

### STUDY AID — PENDING INDEPENDENT AUDIT

These notes are study aids for DGCA examination preparation. They are PENDING INDEPENDENT AUDIT and

**must not be used to decide whether a real landing is within limits**

. Crosswind and headwind limits come from your aircraft's approved flight manual and your operator's rules, and from nowhere else. Always verify against current AIPs, NOTAMs and your operator's manuals.

GENERAL NAVIGATION • THE NAVIGATION COMPUTER

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## Chapter 9

### Multi-drift Winds and Wind Components

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*Two last jobs for the wind face. The first is a way of finding the wind when you cannot measure your ground speed at all. The second is the only calculation in this module that you will make with your hand on the thrust levers, fifty feet above a runway, deciding whether to land.*

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**Opening plate** — Fifty feet, and one decision left. This chapter is the arithmetic you do an hour earlier so that this moment needs no arithmetic at all.

#### SIXTY SECONDS ON SHORT FINAL

The tower has just passed you a spot wind. You are below the height at which you must commit to landing or going around. Your aircraft's crosswind limit is a number you know.

What you do **not** have is time to resolve a wind velocity into components. There is no version of this moment in which you take a hand off the controls and work out a sine.

**So the work happens at top of descent.** You calculate, once, the wind strength from the forecast direction that would put you exactly on your limit. Then at fifty feet you compare one number with one number, and you have already decided.

That is what the second half of this chapter is for, and it is the most directly operational thing in the whole module.

## 1 • Two more jobs for the wind face

Chapters 7 and 8 covered the three main operations — find track, find heading, find wind. Two more remain, and they are different in kind from each other.

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|                          | What it does                                                                                                    | Who needs it                                                                                                                | Does the CX-3 have it?                                                             |
|--------------------------|-----------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------|
| <b>Multi-drift winds</b> | Finds a W/V from <b>drift alone</b> , with no ground speed measurement at all, by flying two or three headings. | Anyone flying without RNAV, GPS, INS or FMS. Bush and maritime patrol pilots build a real skill at estimating drift by eye. | <b>No.</b> There is no such function. Section 2 gives you the mathematics instead. |
| <b>Wind components</b>   | Resolves a wind into the part acting <b>along</b> the runway and the part acting <b>across</b> it.              | Every pilot, on every take-off and landing, for the rest of their career.                                                   | <b>Yes</b> — and it carries the most dangerous trap in this module. See Section 5. |

### Rule-of-thumb crosswind methods are not good enough here

You will meet mental shortcuts for crosswind — the clock-face method, the sixths rule, and others. They are useful airborne and they are worth knowing.

**They are not precise enough for the examination.** General Navigation questions are built so that a rule of thumb lands you between two options. Resolve them properly, with the computer or with the trigonometry.

## 2 • Multi-drift winds — a wind from drift alone

An experienced pilot at low level can judge drift surprisingly well, simply by watching the angle at which a feature on the ground slides underneath the aircraft. It is a real skill and it improves with practice.

**Ground speed is the hard one.** You can time the change of a DME range, but only while tracking directly to or from the beacon. You can time a precalculated distance with a stopwatch, but that means preparation you may not have done. Neither is available on demand.

## The idea, and it is a good one

Each drift observation, on its own, does not tell you the wind. It tells you one thing about the wind — and two or three of those things together pin it down completely.

Fly a heading and note the drift. Turn onto a second heading well away from the first and note the drift again. Ideally take a third. Then combine them.

The best results come from **three headings 60° apart**. For two headings, they must be nearly at right angles — certainly more than 70° apart — or the answer is worthless.

## The worked example

A pilot is flying **030°** at a TAS of **120 knots** and wants an updated wind. He assesses his drift, turns 60° left, assesses again, turns 120° right, assesses a third time, then returns to his original heading. He notes:

| Heading | Drift observed |
|---------|----------------|
| 030°    | 10° port       |
| 330°    | 5° port        |
| 090°    | 5° port        |

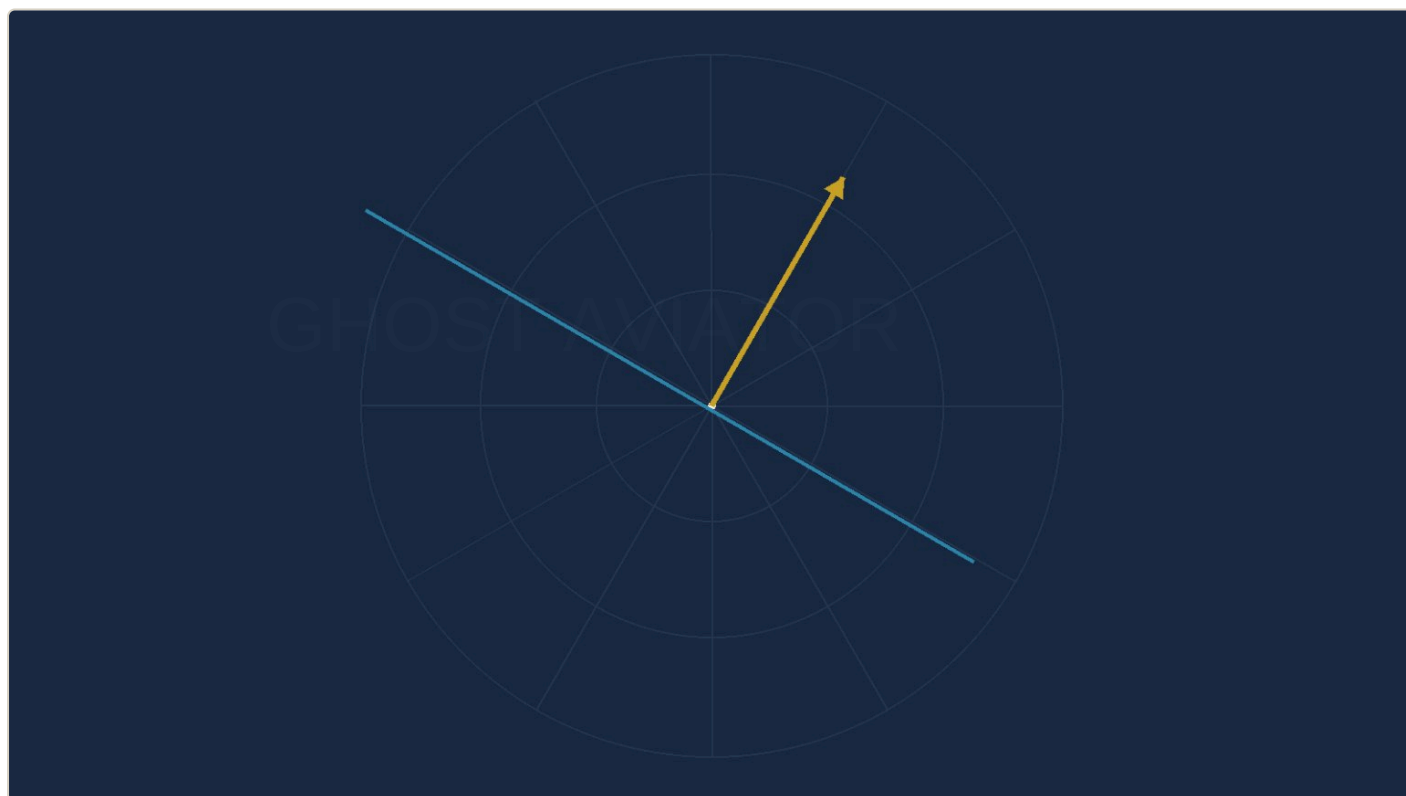


**Figure 9.1** — The first drift line. Every point on this line is a wind that would give exactly 10° of port drift on a heading of 030° at 120 knots. **One observation narrows the wind from everywhere to somewhere**

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on a line.

■ heading 030°, TAS 120    ■ the line of every wind that fits this drift

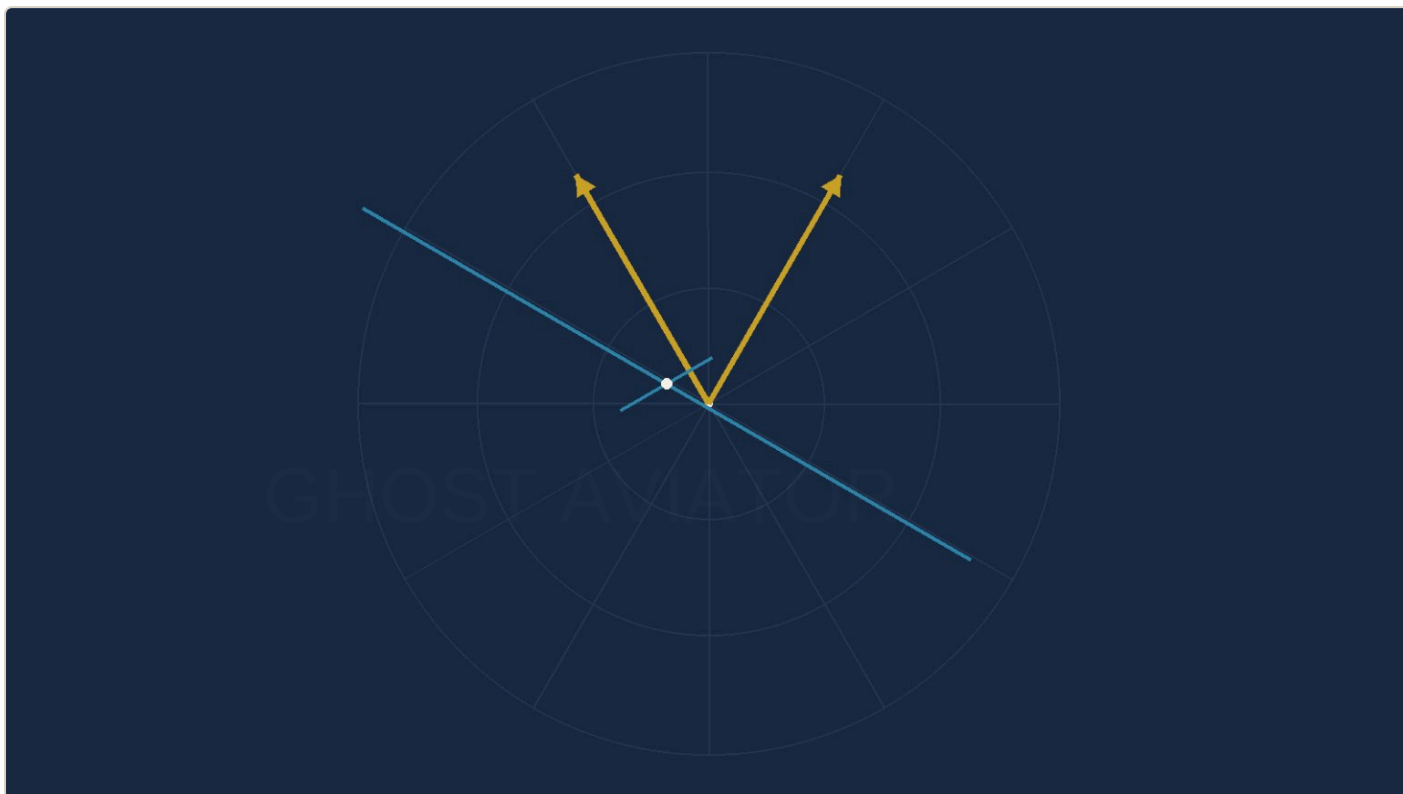
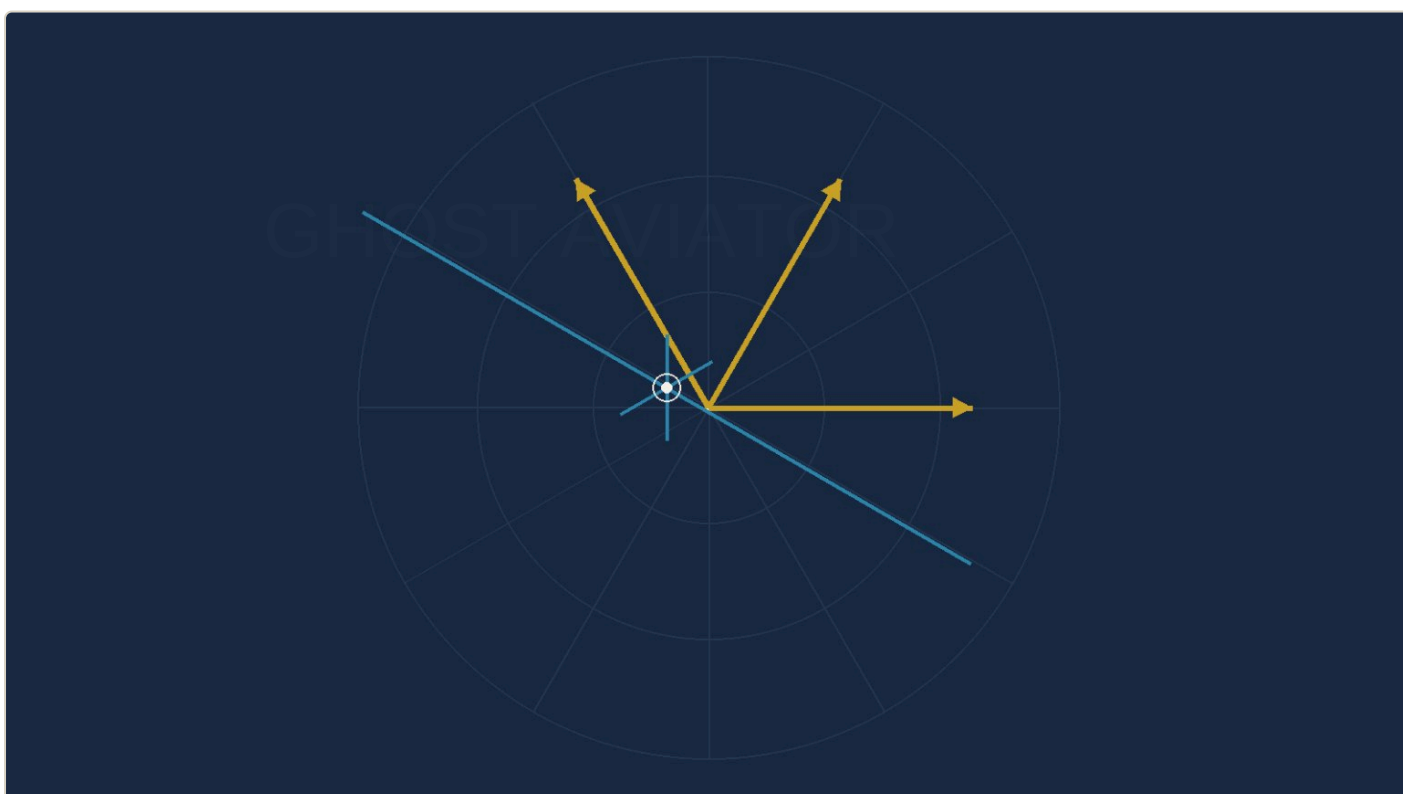


