EASA ATPL(A) · THEORY REVISION

The ATPL Cheat Sheet

every memory item, number and trap, all 14 subjects

The facts that actually get tested, stripped to the bone: definitions, key numbers, formulas, mnemonics and the classic exam traps for each subject. Built for the night before, the commute, and the last scroll before you walk into the exam hall.

14 subjects | **711** memory items | **5** boxes per subject

Definitions, Numbers, Formulas, Mnemonics, Traps

You are reading the static PDF. The interactive web version of this cheat sheet at **skystudyatpl.com/atpl-cheat-sheet** adds a light and dark theme, a quiz mode that covers every key value so you can test your recall, instant search across every memory item, and hover or tap explanations for every aviation abbreviation. Like the rest of SkyStudy, it is free to use in the browser while the beta is open.

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THE 14 SUBJECTS

010 Air Law
Chicago Convention, ICAO Annexes, airspace classes, rules of the air, VFR minima, light signals.

021 Aircraft General Knowledge
Airframe and structures, hydraulics, pneumatics, electrics, engines, propellers, systems.

022 Instrumentation
Pitot-static, gyroscopes, magnetic compass, IRS/AHRS, EFIS, warning systems.

031 Mass and Balance
Mass definitions, centre of gravity, MAC, load and trim, standard masses.

032 Performance
Performance classes, V-speeds, takeoff and landing, climb segments, WAT limits.

033 Flight Planning and Monitoring
Fuel policy, PET and PNR, ICAO flight plan, cruise techniques, altimetry.

040 Human Performance and Limitations
Physiology, hypoxia, vision, illusions, sleep and fatigue, CRM and error.

050 Meteorology
ISA, pressure and altimetry, cloud, wind, fronts, icing, thunderstorms.

061 General Navigation
The Earth, great circles, charts and projections, dead reckoning, the compass.

062 Radio Navigation
Radio waves, NDB, VOR, DME, ILS, radar, SSR, GNSS.

070 Operational Procedures
Ops documents, dangerous goods, low-visibility ops, wake turbulence, MEL.

081 Principles of Flight
Lift and drag, the stall, stability and control, high-speed flight, propellers.

091 VFR Communications
Phonetic alphabet, standard phraseology, readback, light signals, squawks.

092 IFR Communications
IFR clearances, mandatory readback, holding, radio failure, emergencies.

010 Air Law

Chicago Convention, ICAO Annexes, airspace classes, rules of the air, VFR minima, light signals.

AIRSPACE CLASSES A TO G AT A GLANCE

A	IFR only. Every aircraft separated. ATC clearance required.
B	IFR + VFR. Every aircraft separated from every other.
C	IFR + VFR. IFR separated from all; VFR separated from IFR.
D	IFR + VFR. IFR separated from IFR; VFR gets traffic info.
E	IFR + VFR. IFR separated from IFR; VFR needs no clearance.
F	Uncontrolled. IFR advisory service where it is provided.
G	Uncontrolled. Flight information; traffic info on request.

A to E are controlled (an ATC service is given); **F and G are uncontrolled**. Class A is the only class that forbids VFR; class G gives information only.

MUST-KNOW DEFINITIONS AND CONCEPTS

- The **Chicago Convention (1944)** established ICAO and confirms every state has complete and exclusive sovereignty over the airspace above its territory.
- ICAO has **19 Annexes** to the Chicago Convention; each contains Standards (must comply, differences must be filed) and Recommended Practices (should comply, no filing obligation).
- Key Annexes to know cold: **1** Personnel Licensing, **2** Rules of the Air, **3** Meteorological Service, **6** Operation of Aircraft, **7** Nationality and Registration Marks, **8** Airworthiness, **11** Air Traffic Services, **13** Accident and Incident Investigation, **14** Aerodromes, **17** Security.
- The **Five Freedoms of the Air**: 1st and 2nd are technical (overfly, technical stop), 3rd to 5th are traffic freedoms.
- **State of Registry**: the state on whose register the aircraft is entered; responsible for the Certificate of Registration.
- **State of the Operator**: the state where the operator has its principal place of business; issues the Air Operator Certificate.
- Certificate of Airworthiness, Certificate of Registration and Noise Certificate are three separate mandatory documents carried on board.
- Civil aircraft versus State aircraft (military, customs, police): State aircraft are not bound by ICAO Annexes.
- Airspace classes A to G: **A** is IFR only, ATC clearance and separation from all traffic; **G** is uncontrolled, no ATC service, traffic information only on request.
- The **Pilot-in-Command** has final authority and responsibility for the safety of the aircraft and all persons on board.
- **CAVOK** means visibility 10 km or more, no cloud below 5000 ft (or the highest minimum sector altitude if higher), no CB or towering cumulus, no significant weather.
- **Distress (MAYDAY)** = grave and imminent danger requiring immediate assistance. **Urgency (PAN PAN)** = a safety concern not requiring immediate assistance.
- **NOTAM**: time-critical information not known early enough to publish in the AIP. The **AIP** is the primary source of permanent aeronautical information for a state.
- Annex 13 accident and incident investigations exist solely to prevent future accidents, never to apportion blame or liability.

