

PRIVATE PILOT GROUND SCHOOL

MODULE 2-2 — NAVIGATION: PILOTAGE, DEAD RECKONING, VOR, GPS

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MNEMONICS

East is least, west is best — Going from true to magnetic, subtract easterly variation and add westerly variation

The sign rule for variation on the heading chain. Read the isogonic line nearest the route: an easterly variation is subtracted from the true heading to get the magnetic heading, a westerly one is added. Say it at the nav log, where the chain is worked, and again on the checkride when the examiner hands you a chart.

The five Cs — Climb, communicate, confess, comply, conserve

The lost procedure in the order it is flown. Climb for the view, the radio, and the radar. Communicate on a charted frequency or 121.5. Confess that you do not know where you are, which the AIM calls an urgency condition the moment it begins. Comply with the vectors. Conserve the fuel by leaning and slowing while the position is rebuilt. The airplane is flown first, before the first C.

FACTS TO REMEMBER

KNOW THESE COLD

- Pilotage is navigation by visible landmarks compared against the chart.
Source: PHAK ch. 16
- Dead reckoning is navigation by computed heading, speed, and time from a known starting point.
Source: PHAK ch. 16
- On a VFR cross-country the two run together: dead reckoning predicts, pilotage confirms — neither alone is the plan.
Source: PHAK ch. 16
- The required foundation for solo cross-country is charts plus pilotage and dead reckoning with a magnetic compass; electronic navigation rides on top of it, never in place of it.
Source: 14 CFR 61.93(e)(1)
- Variation is the angle between true north and magnetic north at your location, shown by isogonic lines on the chart.
Source: PHAK ch. 16
- "East is least, west is best": going from true to magnetic, subtract easterly variation and add westerly.
Source: PHAK ch. 16 (Mnemonic)
- The heading chain runs: true course, plus or minus wind correction gives true heading; plus or minus variation gives magnetic heading; plus or minus deviation gives compass heading.
Source: PHAK ch. 16
- The wind correction angle points the nose into the wind just enough to keep the ground track on the course

line.

Source: PHAK ch. 16

- Contour lines and shaded relief show terrain elevation on the sectional; tightly packed contours mean steep terrain.

Source: PHAK ch. 16; Chart User's Guide

- A good checkpoint is unique, visible from cruise altitude, and on or near the course line.

Source: PHAK ch. 16

- Line features crossing the course (rivers, highways, railroads) make natural timing gates; line features parallel to the course confirm track and bound drift.

Source: PHAK ch. 16

- Checkpoints are spaced so groundspeed checks come at a regular interval — frequent enough to catch a wind change, sparse enough not to swamp the pilot.

Source: PHAK ch. 16

- The first checkpoint belongs after the top of climb, so the first groundspeed check measures cruise performance, not climb.

Source: PHAK ch. 16

- True course is measured with a plotter against a meridian near the midpoint of the leg.

Source: PHAK ch. 16

- True airspeed is calibrated airspeed corrected for density altitude; it rises roughly 2% per 1,000 ft of altitude for the same calibrated airspeed.

Source: PHAK ch. 11

- Planning TAS comes from the POH cruise table for the chosen altitude, power setting, and temperature.

Source: POH/AFM sect. 5

- Cruise power selection trades speed against fuel flow and range; the POH cruise-performance table is the menu.

Source: POH/AFM sect. 5

- The wind side of the flight computer solves wind correction angle and groundspeed from forecast wind, TAS, and true course.

Source: PHAK ch. 16

- Actual groundspeed equals the distance between two checkpoints divided by the time between them.

Source: PHAK ch. 16

- A groundspeed slower than planned recomputes destination fuel first and the schedule second.

Source: PHAK ch. 16

- Off-course corrections are made by visual re-intercept, then a revised heading that holds the track.

Source: PHAK ch. 16

- A VOR broadcasts 360 radials oriented to magnetic north; a radial always points FROM the station.

Source: PHAK ch. 16; AIM 1-1-3

- A VOR must be identified by its Morse (or voice) identifier before use; a missing identifier means the facility is unusable, often for maintenance.

Source: AIM 1-1-3

- With a course set in the OBS, the CDI shows displacement from that course, and the TO/FROM flag shows whether flying the course would take you to or from the station.

Source: PHAK ch. 16

- CDI sensing is correct only when the selected course roughly matches the direction of flight; flying the

reciprocal of the selected course gives reverse sensing.

Source: PHAK ch. 16

– To fix position with one VOR: center the needle with a FROM indication — the course window then reads the radial you are on.

Source: PHAK ch. 16

– Radials from two VORs cross at exactly one place: a two-VOR cross-fix is a position without any visual landmark.

Source: PHAK ch. 16

– VOR reception is line-of-sight: range grows with altitude, and terrain can block it down low.

Source: AIM 1-1-3

– GPS position comes from satellite ranging; the receiver needs four satellites for a three-dimensional fix.

Source: AIM 1-1-17; PHAK ch. 16

– RAIM is the receiver's integrity self-check: it detects when a satellite signal cannot be trusted; without RAIM the position is unmonitored.

Source: AIM 1-1-17

– A RAIM-loss or integrity annunciation in flight means the GPS position is unverified: crosscheck it, or revert to pilotage, dead reckoning, or VOR.

Source: AIM 1-1-17

– No regulation requires a current GPS database for VFR, but stale airspace and frequency data is a trap: an out-of-date database must be covered by chart crosscheck.

Source: AIM 1-1-17

– Handheld and tablet GPS are situational-awareness aids only: not certified, not primary navigation, and their failure modes (battery, signal, heat) travel with them.

Source: AC 91-78

– VFR flight following provides traffic advisories and safety alerts, workload permitting; request it from approach or center with position, altitude, and destination.

