier will be repeated until the drift remains the same as what was calculated with the previous set of values.

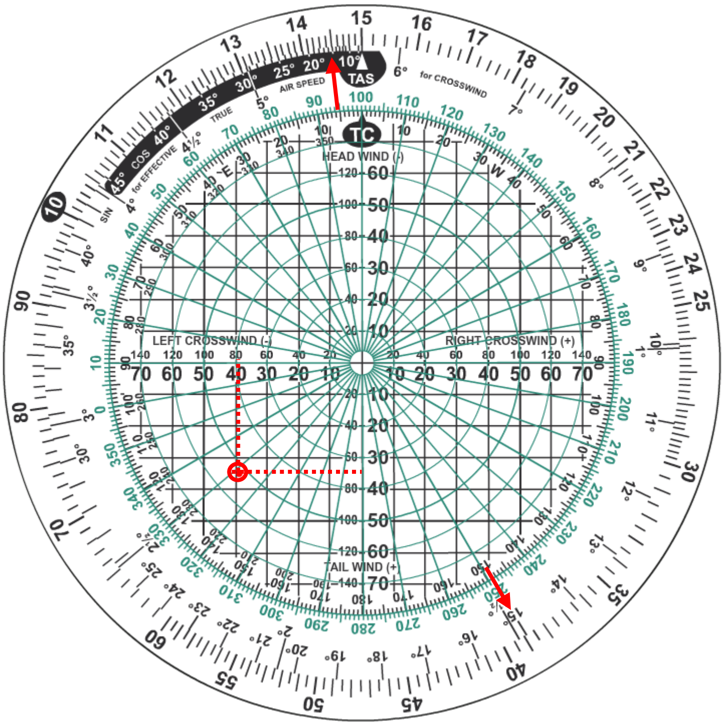
- From the wind dot vertically up towards the left crosswind scale **read the revised crosswind component.** The crosswind component is **38kts** **<u>from</u>** the **left**.
- Locate **38kts** on the outside scale and read the **revised** drift angle opposite the value on the middle disk, **15° right**.



- **Calculate a revised track estimate** by applying the **revised drift** to the **<u>heading</u>.** The aircraft's heading is given as 085°M and the drift angle 15°R The aircraft will make good a track to the right of the heading.

Revised Track = 085° + 15° = **100°M**

- **Set the revised track** opposite the **TC Index** on the inner scale. This process will move the wind dot's position causing the wind components and drift angle to change and alter the track estimate. The key value remaining the same is the drift angle. These steps are repeated until there is no change in the drift angle..
- From the wind dot vertically up towards the left crosswind scale **read the revised crosswind component.** The crosswind component has changed to **39kts** **<u>from</u>** the **left**.
- Locate **39kts** on the outside scale and read the **revised** drift angle opposite the value on the middle disk. The revised drift angle is **15°**R.



- As the drift angles are similar after repeating the above steps, the track is 100°M and the crosswind component 39kts.
- Since the drift angle is 10° or greater use **ETAS** instead of TAS to calculate the groundspeed.
- On the black scale (Cosine scale) to the left of the TAS index, locate the **15°** point. Opposite the **15°** read the ETAS on the outer scale, **145kts**.
- Opposite the TC Index, read the tailwind component by proceeding horizontally to the right from the wind dot to the tailwind component axis (**35kts)**.
- Add the tailwind component to the ETAS to obtain the groundspeed.

Groundspeed = 145 + 35 = **180kts**

6.3.4 Wind Velocity

The following values are required to calculate wind velocity:

- Track Made Good (TMG)
- Heading (HDG)
- True Airspeed (HDG)
- Groundspeed (GS)

If the drift angle (DA) is known:

- Apply the **DA to heading** to obtain **track.**
- Apply **DA to track** to obtain **heading**.

During flight, distance and time between two fixes equals groundspeed.

The following information can be obtained in flight:

- Heading from the compass
- Indicated airspeed from the airspeed indicator
- Pressure altitude from the altimeter
- Outside temperature from the air temperature gauge

TAS can be calculated with the values of the indicated airspeed, pressure altitude and outside temperature.