KEY NUMBERS, LIMITS AND VALUES

- SSR transponder codes: **7500** unlawful interference (hijack), **7600** radio failure, **7700** general emergency.
- Emergency frequency **121.5 MHz** (civil); **243.0 MHz** military. ELT transmits on **121.5 MHz and 406 MHz**.
- ISA: sea level **1013.25 hPa** (29.92 inHg), **15 C**, lapse rate about **1.98 C per 1000 ft** (rounded to 2 C/1000 ft).
- Pressure decreases by roughly **1 hPa per 30 ft** near sea level (the ratio changes with altitude).
- **QNH**: reads elevation AMSL on the ground. **QFE**: reads height above the aerodrome. **QNE**: standard 1013.25 hPa above the transition altitude.
- Semicircular rule: magnetic track **000 to 179** flies odd thousands; **180 to 359** flies even thousands (add 500 ft for VFR where applicable).
- Transition altitude is fixed by the state/aerodrome (flown on QNH); transition level is calculated by ATC and varies with pressure (flown on 1013.25).
- VFR at and above 10,000 ft AMSL: **8 km** visibility, 1500 m horizontal and 300 m (1000 ft) vertical from cloud.
- VFR below 10,000 ft down to 3000 ft AMSL: **5 km** visibility, 1500 m horizontal and 300 m vertical from cloud.
- VFR at or below 3000 ft AMSL (or 1000 ft above terrain) in class F/G: 5 km visibility, clear of cloud, in sight of the surface.
- Minimum height: **1000 ft** above the highest obstacle within 600 m over congested areas; elsewhere not within **500 ft** of any person, vehicle, vessel or structure.
- Runway designators are the magnetic bearing of the centreline rounded to the nearest 10 degrees, last digit dropped (274 becomes 27).
- Right of way order: aircraft in distress, then balloons, gliders, airships, aircraft towing, then powered heavier-than-air aircraft.
- Converging same-category aircraft: the one with the other on its **right** gives way. Head-on: **both turn right**. Overtaking: overtaker alters **right**, overtaken has right of way.
- Aircraft on final approach to land has right of way over aircraft on the ground or about to take off. Time in aviation is always **UTC**.
- Alcohol: a common minimum is **8 hours** bottle to throttle VERIFY.
- Light signals to aircraft **in flight**: steady green = cleared to land; steady red = give way and keep circling; flashing green = return to land; flashing red = aerodrome unsafe, do not land.
- Light signals to aircraft **on the ground**: steady green = cleared for takeoff; flashing green = cleared to taxi; steady red = stop; flashing red = taxi clear of the runway in use; flashing white = return to starting point.

MNEMONICS AND MEMORY ITEMS

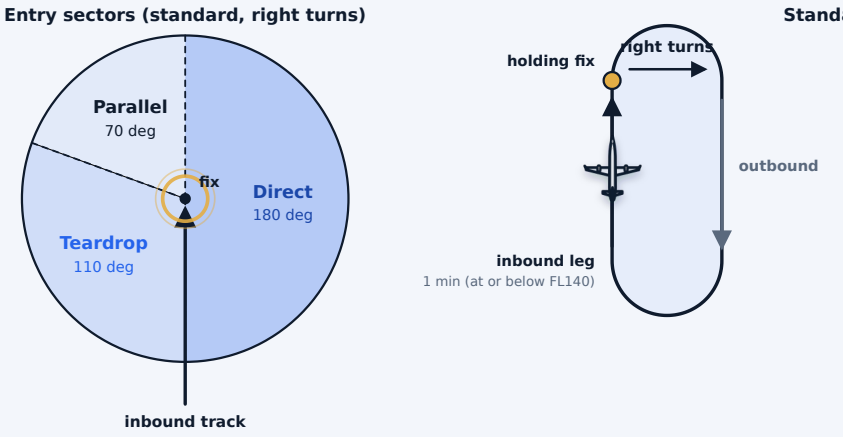
- Anchor the **Annexes by number**: 1 Licensing, 2 Rules of the Air, 3 Met, 6 Operations, 7 Marks, 8 Airworthiness, 11 ATS, 13 Investigation, 14 Aerodromes, 17 Security.
- Right of way pecking order: **Big Girls Always Take Priority** (Balloons, Gliders, Airships, Towing, Powered).
- **MAYDAY = Menace** (grave danger), **PAN = Precaution** (urgent, not yet grave). Each is said three times.
- Squawk ladder by severity: **7500** hijack, **7600** comms lost, **7700** general emergency.
- Cloud clearance hook **1-5-3**: 1500 m horizontal, 300 m (1000 ft) vertical, at every VFR band above the surface layer.
- **QNH** = height above sea level; **QFE** reads zero on the Field.