Source: AIM 4-1-15

– Traffic advisories come as clock positions relative to your ground track — "traffic, two o'clock, five miles" — so the search sector shifts with your wind correction.

Source: AIM 4-1-15

– "Radar service terminated, squawk VFR" ends the service: navigation, terrain, and traffic are all yours again, with no handoff coming.

Source: AIM 4-1-15

– Mode A sends the four-digit squawk; Mode C adds pressure altitude; Mode S adds selective interrogation and data link.

Source: AIM 4-1-20

– Squawk 1200 is VFR; 7500 is hijack, 7600 lost communications, 7700 emergency — and avoid spinning the knobs through them.

Source: AIM 4-1-20

– ADS-B Out broadcasts GPS-derived position and velocity about once a second; it is how modern ATC and equipped aircraft see you.

Source: AIM 4-5-7

– ADS-B In (optional) receives TIS-B traffic and FIS-B weather; TIS-B shows only transponder- or ADS-B-equipped targets with coverage — it never shows every aircraft.

Source: AIM 4-5-7

- If an operable transponder is installed, it runs with altitude reporting whenever airborne in controlled airspace.

Source: 14 CFR 91.215(c)

- Program the navigator before the runway: a mis-set GPS flight plan flown faithfully is the modern way to get lost.

Source: PHAK ch. 16

- In-flight navigation programming is a distraction budget item: aviate first, then navigate — head-down time is scheduled, not stolen.

Source: PHAK ch. 2

- Name the limitation of whatever you navigate by today — VOR line-of-sight, GPS integrity, EFB battery — before flight, not after it bites.

Source: PHAK ch. 16

- On any nav-signal loss (flag, integrity warning, frozen EFB): say it out loud, hold the last crosschecked heading, and rebuild from pilotage and dead reckoning.

Source: PHAK ch. 16

- The lost-procedure spine is the five Cs: climb, communicate, confess, comply, conserve.

Source: AFH (Mnemonic 5 Cs)

- Climbing when lost improves both the view and radio/navaid reception.

Source: AFH

- Position rebuilds from the last known fix: time flown times groundspeed bounds the circle you must be in; then match large features to the chart.

Source: PHAK ch. 16

- A VOR cross-fix or the GPS nearest page resolves position without any visual match at all.

Source: PHAK ch. 16

- Any ATC radar facility can locate you and vector you; 121.5 and squawk 7700 exist for exactly this — asking early is airmanship, not failure.

Source: AIM 6-2-1

- Logging actual times over checkpoints is the raw material for un-losing yourself later: a current nav log is the anti-lost device.

Source: PHAK ch. 16

- The escalation triggers are concrete: fuel below plan, darkness coming, or weather lowering — any one of them means ask for help now or declare.

Source: AIM 6-1-2

- A lost airplane still needs flying: set safe altitude and power first, keep eyes out — circling a landmark head-down over a chart is a collision setup.

Source: AFH

- Unplanned fuel or power consumption while navigating (headwind, rich mixture, deviations) is caught by the checkpoint fuel log, and the response is the fuel decision point, not hope.

Source: PHAK ch. 16

GOING DEEPER

- Winds aloft forecasts and METAR winds are in degrees true; winds voiced by a tower or ATIS are magnetic.

Source: AWH FAA-H-8083-28; AIM

- A persistent planned-vs-actual heading disagreement means the wind is not as forecast: update the wind correction angle rather than re-intercepting again and again.

Source: PHAK ch. 16

- Each dot of a VOR CDI is about 2° of course displacement; full-scale deflection is 10° or more off course.

Source: PHAK ch. 16

- VOR accuracy checks are required for IFR (91.171), not VFR — but a VOT ground check ($\pm 4^\circ$ tolerance) is the free habit that catches a lying receiver.

Source: 14 CFR 91.171; AIM 1-1-4

- DME and GPS distances are slant range: directly over a station at altitude, the readout shows your altitude in miles, not zero.

Source: PHAK ch. 16

- The VOR network is shrinking to a minimum operational network: never assume every charted VOR is in service — check NOTAMs.

Source: AIM 1-1-3

- RAIM needs a fifth satellite to detect a faulty signal and a sixth to isolate and exclude it; barometric aiding can stand in for one satellite.

Source: AIM 1-1-17

- IFR GPS operations require RAIM/integrity prediction before flight; the VFR pilot borrows the habit — know before takeoff whether the box can be trusted today.

Source: AIM 1-1-17

- GPS interference and jamming are real (military test NOTAMs); a sudden unexplained GPS anomaly means crosscheck against ground references immediately.

Source: AIM 1-1-17; GPS NOTAMs

- WAAS augments GPS with corrected, integrity-monitored signals — better accuracy and availability than unaugmented GPS.

Source: AIM 1-1-18

- Mode C reports pressure altitude; ATC's computer applies the correction — the pilot never adjusts the transponder for the altimeter setting.

Source: AIM 4-1-20

- When lost, read from ground to chart — pick the landmark first, then find it on paper; chart-to-ground invites forcing the match.

Source: AFH

THE REGULATIONS BEHIND THIS MODULE

14 CFR 61.93(e)(1) – Solo cross-country flight requirements

A student pilot training for cross-country flight in a single-engine airplane must receive and log training in the use of aeronautical charts for VFR navigation using pilotage and dead reckoning with the aid of a magnetic compass.

Where it goes deeper: This module, in the first Leg.

14 CFR 91.215(c) – Transponder-on operation

In all controlled airspace, each person operating an aircraft equipped with an operable ATC transponder shall operate it, including Mode C if installed, and reply on the appropriate code or as assigned by ATC.

Where it goes deeper: This module, in the transponder Leg.