**Figure 9.2** — The second observation, on 330°, gives a second line. It only needs to be a short cross-cut — a centimetre either side is plenty. **Two lines cross at one point, and that point is the wind.**

■ the two headings flown    ■ two drift lines, and their intersection



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**Figure 9.3** — The third observation, on 090°. If the drifts were assessed correctly it lands on the same point. The third line does not add information — **it is a check on the first two**, and that is exactly why it is worth flying.

### The cocked hat — the oldest quality check in navigation

If the three lines do not meet at a point they enclose a small triangle. It is called the **cocked hat**, and its size is the error in your drift assessments.

**No cocked hat** — all three drifts were probably right.

**Small cocked hat** — small probable error. Take the centre and carry on.

**Large cocked hat** — one or more of the drifts is wrong. The answer you take from it is worth what the worst observation is worth.

This is worth internalising beyond this chapter. **A measurement that agrees with itself is not necessarily right, but a measurement that disagrees with itself is definitely telling you something.**

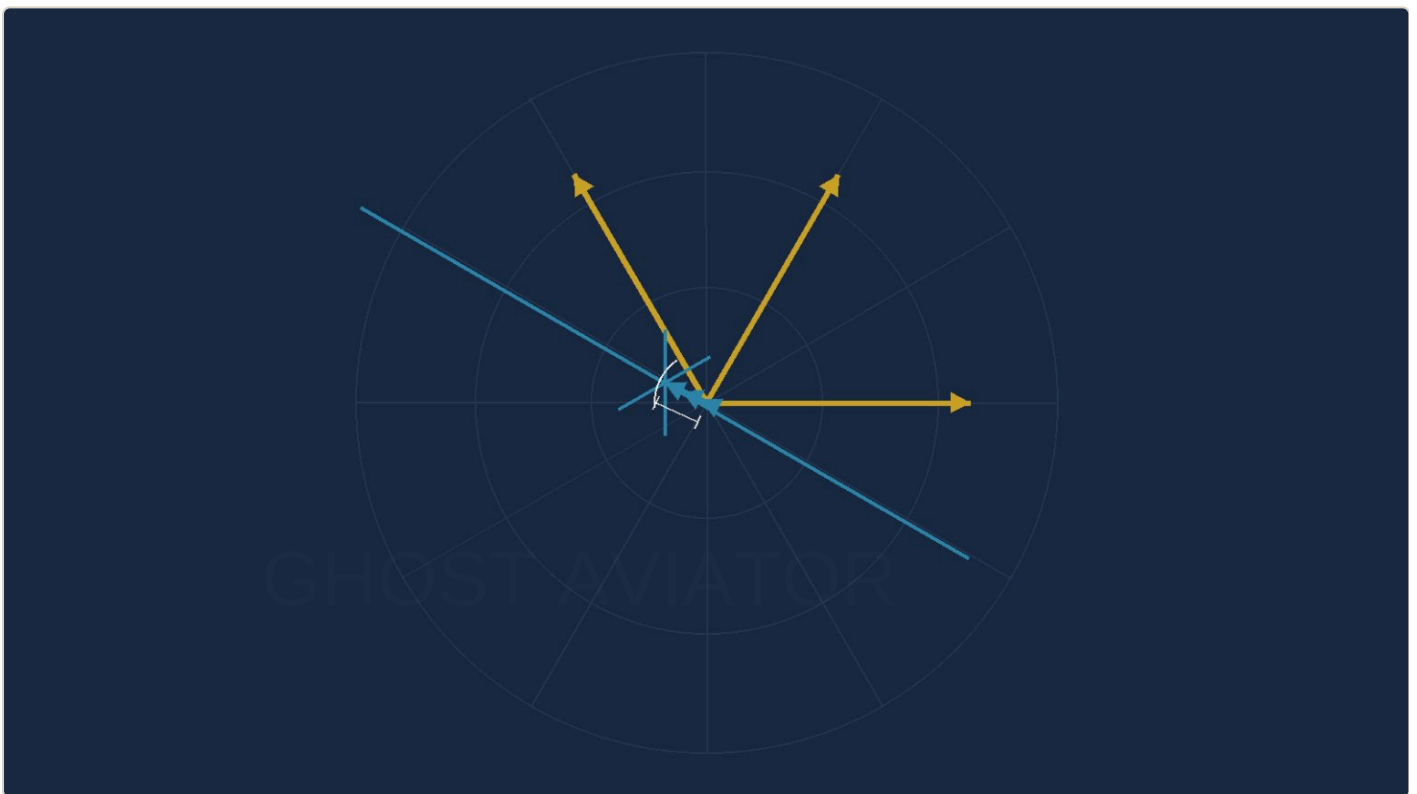


**Figure 9.4** — The intersection is the wind point. Measure from the centre to it and you have the answer: in this example **115/21**.

■ the wind — 115° at 21 knots, from drift alone

### GAP — the CX-3 has no multi-drift function, so here is the arithmetic

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A full-text search of all 24 pages of the CX-3 User's Guide returns **zero matches** for "multi-drift". There is no menu path. Any keystroke sequence you are offered for this has been invented.

**What one drift observation actually tells you.** If you are drifting, the wind must be pushing you sideways by exactly enough to cock your nose off by the drift angle. So the sideways part of the wind, measured across your track, is fixed:

$$W_E \cdot \cos(\text{Track}) - W_N \cdot \sin(\text{Track}) = \text{TAS} \cdot \sin(\text{Drift})$$

where  $W_E$  and  $W_N$  are the east and north parts of the wind-toward vector, and  $\text{Track} = \text{Heading} + \text{Drift}$

That is one equation in two unknowns — which is exactly what "a line of possible winds" means algebraically. **Two observations give two equations. Solve the pair and you have the wind.**

**The method, in five steps:**

1. For each leg,  $\text{Track} = \text{Heading} + \text{Drift}$ . **Port drift is negative.**
2. Write  $a = \cos(\text{Track})$ ,  $b = -\sin(\text{Track})$ ,  $c = \text{TAS} \times \sin(\text{Drift})$  for each leg.
3. Solve the two simultaneously:  
$$\Delta = a_1 b_2 - a_2 b_1$$
$$W_E = (c_1 b_2 - c_2 b_1) \div \Delta$$
$$W_N = (a_1 c_2 - a_2 c_1) \div \Delta$$
4. Wind speed =  $\sqrt{W_E^2 + W_N^2}$ ; wind direction =  $\text{atan2}(W_E, W_N) + 180$ .
5. **With three legs, do it three times** — pairs 1&2, 1&3, 2&3 — and average the three  $W_E$  values and the three  $W_N$  values. **That average is the exact numerical equivalent of taking the centre of the cocked hat**, and the spread between the three answers is the cocked hat's size.

**The trap that will catch you, and it is the sign.** Port drift enters as a **negative** number. The worked example above is 10°P, which goes in as **-10**. Type **+10** and the formula returns a confident, plausible, completely wrong wind — and nothing about the answer will look odd.

**Checked:** run against the book's worked example — TAS 120, headings 030/330/090, drifts 10P/5P/5P — the method returns **115.0° / 20.9 kt** against the published 115/21, with a cocked hat of 0.00 knots. All three leg-pairs agree exactly, which matches the book's own statement that its three lines coincided.

## 3 · Two-drift winds — the airways version

Three headings is a manoeuvre. You are not going to fly one in controlled airspace. But two drifts fall out of ordinary airways flying for free, if you know to collect them.

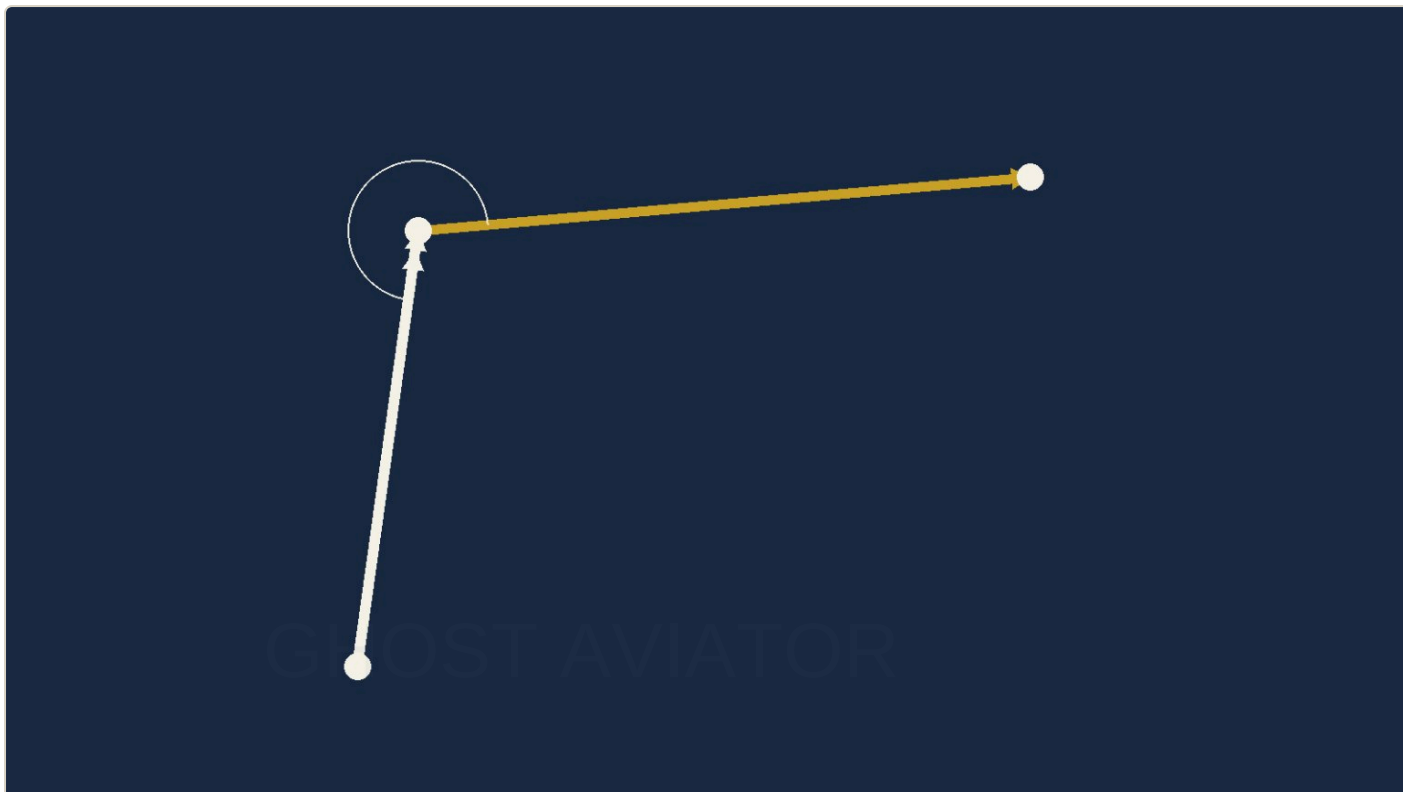


**Figure 9.5** — Two airway legs meeting at a turning point, with an angle of about  $77^\circ$  between them. That angle is what makes the method work. **Two legs less than  $70^\circ$  apart give an answer you should not trust.**

leg one —  $008^\circ(\text{M})$     leg two —  $085^\circ(\text{M})$

Here is how the drifts arrive without your asking for them. You fly the first leg homing on a VOR radial, applying your planned drift. **If the planned drift is wrong, the radial moves.** You correct back to the centre line and adjust. After a short series of corrections you have found the heading that holds the radial — and the difference between that heading and the track is your *actual* drift, measured rather than forecast.

