Contents

AVI310101) Three-Digit Bearings

Exploring the Concept

Why Three-Digit Bearings?

Key Discovery

Picture this:

You are an air traffic controller at Sydney Approach. On your radar screen, 23 aircraft are converging toward the airport. Two of them — QF401 and VA218 — are closing in on the same airspace, 40 seconds from conflict. You need to turn QF401 **now**. Every second you spend thinking about which direction to say is a second those two aircraft get closer together.

In this moment, do you want a system that takes 3 mental steps to process, or 1?

In maths class, you may have seen **direction bearings** like N40°E or S25°W. Aviation does not use them. Here is why.

Direction bearing (e.g., N40°E) requires **3 mental steps**:

1. Identify the reference direction — is it North or South?
2. Identify the rotation direction — towards East or West?
3. Process the angle between them.

Three-digit bearing (e.g., 040°) requires just **1 step** after training:

- Fixed reference: always North.
- Fixed direction: always clockwise.
- One number to process.

Key Idea

A controller managing dozens of aircraft simultaneously cannot afford extra cognitive steps. One moment of confusion — mixing up "N25°W" with "N25°E" — could send an aircraft into the path of another.

Three-digit bearings eliminate this risk. There is only one reference (North), only one direction (clockwise), and only one number. With repeated training, a controller hears "two-seven-zero" and **instantly** visualises due West — no calculation, just pattern recognition.

The Three Rules

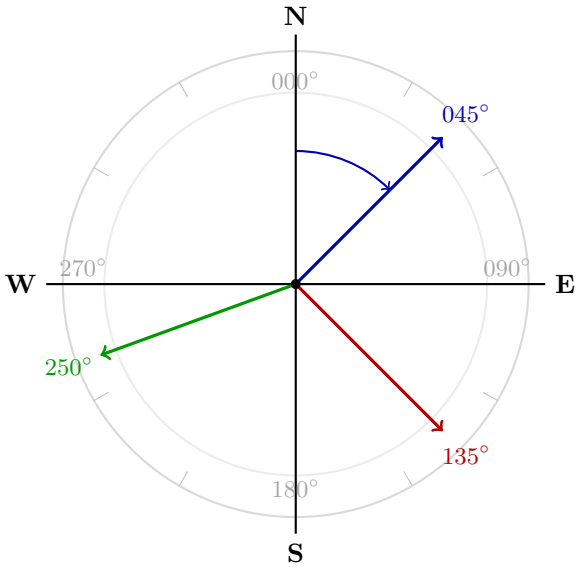
Key Idea

The Three Rules of Three-Digit Bearings:

1. Always measured from **North**.
2. Always measured **clockwise**.
3. Always written as **three digits** (045°, not 45°).

Cardinal directions:

$$\text{N} = 000^\circ \text{ (or } 360^\circ), \quad \text{E} = 090^\circ, \quad \text{S} = 180^\circ, \quad \text{W} = 270^\circ$$



Intercardinal Directions:

Direction	Bearing
NE	045°
SE	135°
SW	225°
NW	315°

How to Read Bearings Aloud

Key Idea

In ICAO radio communication, bearings are spoken **digit by digit**:

- 320° → "three-two-zero"
- 045° → "zero-four-five"
- 270° → "two-seven-zero"
- 008° → "zero-zero-eight"

NEVER "three hundred twenty" or "forty-five". There's no time for multi-syllable number words when aircraft are converging.

Key Discovery

Real World: Every Syllable Counts

Two aircraft are converging. The controller has seconds to act:

*"Qantas 401, turn left heading two-seven-zero, **immediately**."*

The pilot hears 3 digits, instantly pictures due West, and begins the turn. Now imagine the controller had said "two hundred and seventy degrees" — that is **11 syllables instead of 3**. In the time it takes to say those extra 8 syllables, both aircraft have travelled another 2 km closer together.

This is not hypothetical. The 2002 Überlingen mid-air collision killed 71 people partly because of communication delays between controller and pilots. Speed of communication saves lives.

Quadrant Identification

Quick mental check — which quadrant is a bearing in?