COMMON EXAM TRAPS

- Do not confuse **State of Registry** (Certificate of Registration, aircraft) with **State of the Operator** (AOC, operator).
- Standards are not automatically law everywhere: states may file differences; Recommended Practices carry no filing obligation.
- Transition **altitude** is fixed; transition **level** changes with QNH. Do not swap them.
- On converging tracks, the aircraft that gives way is the one with the other on **its right**, not the faster or first-arriving one.
- When overtaking, the **overtaking** aircraft alters right and the overtaken aircraft keeps its heading; students often reverse this.
- Powered aircraft give way to balloons, gliders and airships regardless of which side they are on.
- **CAVOK** has strict thresholds; weather just short of them is not CAVOK even if it looks fine.
- **7500** gives no aural warning to the crew that set it; do not assume all three emergency codes behave the same.
- State aircraft (military, customs, police) are exempt from ICAO Annexes.
- Runway numbers round the **magnetic** bearing, not the true bearing; convert first if a true heading is given.

The holding pattern and its three entry sectors

010 · HOLDING



1 Standard hold

The standard holding pattern uses right-hand turns at rate one (3 deg/s) or 25 degrees of bank, whichever needs the lesser bank; left turns must be published.

2 Leg timing

The inbound leg is timed: 1 minute at or below 14 000 ft, and 1.5 minutes above 14 000 ft. The outbound leg is adjusted to give that inbound time.

3 Maximum holding speeds

Up to 14 000 ft 230 kt, above 14 000 to 20 000 ft 240 kt, above 20 000 to 34 000 ft 265 kt, and above 34 000 ft Mach 0.83 (ICAO).

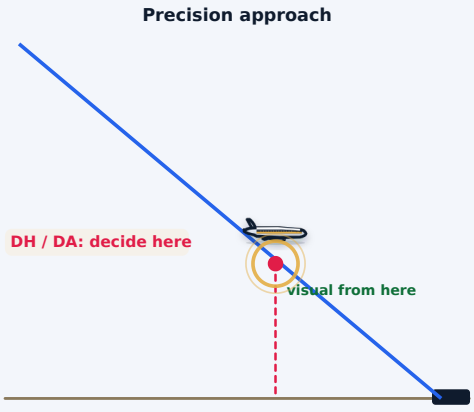
4 The three entries

Join by sector: direct covers 180 degrees on the holding side, teardrop the 110 degree sector, and parallel the 70 degree sector next to the inbound track.

A standard hold uses right turns with a 1-minute inbound leg (1.5 minutes above 14 000 ft); join it by the direct (180 deg), teardrop (110 deg) or parallel (70 deg) sector. Drawn in code.

Precision approach categories and landing minima

010 · LANDING MINIMA



Category	DH / DA	RVR minimum
CAT I	200 ft or above	550 m or more
CAT II	100 to below 200 ft	300 m or more
CAT IIIA	below 100 ft / none	200 m or more
CAT IIIB	below 50 ft / none	75 to 200 m
CAT IIIC	no decision height	no RVR limit

DH is a radio-altimeter height; DA is the same point as an altitude on QNH.

1 DH vs MDA/MDH

A decision height (precision/APV) may be momentarily passed during the go-around; an MDA/MDH (non-precision) must not be descended below until visual with the runway.

2 RVR

Runway visual range is measured along the runway by transmissometer; it is the distance a pilot sees runway lights or markings and sets the approach limit.

3 Fail-passive vs fail-operational

CAT II/IIIA are typically fail-passive (revert to manual with no large out-of-trim); CAT IIIB/C are fail-operational, completing the approach after one failure through redundancy.