Turn at the beacon onto the second leg and the same thing happens again. Two legs, two headings, two measured drifts. Now cross-cut them.

### What two drifts cannot give you

There is no third line, so **there is no cocked hat and no check.** Two lines always cross at exactly one point, whether or not either of them is right. The answer arrives looking just as confident when it is wrong.

That is the whole cost of the two-drift method, and it is the reason the three-heading version exists. Holding a VOR centre line does let you assess drift reasonably well — but "reasonably well" is now the entire accuracy of your wind, unchecked.

# Questions — multi-drift winds

## What you are given

A TAS, and three headings each with an observed drift. Find the W/V.

**P is port and enters as negative. S is starboard and enters as positive.** More marks are lost in this question type on that one convention than on the mathematics.

Use the three-pair average from Section 2. When your three pairs disagree, the spread is telling you how good the observations were — and in one of these four questions it is worth looking at.

| # | TAS | Heading | Drift | W/V |
|---|-----|---------|-------|-----|
| 1 | 180 | 130     | 6°P   |     |
|   |     | 070     | 4°P   |     |
|   |     | 190     | 2°P   |     |
| 2 | 150 | 045     | 3°S   |     |
|   |     | 345     | 6°P   |     |
|   |     | 105     | 8°S   |     |
| 3 | 120 | 270     | 2°S   |     |
|   |     | 210     | 12°S  |     |
|   |     | 330     | 9½°P  |     |
| 4 | 165 | 100     | 2°P   |     |
|   |     | 040     | 14°P  |     |
|   |     | 160     | 12°S  |     |

## Answers

| # | TAS | Headings and drifts      | W/V    | Cocked hat     |
|---|-----|--------------------------|--------|----------------|
| 1 | 180 | 130/6P · 070/4P · 190/2P | 206/19 | 0.3 kt — tight |

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| # | TAS | Headings and drifts        | W/V           | Cocked hat                              |
|---|-----|----------------------------|---------------|-----------------------------------------|
| 2 | 150 | 045/3S · 345/6P · 105/8S   | <b>026/21</b> | <i>0.2 kt — tight</i>                   |
| 3 | 120 | 270/2S · 210/12S · 330/9½P | <b>099/30</b> | <i>0.3 kt — tight</i>                   |
| 4 | 165 | 100/2P · 040/14P · 160/12S | <b>107/39</b> | <i>1.1 kt — the loosest of the four</i> |

### What the answer key does and does not tell you

The published answers are **205/18 · 026/22 · 098/30 · 107/40**. Every one of them agrees with the arithmetic to within **1.5° and 1.2 knots**. This question set is sound.

**The cocked hat column is not in the source** — it is added here because it is free once you have solved the three pairs, and because it teaches the thing the graphical method taught by accident: how much to trust the answer you just got. Question 4's observations agree with each other less well than the other three, and that is a fact about the data, not about you.

## 4 · Wind components — and why they decide things

The wind almost never blows exactly along a runway. There is nearly always an angle between the runway direction and the direction the wind is coming from, and that angle splits the wind into two parts that do completely different things to your aeroplane.

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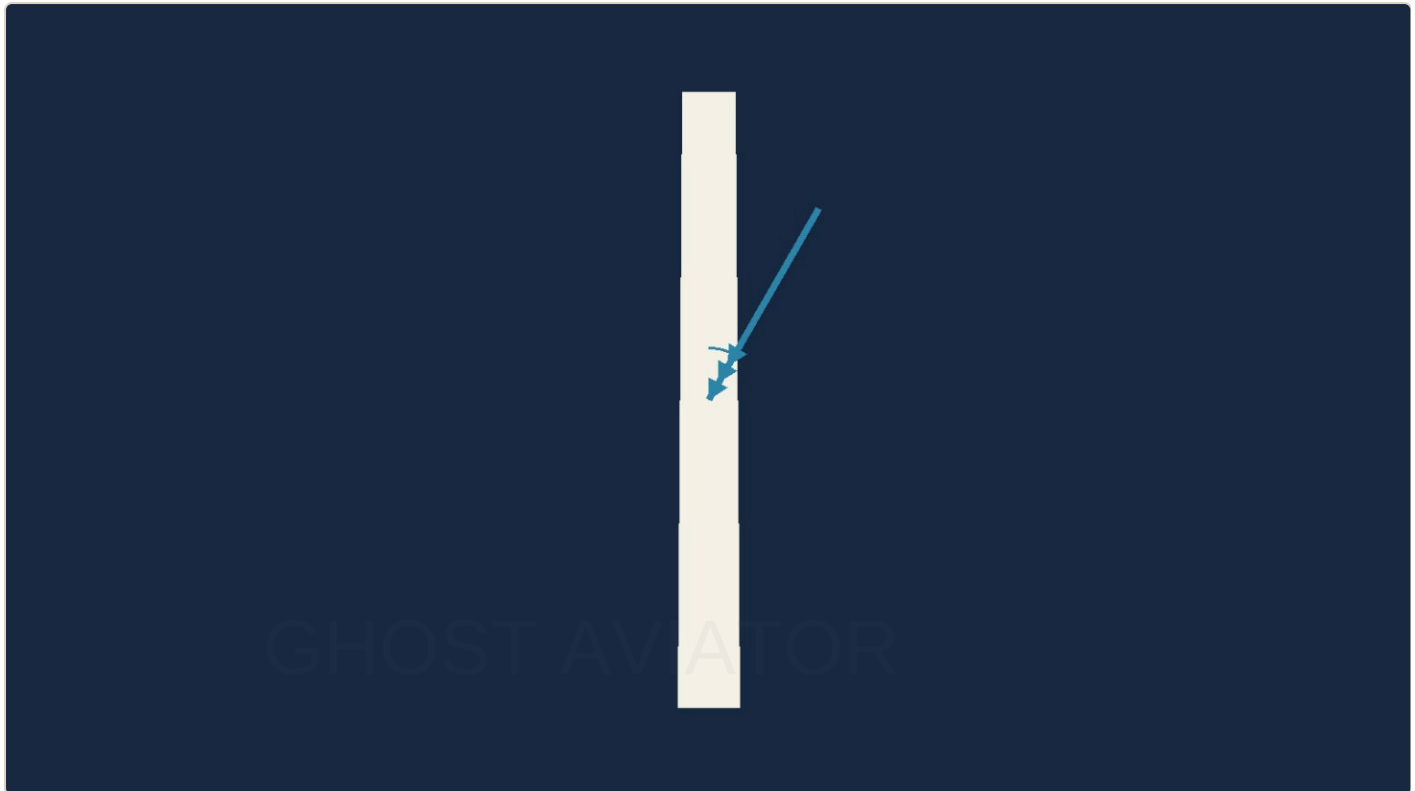


**Figure 9.6** — The wind at an angle-off. Only part of its force acts along the runway; the rest acts across it. The angle decides how the wind divides, and nothing else does.

the runway centreline
  the wind — 30° off, from the right

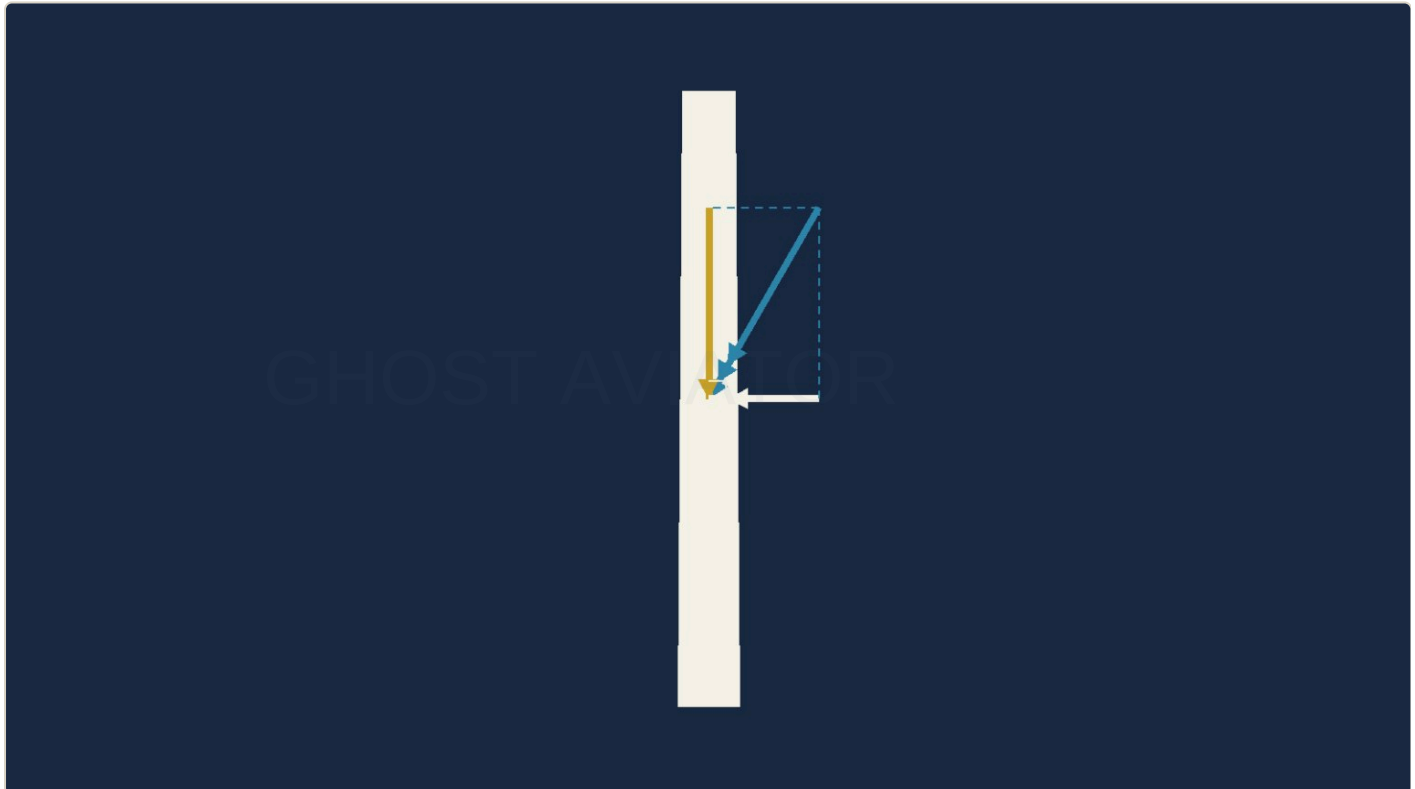


**Figure 9.7** — The same wind, resolved. A 30-knot wind 30° off the nose is **26 knots down the runway** and **15 knots across it**. Two numbers, two different problems.

the wind — 30 kt
  headwind component — 26 kt
  crosswind component — 15 kt

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## What the headwind decides

You cross the threshold at a calibrated airspeed, which corresponds to a true airspeed. But stopping is not about airspeed. **Stopping is about  $\frac{1}{2}mv^2$ , and that  $v$  is ground speed.**

A headwind lowers your ground speed at touchdown, so there is less energy for the brakes to absorb in the runway you have. On a heavy aircraft on a short runway this runs the other way too: there can be a **minimum** headwind below which the numbers do not close with an adequate margin.