Bearing Range	Quadrant
000°–090°	NE quadrant
090°–180°	SE quadrant
180°–270°	SW quadrant
270°–360°	NW quadrant

Example

Example 1) Convert these compass directions to three-digit bearings.

i) Due East

ii) South-West

iii) North-North-East (halfway between N and NE)

Example 2) State which quadrant each bearing falls in, and give the nearest cardinal or intercardinal direction.

i) 148°

ii) 312°

iii) 073°

Example 3) Write how each bearing is spoken in ATC radio communication.

i) 195°

ii) 030°

iii) 270°

Try It Yourself!

a. Convert to three-digit bearings.

i) North-West _____

ii) South-East _____

iii) Due North _____

iv) West-South-West (halfway between W and SW) _____

b. State the quadrant and nearest cardinal or intercardinal direction.

i) 205° _____

ii) 087° _____

iii) 338° _____

c. Write how each bearing is spoken aloud (ICAO phraseology).

i) 145° _____

ii) 006° _____

iii) 350° _____

AVI310102) Bearing FROM and TO

Exploring the Concept

The Reverse Bearing Problem

A controller says: "The bearing of the aircraft from the airport is 100°." This means if you stand at the airport and look toward the aircraft, you face 100° (slightly south of east).

But what if the **pilot** wants to fly back to the airport? The pilot needs the **bearing of the airport from the aircraft** — the reverse direction.

Key Idea

Bearing of A from B means: stand at B, face North, turn clockwise until you face A.

The bearing of A from B is **not** the same as the bearing of B from A. They point in opposite directions.

The Compass Cross Method

To find the reverse bearing, draw a **compass cross** (N–S–E–W lines) at **both** positions. Because all North lines are parallel, you can use the geometry of parallel lines to find the return bearing.

Key Discovery

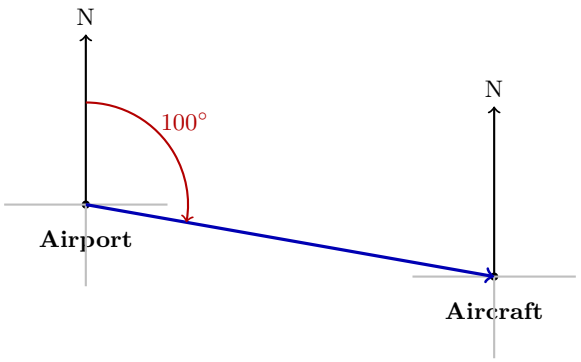
Why does this work?

All North lines across the Earth point in the same direction (toward the North Pole). This means the North line at the airport is **parallel** to the North line at the aircraft. The bearing line connecting the two points is a **transversal** cutting these parallel lines.

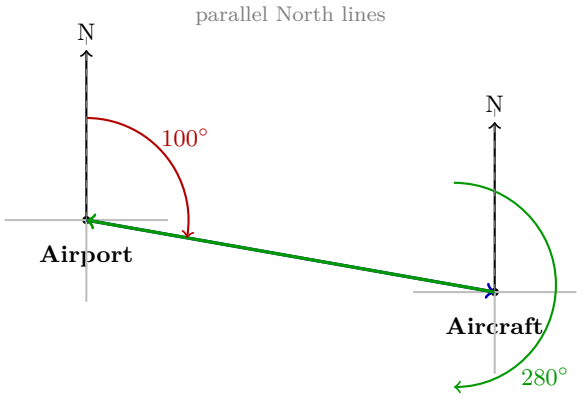
The co-interior angles (same-side interior angles) formed by a transversal cutting parallel lines add up to 180°. This is the geometric reason why the return bearing always differs by 180° from the forward bearing.

Worked Demonstration: The bearing of an aircraft from the airport is 100°. Find the bearing of the airport from the aircraft.

Step 1: Draw both positions with compass crosses.



Step 2: At the aircraft, draw the bearing line back toward the airport. Measure the angle clockwise from North.



Step 3: Read the answer. The bearing of the airport from the aircraft is **280°**.

Notice: $280° = 100° + 180°$. This is not a coincidence — it is a consequence of the co-interior angles formed by parallel North lines.

Important

Always draw the compass cross at both positions. Do not try to guess the return bearing mentally — draw it, measure from North clockwise, and verify. The +180° shortcut will be formalised in the next concept (Reciprocal Bearings).