4 Lower minima, more capability

As the DH and RVR fall, the aircraft, crew and ground equipment must all be approved to that category; CAT II and below need an approved automatic landing system or a head-up display for manual flight.

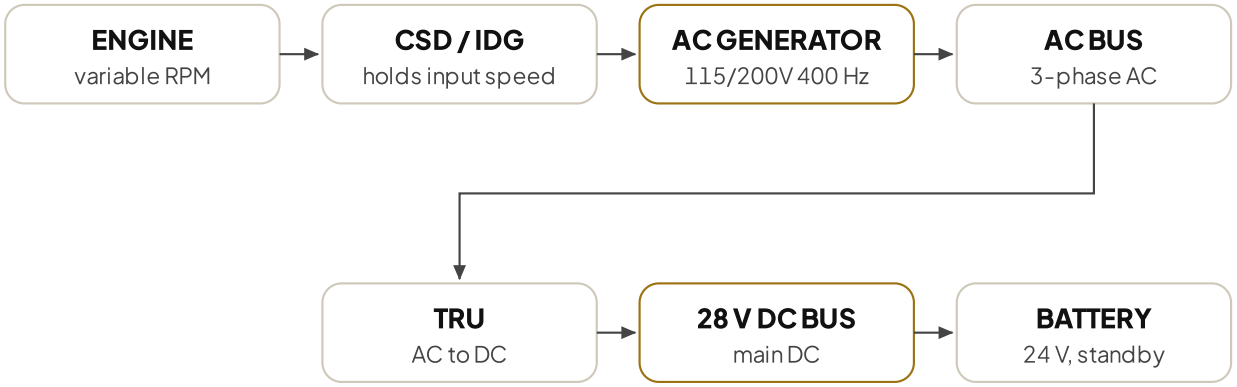
Lower minima need more capability: CAT I is DH 200 ft and RVR 550 m, falling to CAT III with little or no DH, its minima then set by RVR. Drawn in code.

Two of the 369 code-drawn study figures inside the SkyStudy question bank. Try them with the free demo at skystudyatpl.com/demo.

021 Aircraft General Knowledge

Airframe and structures, hydraulics, pneumatics, electrics, engines, propellers, systems.

AC AND DC ELECTRICAL GENERATION CHAIN



Constant-frequency AC: the CSD/IDG holds generator input speed so output stays at 400 Hz. Transformer-rectifier units feed the 28 V DC bus and battery. Modern types (e.g. B787) generate variable-frequency AC and delete the CSD; a RAT gives last-resort emergency power.

MUST-KNOW DEFINITIONS AND CONCEPTS

- Primary structure is **monocoque** (skin carries all loads) or **semi-monocoque** (skin plus stringers and frames share loads); semi-monocoque is standard on transport aircraft.
- **Fail-safe** design keeps adequate residual strength after a single element fails, until damage is found at the next inspection.
- **Damage tolerance**: structure and inspection are designed so a crack grows without catastrophic failure before detection.
- **Fatigue**: cyclic loading (pressurisation cycles, gusts) causes crack initiation and growth over time, independent of a single overload.
- Hydraulics: engine-driven pumps pressurise fluid, reservoirs allow for volume change, accumulators store pressure and dampen pulses; most transports use 3000 psi (some newer types 5000 psi).
- Pneumatic (bleed air): hot high-pressure air tapped from the compressor powers air conditioning, pressurisation, anti-ice and engine start.
- The **Air Cycle Machine** cools bleed air using the Brayton refrigeration cycle (compress, cool, expand), not a vapour cycle.
- Pressurisation: the outflow valve modulates cabin air exit to hold a scheduled cabin altitude and fails to a safe (open) position on loss of power.
- Ice protection: **thermal** (hot bleed air or electric), **pneumatic boots** (inflate to crack ice off), and **fluid** (weeping wing / TKS).
- **Anti-ice** prevents ice continuously; **de-ice** lets ice form then removes it cyclically.
- AC generation: engine-driven generators produce three-phase AC, typically 115/200 V at **400 Hz** on constant-frequency systems.
- A **Constant Speed Drive (CSD/IDG)** turns variable engine speed into a constant generator input speed so output stays at 400 Hz.
- Modern **Variable Frequency** systems (e.g. B787) generate variable-frequency AC and convert as needed, removing the CSD.
- **RAT** (Ram Air Turbine) deploys automatically to give emergency hydraulic and/or electrical power after major power loss.
- The **squat switch** (weight-on-wheels) switches logic between air mode and ground mode (spoilers, reverse, radio-altimeter callouts, pressurisation).
- Oxygen: gaseous cylinders for the crew, chemical generators (sodium chlorate) for passenger drop-down masks on most narrowbodies.
- Piston engine: **Otto cycle**, four-stroke, spark ignition, idealised constant-volume heat addition.
- Turbine engine: **Brayton cycle**, continuous flow, idealised constant-pressure heat addition.
- **Bypass ratio**: fan bypass mass flow divided by core mass flow; high-bypass engines are more efficient and quieter at airline cruise speeds.
- Constant-speed (variable-pitch) propellers use a governor to hold selected RPM by varying blade angle; **feathering** aligns blades with the airflow to stop windmilling drag.