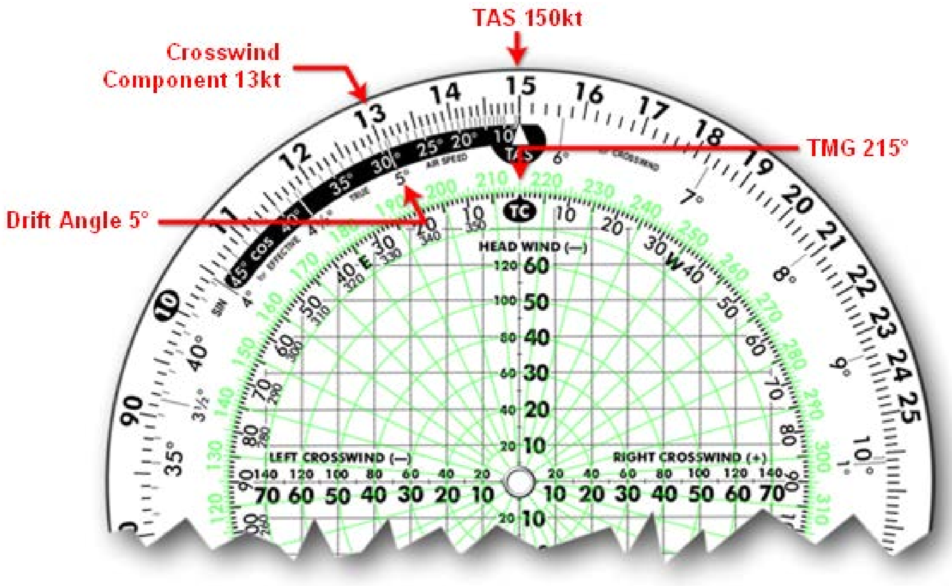
Accuracy is more difficult to achieve with this method and satisfactory answers are within 5° and within 2kts.

Since track and TAS are given set the values opposite the required indexes. Once the crosswind component and the head- or tailwind components are known, proceed to fix the two coordinates for the wind dot.

Example 4	Heading	220°M
	Track Made Good	215°M
	True Airspeed	150kts
	Groundspeed	130kts

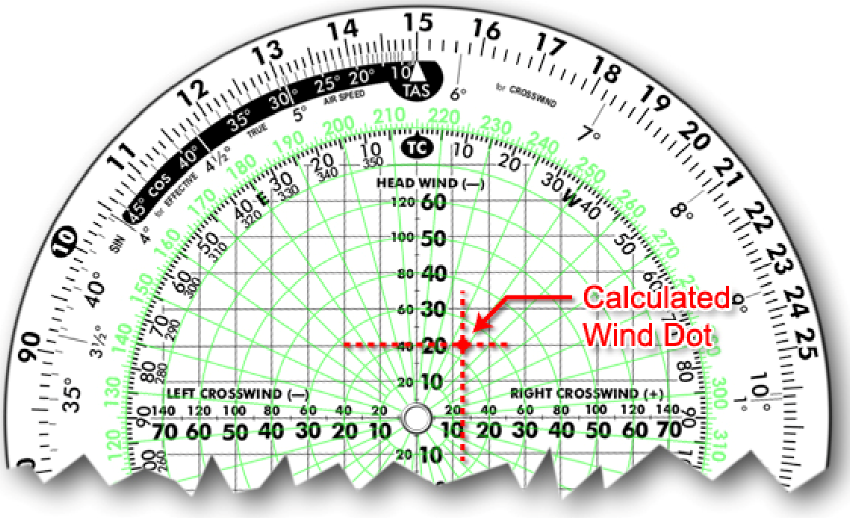
Solution

- Set the TAS index to **150kts**.
- Set the TMG **215°M** opposite the TC Index (with the magnetic track set the wind direction will be in degrees magnetic).
- Calculate the drift angle by comparing the heading and TMG. With the nose of the aircraft pointing towards 220°M, the aircraft is making good a track to the left of 220°M, i.e. TMG is 215°M, therefore the drift angle is left, **5°L (wind from the right)**.
- Opposite 5° on the middle disc read **13** on the outside disc, i.e. Crosswind component = **13kts**.