Example

Example 1) The bearing of a ship from the lighthouse is 065°. Find the bearing of the lighthouse from the ship.

Example 2) The bearing of Town B from Town A is 215°. Find the bearing of Town A from Town B.

Example 3) A rescue helicopter spots a stranded hiker. The bearing of the hiker from the helicopter's base is 310°. The helicopter flies to the hiker. What bearing should the pilot fly to return directly to base?

Try It Yourself!

a. The bearing of a plane from the control tower is 070°. Draw compass crosses at both positions and find the bearing of the control tower from the plane.

b. The bearing of City B from City A is 195°. Find the bearing of City A from City B by drawing compass crosses.

c. A pilot flies from airport X to airport Y on a bearing of 325°. What bearing should the pilot fly to return from Y to X?

d. The bearing of a lighthouse from a ship is 260°. What is the bearing of the ship from the lighthouse?

AVI310103) Reciprocal Bearings

Exploring the Concept

What is a Reciprocal Bearing?

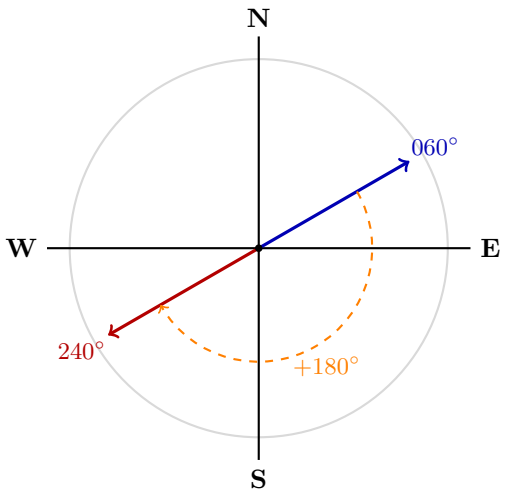
A reciprocal bearing is the **opposite direction** — the bearing you would be on if you turned exactly 180°.

Key Idea

The **reciprocal** of a bearing is found by adding or subtracting 180°:

- If bearing $< 180°$: reciprocal = bearing $+180°$
- If bearing $\geq 180°$: reciprocal = bearing $-180°$

Simple check: the reciprocal always differs from the original by exactly 180°.



Aviation Applications

Key Discovery

Bearing TO vs Bearing FROM

When a pilot reports their position relative to a navigation aid (like a VOR), there is an important distinction:

- **Bearing TO** the station: the bearing you would fly to reach it
- **Bearing FROM** the station: the direction away from the station toward you

These are always reciprocals of each other. If the bearing TO a VOR is 045°, then the bearing FROM that VOR is 225°.

VOR radials are defined as bearings FROM the station. If you are on the 090 radial, the station is to your west (bearing TO station = 270°).

Key Discovery

The 180° Turn

If you are flying heading 025° and ATC tells you to "turn 180" (a complete reversal), your new heading will be $025° + 180° = 205°$. Reciprocal bearings help you instantly know your return heading.

Example

Example 1) Find the reciprocal of 070°.

Example 2) Find the reciprocal of 315°.

Example 3) A pilot is flying heading 195°. ATC instructs "turn 180." What is the new heading?

Example 4) An aircraft is on the 135 radial of a VOR. What bearing should the pilot fly to head directly toward the VOR?

Try It Yourself!

a. Find the reciprocal bearing.

i) 040° _____

ii) 265° _____

iii) 180° _____

iv) 355° _____

v) 090° _____

b. A pilot is flying heading 310°. What heading will they be on after a 180° turn?

c. An aircraft is on the 220 radial of a VOR.

i) What is the bearing FROM the VOR to the aircraft? _____

ii) What bearing should the pilot fly to head directly TO the VOR? _____

AVI310104) Heading, Track, and Bearing

Exploring the Concept

Three Navigation Terms

Three terms describe directions in aviation, and each means something different:

Key Idea

- **Heading**: the direction the aircraft's **nose** is pointing (what the pilot sets on the compass).
- **Track**: the direction the aircraft is actually **moving** over the ground.
- **Bearing**: the direction from **one point to another** (e.g., the bearing of the airport from your current position).