KEY NUMBERS, LIMITS AND VALUES

- Standard transport AC frequency: **400 Hz**; generator output **115 V** line-to-neutral / **200 V** line-to-line, three-phase.
- Typical hydraulic pressure **3000 psi**; some modern types **5000 psi** VERIFY.
- Maximum certificated cabin altitude for a pressurised transport at max operating altitude: **8000 ft**.
- Cabin altitude warning typically triggers around **10,000 ft** cabin altitude VERIFY.
- Aircraft DC bus typically **28 V DC**; battery commonly **24 V** (Ni-Cd or lead-acid), fed via transformer-rectifier units.
- Turbine gas temperature limits (EGT/ITT/TGT) are engine-type specific and lowest at start; do not memorise a generic number VERIFY.
- Fire protection: typically **two bottles per engine**, discharged from the flight deck.
- V-speeds are aircraft-specific; for 021 learn the definitions, not fixed numbers.
- ISA reference for systems work: 1013.25 hPa, 15 C, 1.98 C/1000 ft to the tropopause at 36,090 ft.

FORMULAS AND RELATIONSHIPS

- Otto cycle efficiency rises with **compression ratio** (idealised constant-volume heat addition).
- Brayton cycle efficiency rises with **overall pressure ratio** (idealised constant-pressure heat addition).
- Thrust is proportional to **mass flow times change in velocity** (Newton's third law).
- AC output frequency is proportional to rotational speed, f = (pole pairs x RPM)/60, so the CSD must hold input speed constant for 400 Hz.
- Gas law PV = nRT underlies pressurisation and bleed systems: compressing bleed air raises pressure and temperature, so it needs cooling before cabin use.
- Basic electrical relationships V = IR and P = VI apply to DC systems, generator loading and load-shedding.

MNEMONICS AND MEMORY ITEMS

- **Anti before, De after**: anti-ice prevents ice, de-ice removes it once formed.
- **CSD keeps it constant**: Constant Speed Drive gives a constant 400 Hz.
- **Brayton = continuous burn** (turbine); **Otto = one bang per two revolutions** (piston).
- Squat switch: weight **on** wheels = ground logic; weight **off** wheels = air logic.
- Feathered blades turn edge-on to the wind (flat to the flow) to kill drag.
- **RAT** deploys when you lose the juice: last-resort emergency power.

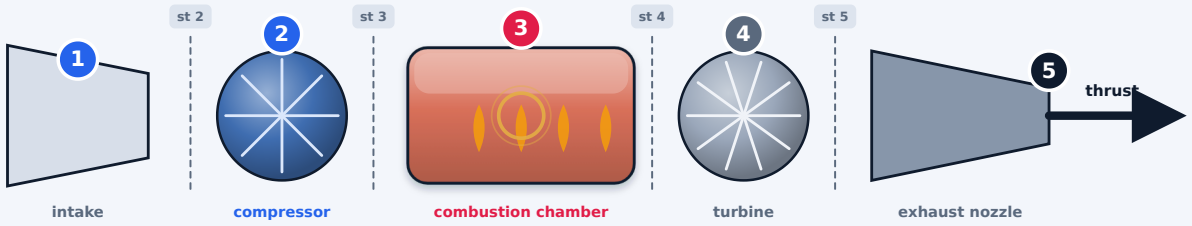
COMMON EXAM TRAPS

- Do not confuse **anti-ice** (continuous prevention) with **de-ice** (cyclic removal); boots are de-ice, hot leading edges are usually anti-ice.
- Do not swap **Otto** (piston, intermittent, constant-volume) with **Brayton** (turbine, continuous, constant-pressure).
- 400 Hz is the standard constant frequency, but not every modern aircraft uses fixed frequency; some use variable-frequency generation with converters.
- Cabin altitude and aircraft altitude differ: the cabin is always at a lower altitude (higher pressure) than the aircraft in cruise; the 8000 ft limit is a design limit, not a target.
- Accumulators store energy and dampen pulses; the **pump** is the source of sustained pressure.
- The propeller governor controls **blade angle to hold RPM**; the power lever sets power, the RPM lever sets the governor target.
- Weight-on-wheels logic gates many unrelated systems (spoiler arming, autobrake, reverse, radio-altimeter callouts).
- Do not conflate **fail-safe** (structural redundancy) with **damage tolerance** (inspection-driven crack management).