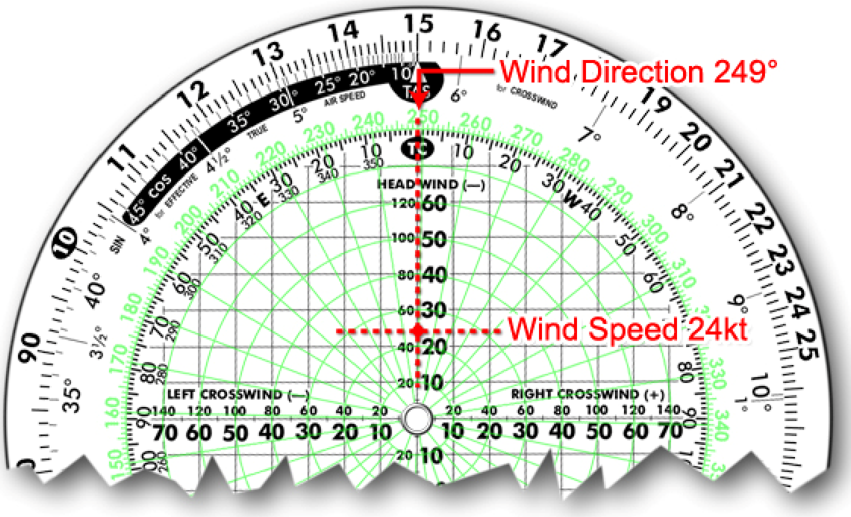


- Refer to the picture below. Locate **13kts** crosswind on the **right crosswind axis** and draw a **vertical pencil line**, parallel to the vertical black lines in the background. Use a ruler so the line is straight.
- It is only necessary to draw the vertical line up towards the headwind. Draw it downwards for a tailwind component. The result will be a headwind, since the groundspeed is less than the TAS. The reverse is true for a tailwind component.
- **No ETAS calculation is necessary** since the **drift angle** is **less than 10°.**

  Note*: If the drift angle was greater than 10° the ETAS could be calculated by entering the drift angle on the black cosine scale on the middle disk and reading the ETAS opposite on the outer disk. A headwind- or tailwind component is the difference between ETAS and groundspeed.*
- Subtract the groundspeed from the TAS to calculate the headwind component: 150kts - 130kts = **20kts**.
- Locate **20kts** on the **vertical headwind component axis** and draw a **horizontal pencil line** intersecting the vertical line drawn earlier for the crosswind component. The intersection marks the position of the wind dot.



- Turn the inner disc until the wind dot is positioned along the vertical headwind component axis.



- Read the wind direction (magnetic) opposite the TC index, **249°M**.
- Read the wind speed on the low speed scale, **24kts**.

Wind Velocity = **249/24**

6.3.5 Runway Wind Components

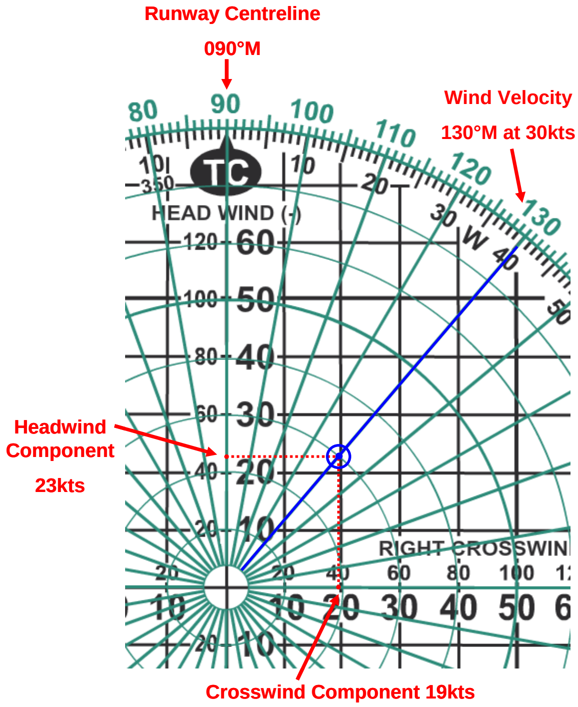
Runway directions are in degrees magnetic, the centreline direction can be obtained from the Jeppesen Terminal section.

Air Traffic Control (ATC) and the Automatic Terminal Information Service (ATIS) report the surface wind in degrees magnetic. If required, the calculation can be done in degrees true, ensure that both the runway- and wind direction are in degrees true.

Example 5	Runway	RWY 09 (centreline direction 090°M)
	Wind Velocity	130°M at 30kts

Solution:

- **Plot the wind velocity**, on the **green** (inner) disc find the direction **090°M** and plot the wind speed on the intersection of the 90° green line and the green **30kts** arc. .
- Set the **runway centreline direction** on the **TC Index.**
- Read the crosswind component from the horizontal crosswind axis, **19kts** from the right.
- Read the head- or tailwind component from the vertical axis, **23kts** headwind.



Headwind Component = **23kts**

Crosswind Component = 19kts from the right