## What the crosswind decides, and it is usually the harder one

Crosswind is more often the limiting factor, for four reasons that stack:

1. **The approach.** You line up on the extended centreline and point the nose into wind to hold it. The stronger the crosswind, the larger the correction you are holding all the way down.
2. **The moment of touchdown.** As the wheels arrive you use rudder to swing the nose back into line with the runway. It is called *kicking off the drift*, though a kick is exactly what it should not be — it is a measured application, and getting the amount right takes skill and judgement.
3. **The tyres.** Even flown perfectly, with the aircraft precisely aligned as the tyres touch, there is still sideways velocity. Tyres are stressed mainly for fore-and-aft loads. **You can burst a tyre on a crosswind landing.**
4. **The rollout.** Once down, the fin is still catching the wind while the rudder's authority falls away with speed. On an aircraft with a large tail, the point comes where the rudder can no longer hold it — and the aircraft leaves the runway.

### Two different limits, and they are not the same number

Every type has a **maximum demonstrated crosswind component**. Your **operator** may impose a lower one, and may impose it differently on different crew.

An aircraft cleared to 25 knots may sit under a company rule that a first officer lands up to 15 knots and above that it is the captain's landing. Both numbers are real, and the one that binds you is the lower.

**Neither number comes from this chapter.** They come from the approved flight manual and your operator's manuals. This chapter only tells you how to work out which side of them you are on.

## 5 • True or magnetic? — the question that decides everything

### WARNING — get this wrong and every component you calculate is wrong

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Runway directions are **magnetic**. Always. Runway 27 is a runway whose QDM is about  $270^\circ$  *magnetic*.

So a wind can only be resolved against a runway if the wind is also in magnetic. And **some of the winds you are given are not**.

| Source                  | Direction is in | Why                                                                                                                            |
|-------------------------|-----------------|--------------------------------------------------------------------------------------------------------------------------------|
| ATC (tower, spot winds) | MAGNETIC        | It exists to help you line up on a runway, and runways are magnetic.                                                           |
| ATIS                    | MAGNETIC        |                                                                                                                                |
| TAF                     | TRUE            | Written meteorological information. Met works in true, and navigation tracks are measured in true before variation is applied. |
| METAR                   | TRUE            |                                                                                                                                |
| VOLMET                  | TRUE            |                                                                                                                                |

**MAGNETIC — spoken to you by a controller.**

**TRUE — written down in a met message.**

A  $20^\circ$  variation applied the wrong way, or not applied at all, moves the angle-off by  $20^\circ$  or  $40^\circ$ . On a 30-knot wind that is the difference between a 10-knot crosswind and a 25-knot one.

**And the reverse trap, which the examination uses more often than the first:** a question gives you a variation *and* an ATIS wind. The ATIS is already magnetic. **The variation is not needed and putting it in is the error the question is hunting for.** Question 4 at the end of this chapter does exactly this.

**Before every component calculation, ask one question:** *who told me this wind?* A controller's voice, or a written met message. That answers it, every time.

## 6 • Calculating the components

- **Runway** — 27, so a QDM of  $270^\circ$ (M)
- **ATIS W/V** — 310/30, and ATIS is already magnetic

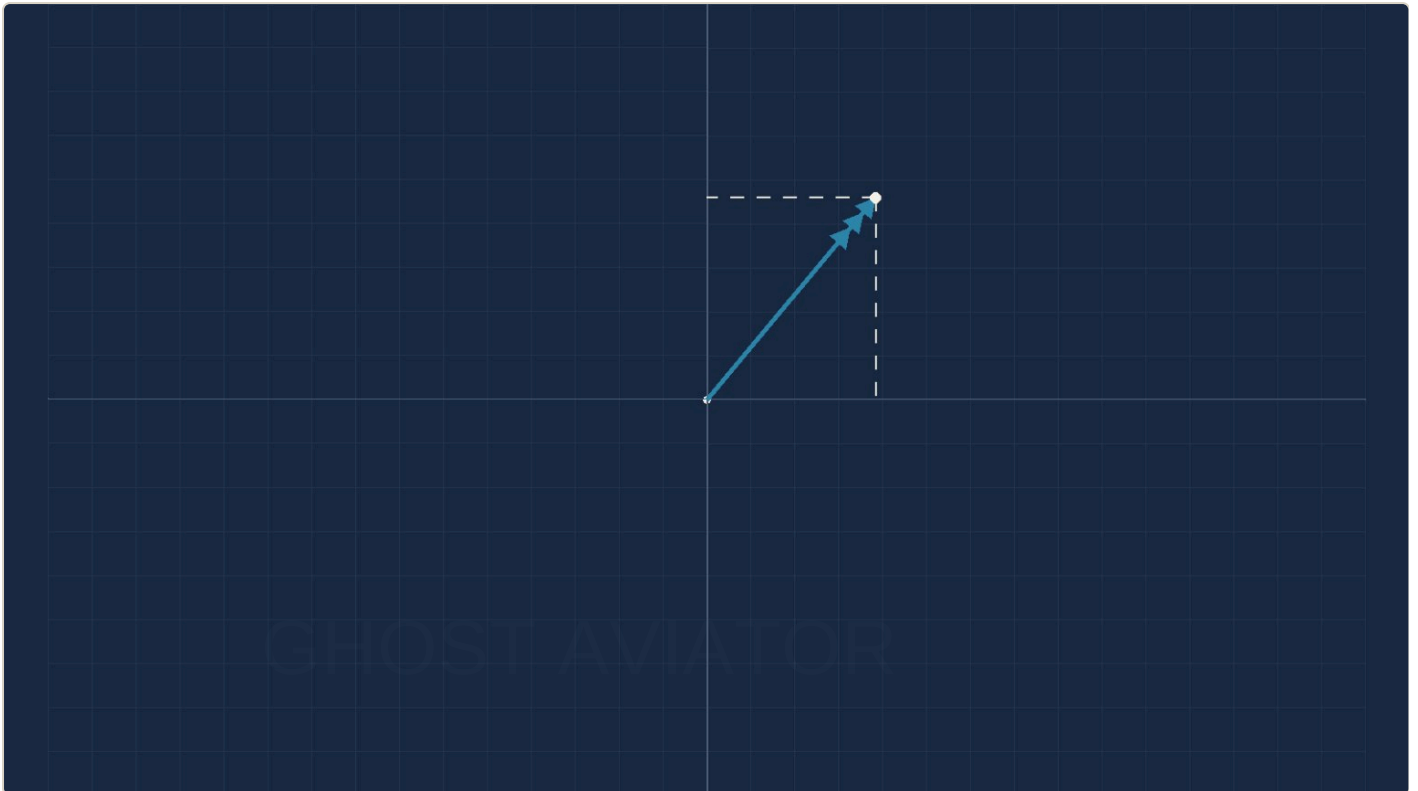


**Figure 9.8** — Plot the wind on the squared part of the slide, exactly as in Chapter 7. Nothing new has happened yet.

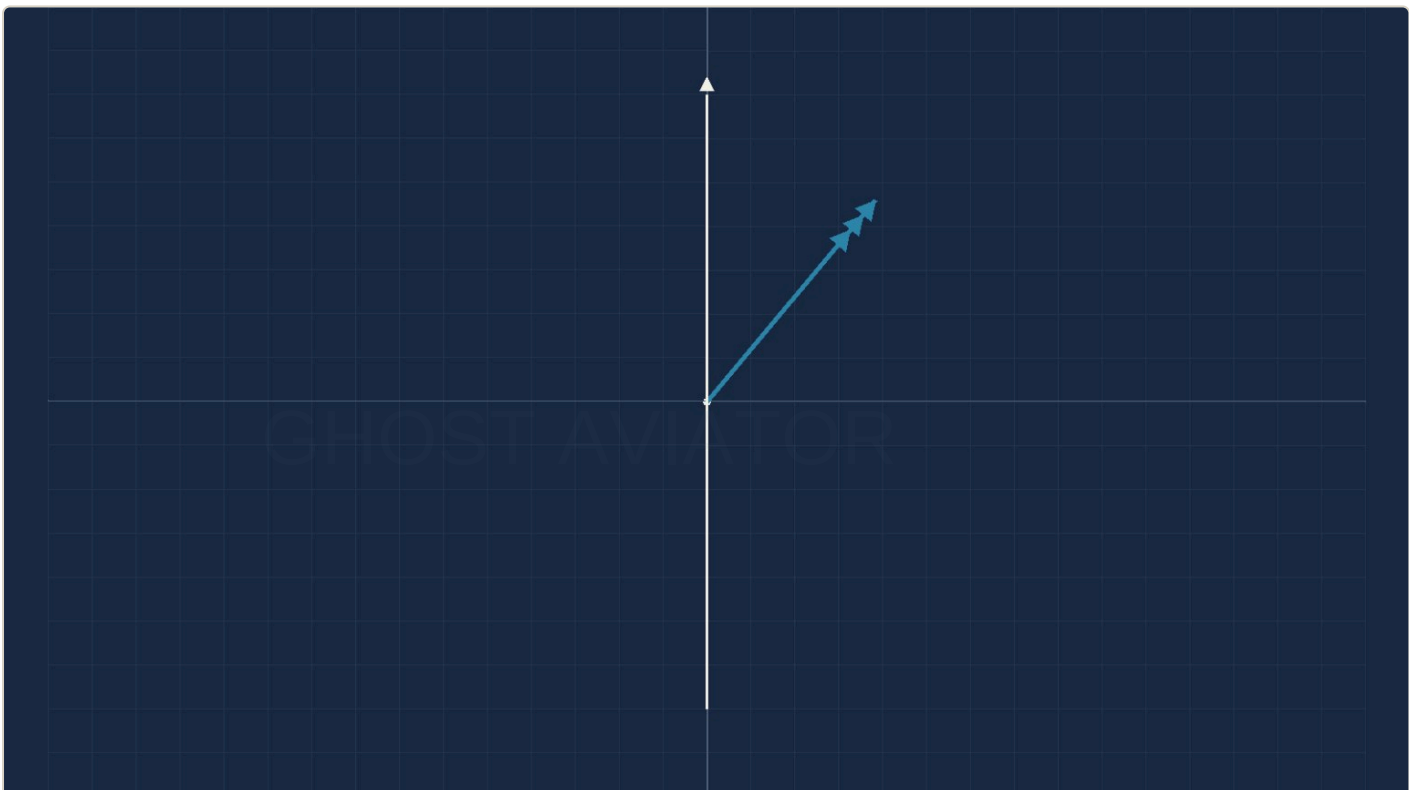


**Figure 9.9** — Now rotate until the **runway QDM** sits at the top. The grid is now aligned with the runway rather than with north, and that single move is what turns a wind into components.