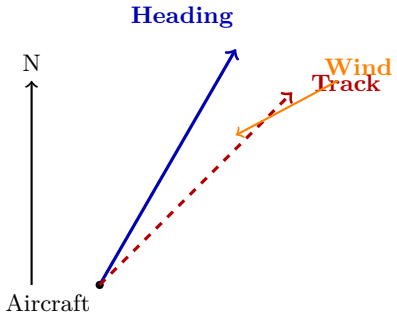
When there is no wind, heading = track. When there is wind, the aircraft drifts sideways, so heading $\neq$ track.

Key Discovery

The River Crossing Analogy

Imagine you are rowing straight across a river (heading = 090°). If the current pushes you downstream, your actual path (track) might be 110°. You are pointing one way but moving another.

Pilots experience the same thing with crosswinds. The aircraft's nose points in one direction, but the wind carries the whole aircraft sideways, so it traces a different path over the ground.



Important

Heading, track, and bearing are **NOT** the same thing. A common mistake is to use "heading" when you mean "bearing." Heading describes where the aircraft is pointed; bearing describes the direction between two positions.

Waypoint Navigation

Key Discovery

Real World: Waypoints and the FMC

In air traffic control, flights are routed through **waypoints** — fixed geographic coordinates with five-letter names like RIVET, TESAT, or AKMIR.

A typical ATC instruction sounds like:

"QF401, cleared direct TESAT, then RIVET, flight level 350."

Think of it like a road network in the sky:

- **Waypoints** = intersections (fixed points in the sky)
- **Airways** = roads connecting waypoints
- **Holding patterns** = roundabouts (circling until cleared)

The aircraft's **Flight Management Computer (FMC)** stores the coordinates of every waypoint. When the pilot enters the route, the FMC automatically calculates:

1. The **bearing** from the current position to each waypoint.
2. The **distance** between waypoints.
3. The required **heading** (adjusted for wind) to maintain the correct track.

Pacific Routes

Key Discovery

Over **land**, airways are based on ground navigation facilities. Waypoints have permanent five-letter names (like RIVET or TESAT) and never change.

Over the **Pacific Ocean**, there are no ground stations. Routes use **coordinate-based waypoints** like 35N140E (35° North, 140° East). These routes, called **PACOTS** (Pacific Organised Track System), are **redrawn every day** to follow the jet stream.

The same Incheon → Sydney flight might take 40 minutes less today than yesterday — simply because today's jet stream gives a stronger tailwind along a different track.

Example

Example 1) A pilot sets heading 350° but the wind pushes the aircraft to the right. The actual track over the ground is 005°.

i) Is the wind coming from the left or the right?

ii) What is the difference between heading and track?

Example 2) An aircraft at point A needs to fly to point B. The bearing of B from A is 130°. There is no wind. What heading should the pilot set?

Example 3) Identify which term (heading, track, or bearing) fits each description.

i) "The direction of the airport from your current position."

ii) "What the compass in the cockpit reads."

iii) "The path your GPS traces on the ground."

Try It Yourself!

a. Fill in the blanks with *heading*, *track*, or *bearing*.

i) The _____ of Sydney from Melbourne is approximately 025°. _____

ii) The pilot's compass shows a _____ of 290°. _____

iii) The GPS shows the aircraft's _____ is 285° due to a crosswind from the south. _____

b. A pilot sets heading 080° but the wind blows the aircraft to the left.

i) Will the track be greater than or less than 080°? _____

ii) If the track is 065°, what is the difference between heading and track? _____

c. In calm conditions (no wind), what is the relationship between heading, track, and bearing to the destination?

AVI3100 — Section 1 Review: Aviation Bearings

Question 1) *(AVI310101 — Three-Digit Bearings)*

An air traffic controller gives the instruction: "Turn right heading three-one-five." Write this heading as a number, and state which quadrant and nearest intercardinal direction it falls in.

Question 2) *(AVI310101 — Three-Digit Bearings)*

A student writes the bearing of East as "90°." Is this correct? Explain what should be written instead and how it is spoken in radio communication.