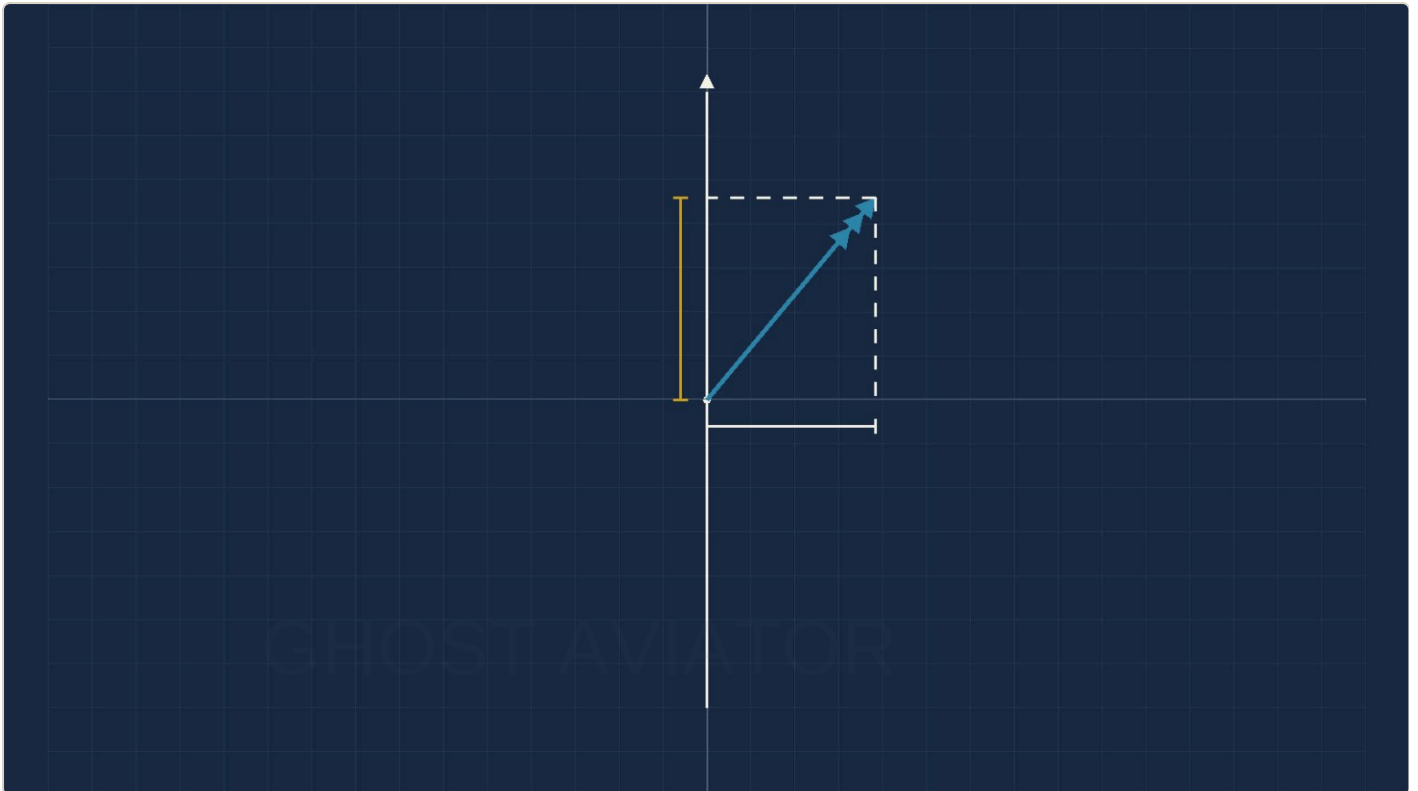


**Figure 9.10** — Read down the vertical axis for the **headwind**, across the horizontal for the **crosswind**. Here: 23 knots headwind, 19 knots crosswind from right to left.

■ headwind — 23 kt    ■ crosswind — 19 kt from the right

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**Worked example 9.1.** Runway 27, ATIS W/V 310/30. Find the headwind and crosswind components.

**METHOD 1 – THE ARITHMETIC**

*two lines, and it is exact*

**1. Angle off:**

$$\theta = 310 - 270 = 40^\circ$$

Positive, so the wind is from the *right*.

**2. Headwind:**

$$30 \times \cos 40 = 22.98$$

**3. Crosswind:**

$$30 \times \sin 40 = 19.28$$

**Sign rule:** a `cos` that comes out *negative* means a **tailwind**. That is the only thing you have to watch.

**23 kt headwind · 19 kt crosswind  
from the right**

**METHOD 2 – THE CX-3**

*and read the red box below before you touch it*

1. `FLT` → **Wind Component.**
2. `WSpd` **30.**
3. `WDir` **310** — and it **must be magnetic.**
4. `Runway` **27** — the runway *number*. Not 270.
5. Read `X Wnd` and `H Wnd`.

**H Wnd +23 · X Wnd +19 (from the right)**

**Which do you use?** *The CX-3, every time, for the forward problem — it is two fields and it applies the sign conventions for you. Know the trigonometry anyway, because Section 7 is full of problems the machine cannot do at all.*

**Sanity check — three anchors worth memorising.** At  $30^\circ$  off, you get about **87% headwind and 50% crosswind**. At  $45^\circ$ , about **70% of each**. At  $60^\circ$ , about **50% headwind and 87% crosswind**.

Here the angle is  $40^\circ$ , so expect a bit under 80% headwind and a bit over 60% crosswind of 30 knots — roughly 23 and 19. Those three anchors will catch almost any keying error you can make.

## The two traps inside the CX-3's Wind Component function

**1. It wants the runway NUMBER, not the runway direction.** The Guide is explicit, and it repeats itself because people get it wrong:

*"The runway number must be entered—not the course. Remember: it must be the runway number, not the heading. For example, runway 27 (not 270), and runway 9 (not 90)."*

Type 270 into a field expecting 27 and you have not made a small mistake. You have asked the machine about a runway direction of  $2700^\circ$ , and what comes back is nonsense that looks like an answer.

**2. It wants a MAGNETIC wind.** The Guide says so, in the same breath, and gives the reason:

*"Since runways are numbered by their magnetic course, the wind direction must be magnetic as well (predicted winds aloft are given in true, rather than magnetic orientation, while airport wind advisories and runway headings are both magnetic)."*

**Feed it a TAF or METAR wind without converting and it will answer you.** It has no way to know. The number it returns will be wrong by the variation, it will look entirely normal, and nothing will warn you.

**The output signs, and they are worth learning rather than re-deriving:**

| Field | Positive means                  | Negative means                 |
|-------|---------------------------------|--------------------------------|
| X Wnd | crosswind from the <b>RIGHT</b> | crosswind from the <b>LEFT</b> |
| H Wnd | <b>HEADWIND</b>                 | <b>TAILWIND</b>                |

*The Guide's own worked example: wind 350° at 10 knots, runway 03 → **-6.43 X Wnd** (a left crosswind) and **7.66 H Wnd** (a headwind). Checked against the trigonometry:  $\theta = 350 - 030 = -40^\circ$ , and  $10 \times \sin(-40) = -6.43$ ,  $10 \times \cos(-40) = +7.66$ . Exact to two decimal places, which is what confirms both the convention and the formula.*

## 7 • Running it backwards — the questions that actually matter

Everything so far has gone one way: here is a wind, what are the components? The operationally useful questions run the other way. *How strong can the wind get before I am out of limits? Between which directions may it blow?*

**GAP — the CX-3 solves this direction only, so the rest of this section is arithmetic**

The Wind Component function takes `WSpd`, `WDir` and `Runway` and returns `X Wnd` and `H Wnd`. There is no field for a limit and no way to run it backwards.

**You can brute-force it** — enter a wind speed, read the crosswind, adjust, repeat — and on the ground with time to spare that works. It is the balancing-the-drift loop all over again, and it is not what you want at top of descent.

**The three formulas below are one line each and they are exact.**

**Max wind for a crosswind limit:  $W = \text{Crosswind limit} \div \sin\theta$**

**Max wind for a head/tailwind limit:  $W = \text{Limit} \div |\cos\theta|$**

**Allowable wind directions at a given speed:  $\theta = \sin^{-1}(\text{Crosswind limit} \div W)$ , then Runway  $\pm \theta$**

*$\theta$  is the angle between the wind direction and the runway direction, **both magnetic***

**Gusts.** There is no gust field and no trick to it. **Run the formula twice** — once on the steady wind, once on the gust. Crosswind limits are normally quoted against the gust value, so the gust is usually the one that binds.

## Case A — the maximum wind for a crosswind limit

This is the calculation you make at top of descent so that the decision at fifty feet is a comparison and not a calculation.

- **TAF W/V** — 180/10G50
- **Variation** — 15°W
- **Runway** — 23
- **Crosswind limit** — 25 kt

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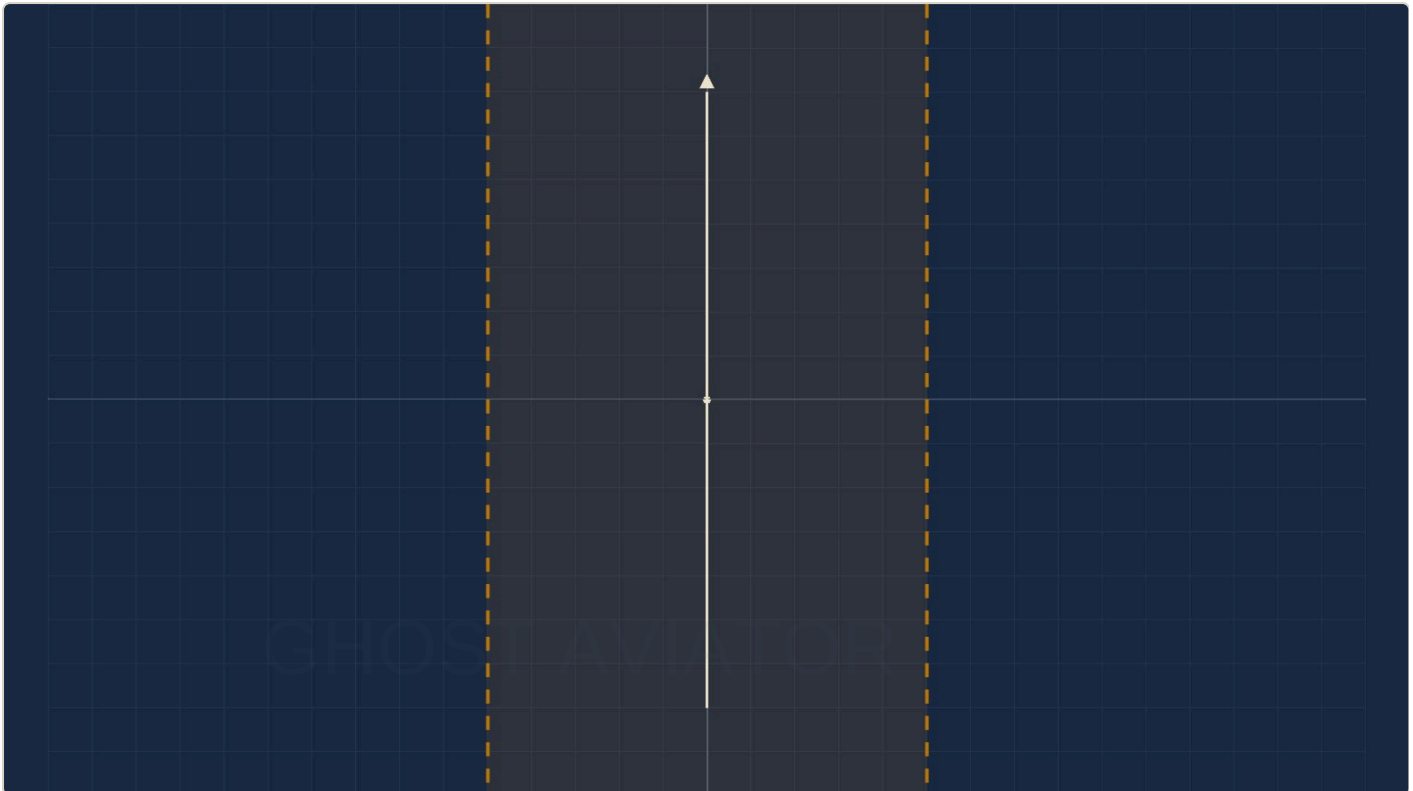


**Figure 9.11** — Set the runway at the top and draw the crosswind limit as two lines, one either side of the centreline. Anything falling *between* them is inside limits.

runway 230°(M) at the top
  ±25 kt crosswind limit lines

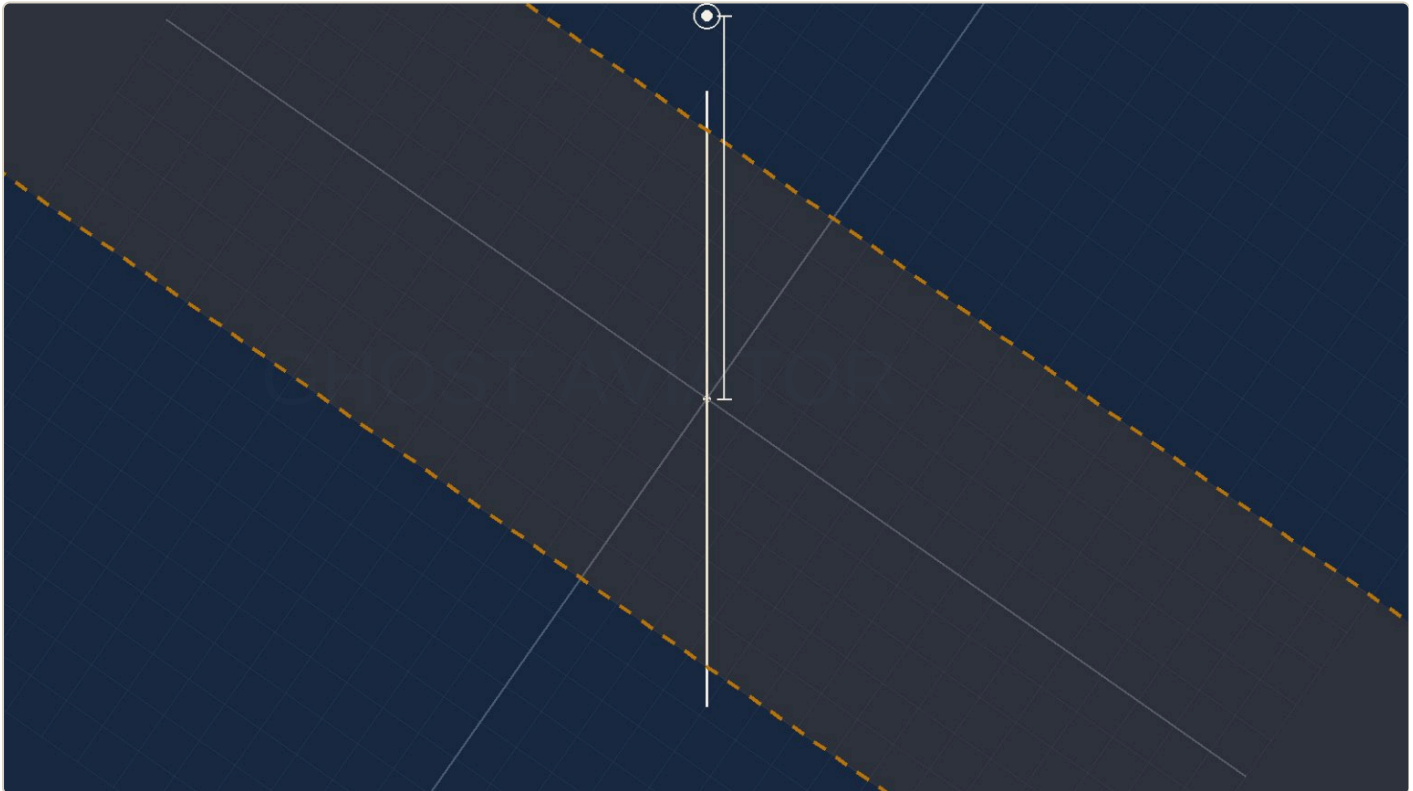


**Figure 9.12** — Rotate to the wind's direction. Where the limit line crosses the centreline is the wind speed at which you reach your limit.

**Worked example 9.2.** At what wind strength from this direction do you reach your 25-knot crosswind limit on runway 23?

**METHOD 1 — THE ARITHMETIC**

*and step 1 is the one that catches people*

**1. Convert the wind.** A TAF is **true**.  
Variation  $15^\circ$  West, so magnetic is *best*:

$$180 + 15 = 195^\circ(\text{M})$$

**2. Angle off the runway:**

$$\theta = 230 - 195 = 35^\circ$$

**3. Apply the formula:**

$$W = 25 \div \sin 35$$

$$= 25 \div 0.5736 = 43.6$$

**43.6 kt — but see the flag below**

**METHOD 2 — THE CX-3**

*not directly available*

1. There is no inverse function.
2. You can search for it: set **Runway** 23 and **WDir** 195, then try wind speeds until **X** **Wnd** reads 25.
3. Try  $40 \rightarrow 22.9$ . Try  $44 \rightarrow 25.2$ . Try  $43.5 \rightarrow 24.9$ .
4. Three or four goes will find it, and the formula found it in one.

**converges on 43.6**

**What the answer means, and it is worth saying in plain words.** *Below that wind speed from  $195^\circ(\text{M})$  you are inside your crosswind limit on runway 23, and above it you are not. That single number is what you carry down the approach.*

**FLAGGED — the source says 41 knots, the arithmetic says 43.6. Captain's ruling needed.**

The published worked answer is **41 knots**, read off the wind slide. The trigonometry gives **43.6**.

**The check:** a wind of 41 knots from  $195^\circ(\text{M})$  on runway 230 gives a crosswind component of  $41 \times \sin 35 = 23.5$  knots — not the 25 the example is solving for. To reach exactly 25 the wind has to be 43.6.

**It errs on the safe side**, which is worth noting: a pilot using 41 goes around slightly earlier than they had to. That is the right direction for an error to lie in, and it is still an error.

**I have not corrected it in the answer, and I will not.** Unlike the two errata at the end of this chapter, there is no independent evidence here — nothing else in the book cross-checks this figure. Changing a published number on my arithmetic alone is the Captain's call, not mine.

**What to do in the meantime:** learn the method, use the formula, and if an examination option sits at 41 rather than 43 or 44, take the graphical value — the paper was written from the same construction. Then tell your instructor why.

## Case B — when you are limited at both ends

A heavy aircraft, a single short runway, and a crosswind. You need a **minimum** headwind to stop in the distance available, and you have a **maximum** crosswind. The acceptable wind is now a band, not a ceiling.

- **Runway** — 35
- **ATC W/V** — 030/10G40 — ATC, so already magnetic
- **Minimum headwind** — 10 kt
- **Crosswind limit** — 20 kt

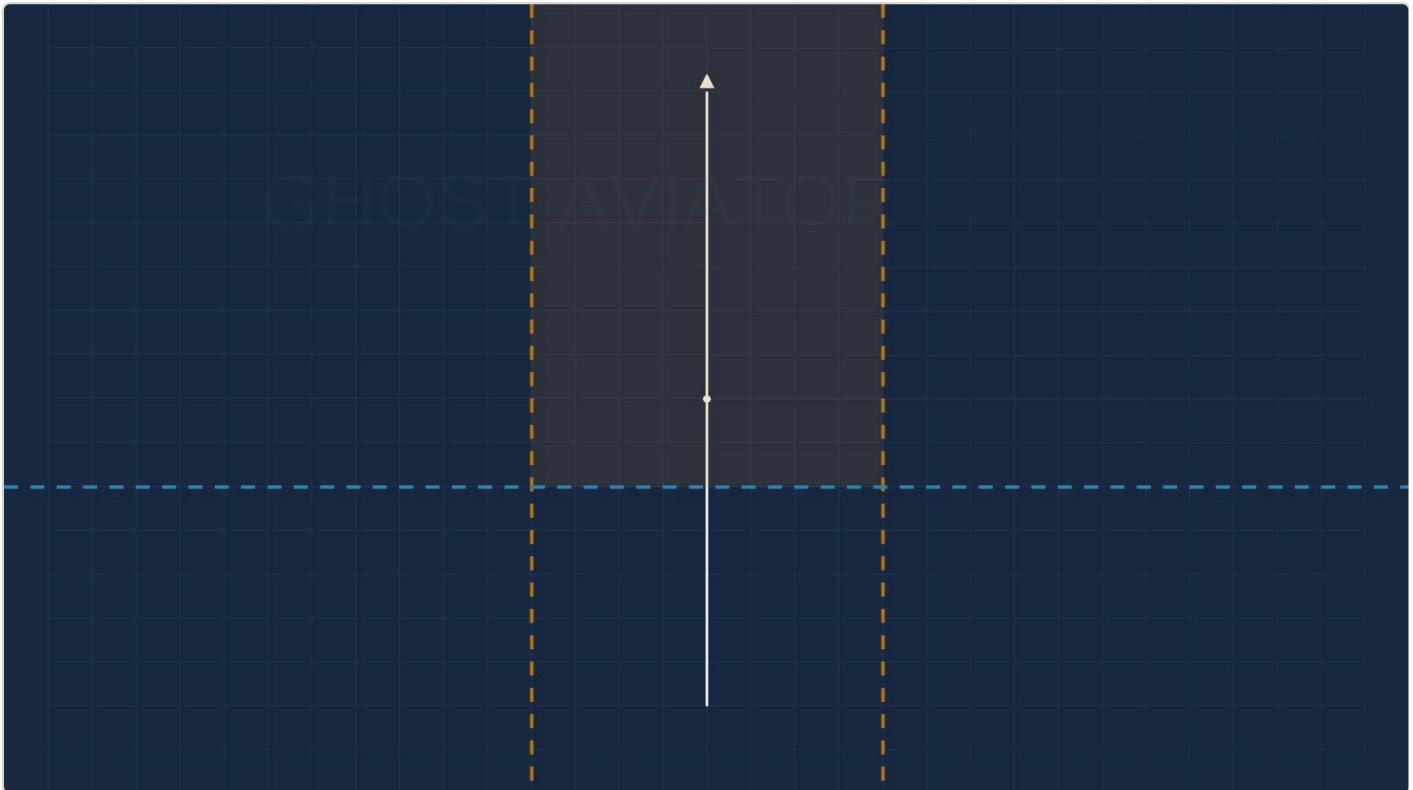


**Figure 9.13** — Two limits drawn at once: the crosswind pair running vertically, and a horizontal line for the minimum headwind. The acceptable winds live in the region bounded by both.

■  $\pm 20$  kt crosswind limit   ■ 10 kt minimum headwind

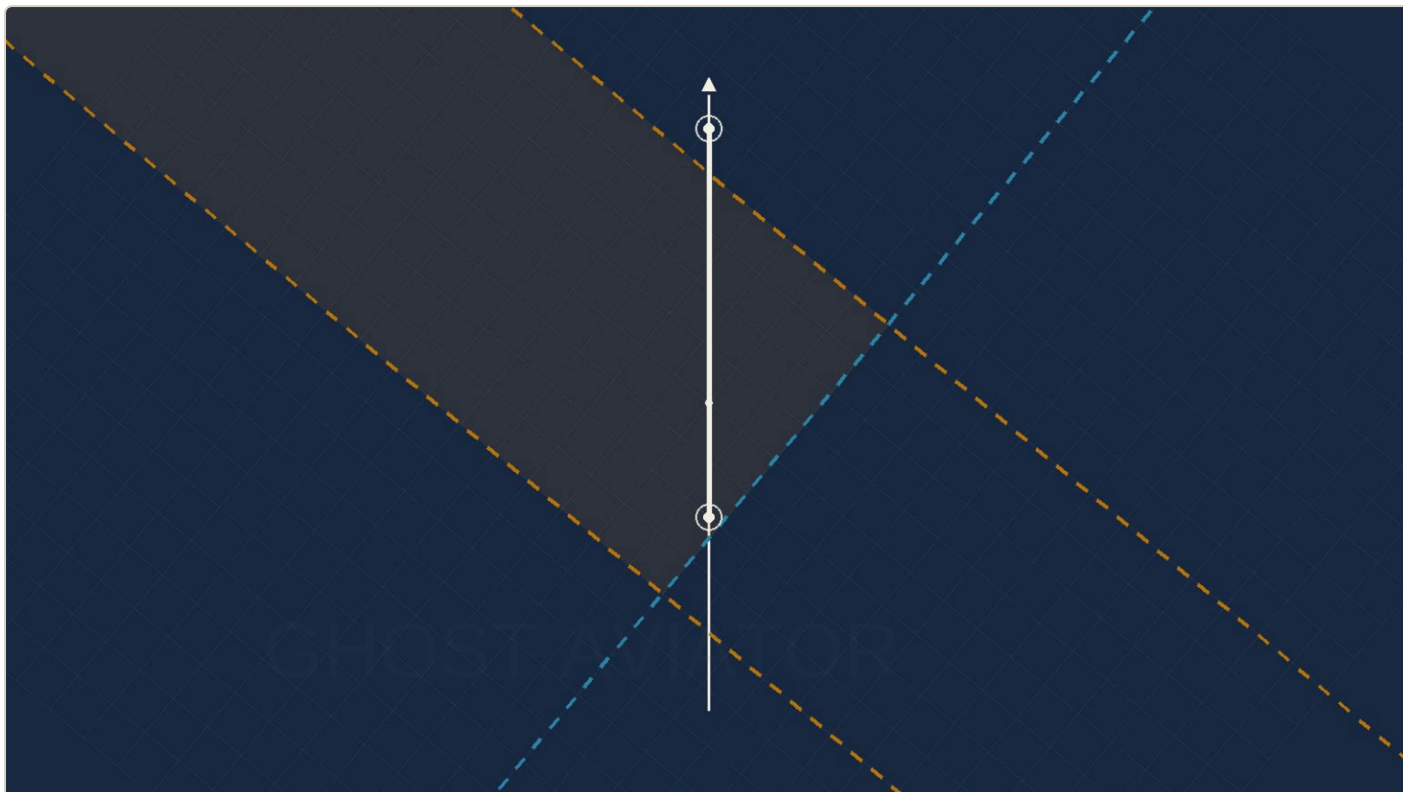


**Figure 9.14** — Rotated to the wind. The two limits now cross the centreline at two different speeds, and the wind must fall *between* them. Too light and you have no braking margin; too strong and you are out of crosswind.