Question 3) *(AVI310102 — Bearing FROM and TO)*

The bearing of a helicopter from the airport is 140°. By drawing a compass cross at the helicopter's position, find the bearing of the airport from the helicopter.

Question 4) *(AVI310102 — Bearing FROM and TO)*

Town B is on a bearing of 250° from Town A. Find the bearing of Town A from Town B.

Question 5) *(AVI310103 — Reciprocal Bearings)*

An aircraft is on the 310 radial of a VOR. What bearing should the pilot fly to head directly toward the VOR?

Question 6) *(AVI310103 — Reciprocal Bearings)*

A pilot is flying heading 158° and receives the instruction to reverse course (turn 180°). What will the new heading be?

Question 7) *(AVI310104 — Heading, Track, and Bearing)*

A pilot sets heading 270° (due west). A southerly wind (from the south) pushes the aircraft. Will the track be north of west or south of west? Explain.

Question 8) *(AVI310104 — Heading, Track, and Bearing)*

In what conditions are heading, track, and bearing to the destination all equal?

AVI310101) Three-Digit Bearings — Homework

Question 1) Convert to three-digit bearings.

i) Due South

ii) North-East

iii) West-North-West (halfway between W and NW)

iv) South-South-East (halfway between S and SE)

v) Due West

Question 2) State the quadrant for each bearing and give the nearest cardinal direction.

i) 112°

ii) 267°

iii) 029°

iv) 193°

Question 3) Write the ICAO radio phraseology for each bearing.

i) 240°

ii) 015°

iii) 308°

iv) 090°

Question 4) A student pilot writes a heading as "45°" in their navigation log. The instructor marks it wrong. Explain why, and write the correct form.

AVI310102) Bearing FROM and TO — Homework

1. For each situation, draw compass crosses at both positions and find the return bearing.

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The bearing of a yacht from the harbour is 045°. Find the bearing of the harbour from the yacht.

The bearing of Town Q from Town P is 230°. Find the bearing of Town P from Town Q.

The bearing of a plane from the radar station is 172°. Find the bearing of the radar station from the plane.

2. A search plane takes off from base and flies to a crash site on a bearing of 118°. After the rescue, the pilot needs to fly back to base. What bearing should the pilot fly?

3. The bearing of Lighthouse B from Lighthouse A is 295°. A ship at Lighthouse B wants to sail to Lighthouse A. What bearing should it follow?

4. A pilot radios: “I can see the airport on bearing two-four-zero.” The controller needs to know the bearing of the aircraft from the airport. What is it?

5. Explain why the return bearing is always exactly 180° different from the forward bearing. Use the words “parallel” and “North lines” in your answer.

AVI310103) Reciprocal Bearings - Homework

Question 1) Find the reciprocal of each bearing.

i) 125°

ii) 298°

iii) 060°

iv) 210°

v) 345°

vi) 180°

Question 2) Complete the table.

Bearing	Reciprocal
055°	
	320°
170°	
	095°

Question 3) A Cessna 172 is flying heading 248°. The pilot decides to return to the departure airport by turning 180°. What is the new heading?

Question 4) An aircraft is on the 075 radial of Brisbane VOR.

i) What is the bearing FROM the VOR to the aircraft?

ii) What bearing must the pilot fly to head TO the VOR?

iii) If the pilot flies to the VOR and then continues past it, what radial will they now be on?

AVI310104) Heading, Track, and Bearing — Homework

Question 1) Match each description to the correct term: heading, track, or bearing.

i) The direction an aircraft's nose is pointing.

ii) The actual path the aircraft traces over the ground.

iii) The direction from one waypoint to another.

iv) What ATC tells you to fly when they say "turn left heading two-seven-zero."

Question 2) A pilot sets heading 200° but the wind blows from the west (from the left side).

i) Will the aircraft drift left or right?

ii) Will the track be greater than or less than 200°?

Question 3) An FMC shows the bearing from the aircraft's current position to waypoint TESAT is 315°. The wind is blowing from the north-west.

i) In which general direction will the wind push the aircraft?

ii) Will the pilot need to set a heading greater than or less than 315° to compensate?

Question 4) Explain in your own words why heading $\neq$ track when there is wind. Use the river crossing analogy or an aviation example.