**Worked example 9.3.** Between which wind strengths from 030°(M) can you land on runway 35?

#### METHOD 1 — THE ARITHMETIC

*one angle, two formulas*

1. ATC wind, so no conversion.

$$\theta = 030 - 350 = 40^\circ$$

2. **The lower bound** — the lightest wind giving 10 kt of headwind:

$$W = 10 \div \cos 40$$

$$= 10 \div 0.7660 = 13.05$$

3. **The upper bound** — the strongest wind inside 20 kt of crosswind:

$$W = 20 \div \sin 40$$

$$= 20 \div 0.6428 = 31.11$$

**land between 13 and 31 knots  
from 030°(M)**

#### METHOD 2 — THE CX-3

*two searches, same as Case A*

1. Runway 35, WDir 030.
2. Search WSpd until H Wnd reads 10 — that is your lower bound.
3. Search again until X Wnd reads 20 — the upper.
4. Two searches against two one-line formulas. The formulas win.

**13 and 31**

**Read the band, not the numbers.** Below 13 knots you do not have the headwind the runway length demands. Above 31 you are outside the crosswind limit. **Between them, and only between them, you can land.** It is the only case in this chapter where a wind can be too light.

## Case C — tailwinds

### First, the airmanship

Avoid landing with a tailwind. If you are offered a runway with one, ask for the other end.

Accepting a tailwind you did not have to accept is poor airmanship, and if you run off the end afterwards you will have nothing to say for yourself — even if the brakes failed. **The examination will still ask you about them, so know how they work.**

- **Runway** — 09
- **Variation** —  $10^{\circ}\text{E}$
- **ATIS W/V** — 320/10G30
- **Maximum tailwind** — 10 kt

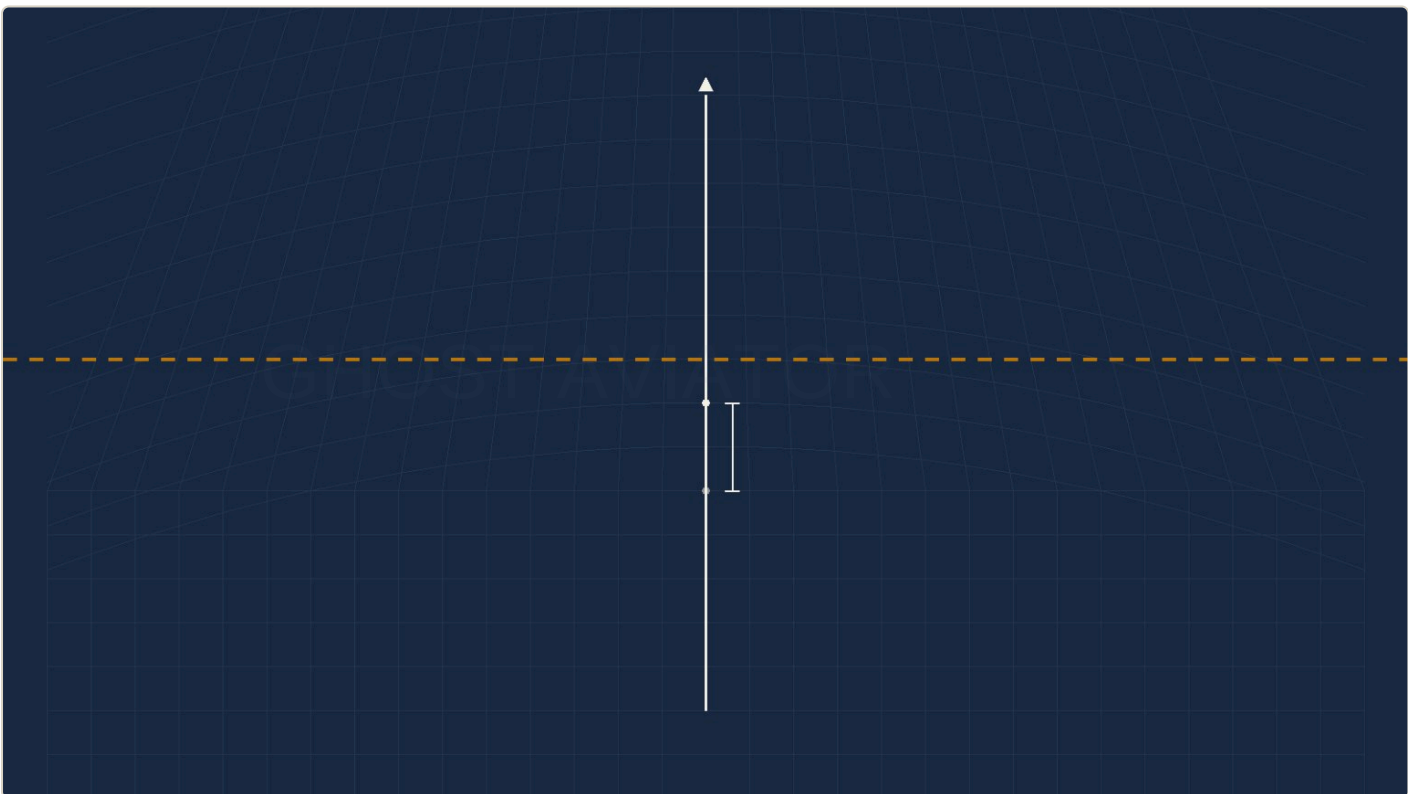


**Figure 9.15** — A tailwind line cannot be drawn in the usual place. It sits *above* the horizontal scale line, in the curved part of the slide, which is why this case gets its own procedure on a mechanical computer.

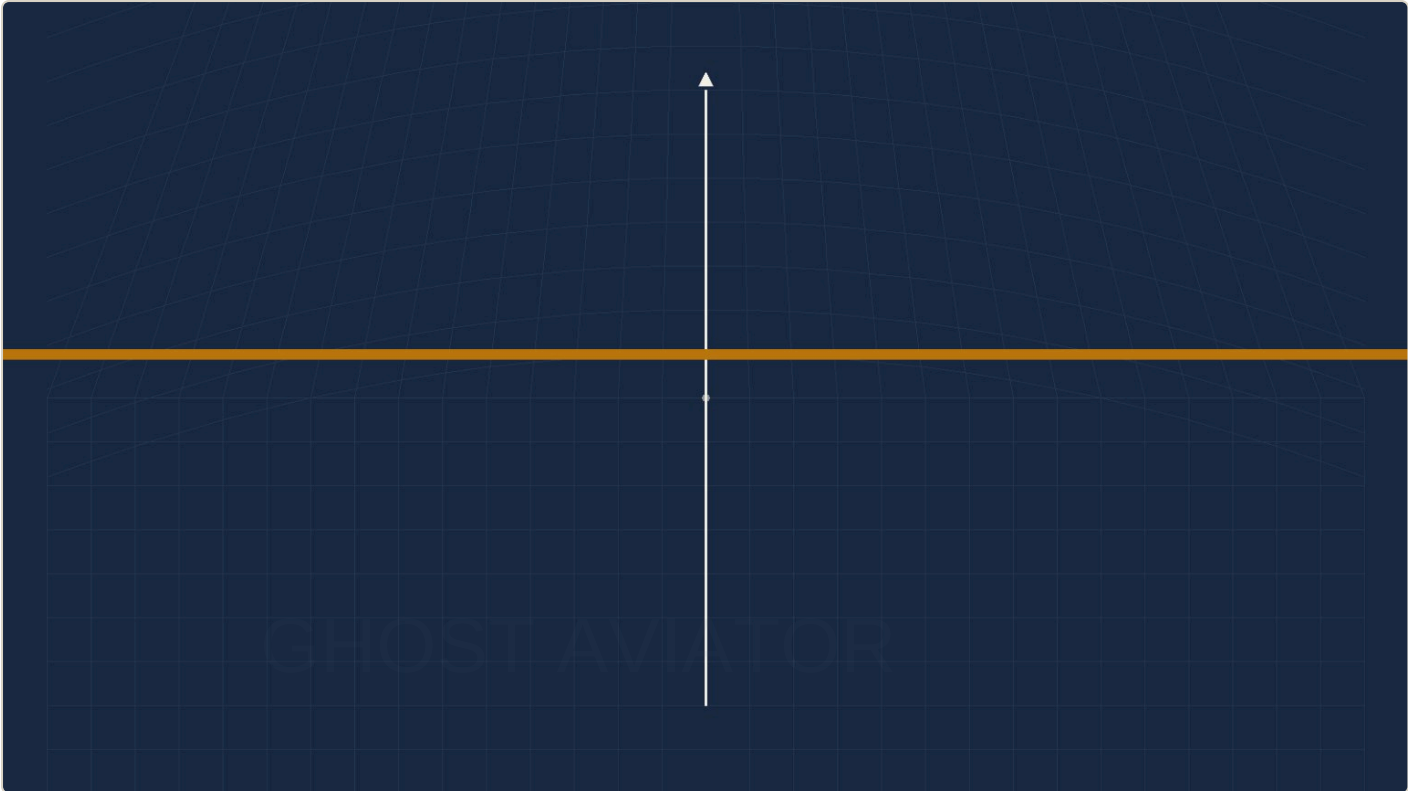


**Figure 9.16** — And then the step everybody forgets: **slide the scale back so zero is under the centre dot.** Leave it where it was and every reading afterwards is offset by ten knots.

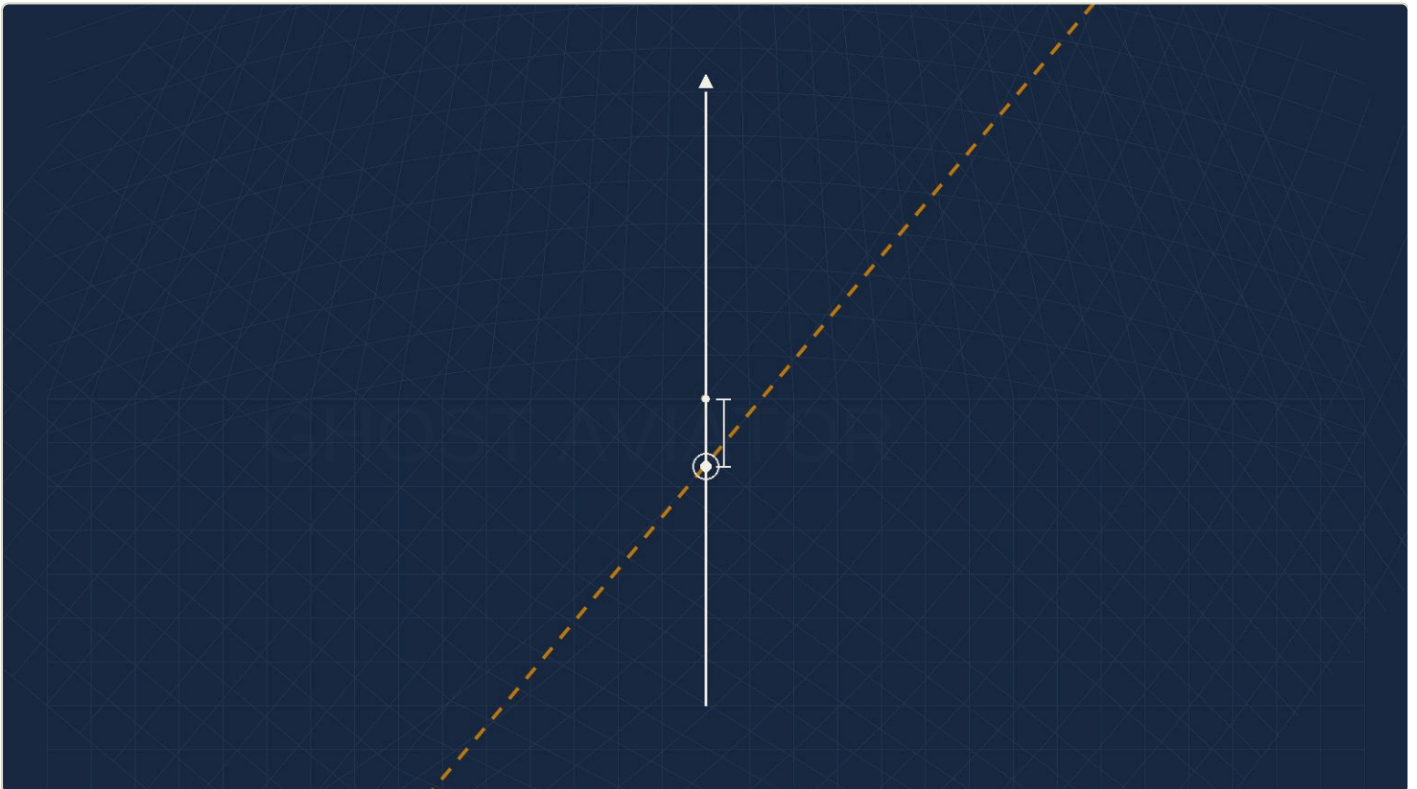


**Figure 9.17** — Rotate to the wind direction and read the intersection: **16 knots.**

**Worked example 9.4.** What is the strongest wind from 320 you can accept on runway 09 with a 10-knot tailwind limit?

**METHOD 1 – THE ARITHMETIC**

*identical to Case B, one absolute sign*

1. ATIS, so 320 is already magnetic. **The 10°E variation is not needed.**

2.  $\theta = 320 - 090 = 230^\circ$ , i.e. 130° off.  
Over 90°, so it is a tailwind.

3.  $\cos 130 = -0.6428$

$$W = 10 \div 0.6428 = 15.6$$

**16 knots**

**METHOD 2 – THE SHORTCUT WORTH KEEPING**

*and it needs no instrument at all*

1. A tailwind on runway 09 is a **headwind on runway 27**. It is the same wind and the same aeroplane.

2. So run it as a headwind problem on the reciprocal:

$$\theta = 320 - 270 = 50^\circ$$

3.  $W = 10 \div \cos 50 = 15.6$

4. **Same answer, no curved scale, no sliding the zero back.**

**16 knots**

**Use the reciprocal shortcut.** *It is the source's own suggestion, it is instrument-independent, and it turns the one case with a fiddly procedure into the case you already know. There is no tailwind problem — there is only a headwind problem on the other runway.*

**And notice the trap you just walked past.** *The question handed you a variation of 10°E. The wind came from the ATIS, so it was already magnetic and the variation was never needed. It was there to see whether you would use it.*

## Case D — between which directions may the wind blow?

The last shape of the question: the wind speed is fixed and you want to know the arc of directions that keeps you inside your crosswind limit.

**Worked example 9.5.** Between which directions may a 50-knot wind blow without giving more than 30 knots of crosswind on runway 250°(M)?

1.  $\theta = \sin^{-1}(30 \div 50) = \sin^{-1}(0.6) = 36.9^\circ$

2. The limits sit that far either side of the runway:

$$250 - 36.9 = 213^\circ(\text{M}) \quad \text{and} \quad 250 + 36.9 = 287^\circ(\text{M})$$

3. So a 50-knot wind between **213°(M) and 287°(M)** gives 30 knots of crosswind or less, with a headwind component.

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4. **And their reciprocals, 033°(M) to 107°(M), give exactly the same crosswind** — but with a *tailwind*. The crosswind arithmetic does not care which way along the runway the wind is going, and that is precisely why you must check the headwind sign separately.

*The published answers are 214° and 286°, from reading 36° off the disc where the arcsine is 36.87°. One degree either way, and the arithmetic values are 213 and 287.*

## Questions — wind components

### Before you start, ask the one question

*Who told me this wind?* A controller's voice is magnetic. A written met message is true. Every one of these four questions turns on that, and one of them punishes you for applying a variation you did not need.

#### Four questions

1. **An airfield has runways 18/36 and 07/25, all of equal length. The TAF W/V is 310/25. Variation is 20°E. Which is the best runway for take-off and landing?**  
(a) 18 · (b) 36 · (c) 07 · (d) 25
2. **In the Question 1 situation, what are the head and crosswind components on that runway?**  
(a) 24 / 17 · (b) 13 / 19 · (c) 19 / 16 · (d) 17 / 12
3. **An aircraft requires a 10-knot headwind component for take-off. Its crosswind limit is 20 knots. The only runway available is 25. The ATIS W/V is 290/10G40. What are the minimum and maximum wind speeds for take-off?**  
(a) 17 / 31 · (b) 13 / 17 · (c) 13 / 31 · (d) 17 / 26
4. **On a particular take-off you can accept up to 10 knots of tailwind. The runway QDM is 047, the variation is 17°E, and the ATIS gives the wind direction as 210. What is the maximum wind strength you can accept?**  
(a) 18 kt · (b) 11 kt · (c) 8 kt · (d) 4 kt

# Answers

| Question | 1 | 2 | 3 | 4 |
|----------|---|---|---|---|
| Answer   | d | c | c | b |

**Question 1 & 2 — worked.** TAF 310/25, variation 20°E, runways 18/36 and 07/25.

**Step one, and it decides the whole question.** A TAF is **true**. Variation 20°East, so magnetic is *least*:  $310 - 20 = 290^\circ(M)$ .

Work it in true against magnetic runways and every component below is wrong.

| Runway | QDM | Angle off | Headwind | Crosswind |                                |
|--------|-----|-----------|----------|-----------|--------------------------------|
| 18     | 180 | 110°      | -8.6     | 23.5      | tailwind                       |
| 36     | 360 | 70°       | +8.6     | 23.5      | little headwind, big crosswind |
| 07     | 070 | 140°      | -19.2    | 16.1      | tailwind                       |
| 25     | 250 | 40°       | +19.2    | 16.1      | most headwind, least crosswind |

**Q1 → (d) runway 25 · Q2 → (c) 19 head / 16 cross**

**Note the shape of it.** 18 and 36 share a crosswind, and so do 07 and 25 — reciprocal runways always do. What separates them is the sign of the headwind. So the question is really two questions: which pair has the smaller crosswind, and then which end of that pair faces the wind.

**Question 3 — worked.** Runway 25, ATIS 290/10G40, minimum headwind 10 kt, crosswind limit 20 kt.

**ATIS, so 290 is already magnetic.** No variation is given and none is needed.

$$\theta = 290 - 250 = 40^\circ$$

**Minimum:**  $10 \div \cos 40 = 13.05 \rightarrow 13 \text{ kt}$

**Maximum:**  $20 \div \sin 40 = 31.11 \rightarrow 31 \text{ kt}$

**(c) 13 and 31**

**And this question settles an error in the chapter's own worked example** — see the errata below. The geometry here is identical to Case B: the same 40°, the same 10-knot minimum headwind, the same 20-knot crosswind limit. The answer key says 13. The worked example said 11. The answer key is right.

**Question 4 — worked.** Maximum tailwind 10 kt, runway QDM 047, variation 17°E, ATIS wind direction 210.

**The trap first.** The wind came from the **ATIS**, so it is already magnetic. **The 17°E variation is not needed.** Apply it and you get 193°(M), an angle of 146°, a tailwind factor of 0.829 and an answer of 12 — which is not an option, and that is your warning.

$\theta = 210 - 047 = 163^\circ$  — well over 90°, so a tailwind, and almost straight down the runway.

$\cos 163 = -0.9563$

$W = 10 \div 0.9563 = 10.5$

**(b) 11 knots**

**Sanity check.** At 163° the wind is only 17° off the runway's reciprocal — almost a pure tailwind. So nearly all of it acts down the runway, and the wind you can accept must be only slightly more than your 10-knot limit. 10.5 knots. If you had produced 18, you resolved it as though the wind were nearly across the runway.

## Errata in the source

**CORRECTED — Case B says 11 knots. It is 13, and the book's own answer key proves it.**

The worked example for the combined-limits case (Figures 9.13 and 9.14) states that landing on runway 35 with the wind from 030°(M), the acceptable band runs from **11** knots to **31** knots.

**The upper bound is right and the lower one is not.**

|                               | Published | Correct   | Check                                                                                                                |
|-------------------------------|-----------|-----------|----------------------------------------------------------------------------------------------------------------------|
| Lower bound (10 kt headwind)  | 11        | <b>13</b> | 11 kt from 030°(M) gives $11 \times \cos 40 = 8.4$ kt of headwind — <b>below the 10 kt minimum it claims to meet</b> |
| Upper bound (20 kt crosswind) | 31        | 31        | $20 \div \sin 40 = 31.11$ — correct                                                                                  |

**Why this one is CORRECTED and not merely flagged.** Ordinarily I would not overrule a published figure on my own arithmetic. Here I do not have to: **the book contradicts itself, and its own answer key is the half that is right.**

Question 3 above is the same geometry — a  $40^\circ$  angle-off, a 10-knot minimum headwind, a 20-knot crosswind limit. Its published answer is **(c) 13 and 31**. The worked example on the same subject says 11 and 31. **The same  $40^\circ$  that produces the book's own correct upper bound of 31 cannot also produce a lower bound of 11.**

**And this error runs in the dangerous direction.** A pilot using 11 knots believes they have their 10 knots of headwind when they have 8.4 — on a runway chosen precisely because the margin was tight. The other errors in this chapter err safe. This one does not.

**A second, plain defect in the same paragraph.** The prose concludes that between the two bounds "*you have 10 knots or more of headwind component AND you have 25 knots or less of crosswind component.*" The crosswind limit stated four lines earlier is **20 knots**. There is only one reading: 25 is a typo for 20.

### **FLAGGED and NOT corrected — Case A, 41 versus 43.6 knots**

Covered in full in Section 7. The published 41 knots gives 23.5 knots of crosswind, not the 25 the example solves for; the arithmetic gives 43.6.

**No independent evidence exists either way** — nothing else in the book cross-checks this figure, unlike the case above. It errs on the safe side. **It stays flagged for the Captain's ruling and neither number is published here as the answer.**

### **What I checked in this chapter, and what I could not**

**Multi-drift: 5 of 5 clean.** The worked example and all four questions were resolved by simultaneous equations and every published answer agrees to within  $1.5^\circ$  and 1.2 knots. The cocked-hat residuals run from 0.00 to 1.13 knots, which confirms the drift sets are internally consistent.

**Forward components: 2 of 2 exact.** Both worked examples, and the CX-3 Guide's own published example, reproduce to two decimal places.

**Exam questions: 4 of 4 correct.** Every option checked, not just the marked one.

**Inverse components: 2 defects and 1 minor rounding,** all set out above. The allowable-wind-angle example reads  $214^\circ/286^\circ$  where the arcsine gives  $213^\circ/287^\circ$  — a degree, from reading  $36^\circ$  off a disc where the true value is  $36.87^\circ$ .

**What I could not settle:** whether the 41-knot figure is a reading error or a working error. Both produce the same symptom and the source does not show its intermediate steps.

# The chapter in eight lines

## Take these into the exam, and into the aeroplane

1. **Who told me this wind?** A controller's voice — ATC or ATIS — is **magnetic**. A written met message — TAF, METAR, VOLMET — is **true**. Runways are always magnetic.
2. **If the question gives you a variation and an ATIS wind, the variation is a decoy.** Using it is the error the question was built to catch.
3. **Headwind =  $W \cdot \cos\theta$ . Crosswind =  $W \cdot \sin\theta$ .** A negative cosine is a tailwind. That is the whole of the forward case.
4. **Angles:**  $30^\circ$  off gives 87% head and 50% cross;  $45^\circ$  gives 70% of each;  $60^\circ$  gives 50% head and 87% cross. These catch almost any keying error.
5. **Running it backwards:** max wind for a crosswind limit is  $X \div \sin\theta$ ; for a head or tailwind limit,  $H \div |\cos\theta|$ ; the allowable arc is  $\sin^{-1}(X \div W)$  either side of the runway. **The CX-3 cannot do any of these.**
6. **A tailwind problem is a headwind problem on the reciprocal runway.** Same wind, same aeroplane, no curved scale.
7. **On the CX-3: the runway NUMBER, not the course** — 27, never 270 — and the wind must be **magnetic**. It will answer a wrong input without complaint.
8. **Multi-drift: each drift is one equation, two drifts are a solution, three are a check.** Port drift is negative. The size of the cocked hat is the honesty of your observations.

***That is the module.** Chapter 5 gave you distance, speed, time and the conversions. Chapter 6 turned an indicated airspeed into a true one. Chapter 7 built the triangle of velocities and Chapter 8 solved it in both directions, then assembled a whole flight plan out of it. This chapter closed the last two jobs the wind face ever did.*

***What the machine changed, and what it did not.** The CX-3 removes the iterations, the guessing and most of the arithmetic. It does not remove the triangle, the sign of a variation, or the question of who told you the wind. Those were never the computer's job. They were always yours.*