EXAM FIGURES FROM THE SKYSTUDY QUESTION BANK

Gas turbine layout: the gas-path & stations

021 · AIRFRAME & POWERPLANT



Turbofan: a fan and bypass duct wrap this core; station numbers mark gas-path boundaries.

1 Air intake

Slows and diffuses the incoming air, raising its static pressure before it reaches the compressor (station 2).

2 Compressor

Axial or centrifugal stages raise the air's pressure (and temperature) between stations 2 and 3.

3 Combustion chamber

Fuel burns continuously at roughly constant pressure, adding heat and greatly raising the gas temperature (station 3 to 4).

4 Turbine

Extracts enough energy from the hot gas (station 4 to 5) to drive the compressor on the same shaft.

5 Exhaust nozzle

Accelerates the remaining energy in the gas to a high velocity, producing thrust by reaction.

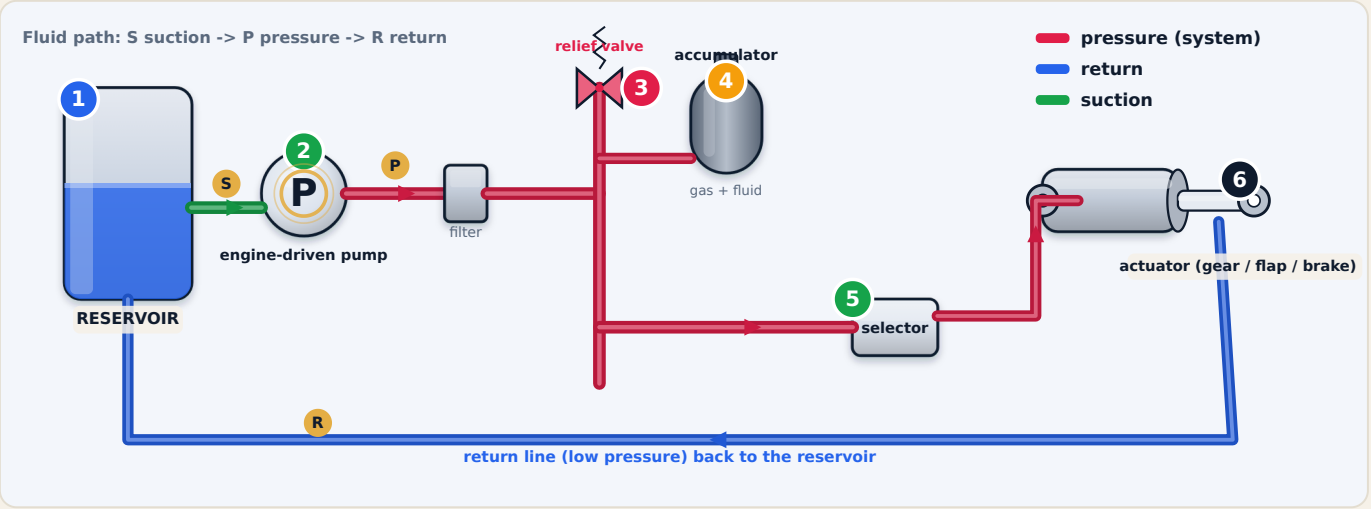
6 Brayton cycle & stations

The gas-path mirrors the Brayton cycle of compression, heat addition and expansion; stations 2 to 5 mark each stage boundary.

Intake, compressor, combustor, turbine, nozzle: the turbine only extracts enough energy to drive the compressor, the rest accelerates out as thrust. Drawn in code.

Hydraulic system schematic

021 · AIRFRAME & POWERPLANT



1 Reservoir
Stores fluid, allows for thermal expansion and actuator demand, and lets air separate out; often slightly pressurised to feed the pump.

2 Pump
Engine-driven (EDP) or electric (EMP) pumps raise the pressure; constant-delivery pumps need a regulator, but variable-delivery pumps self-regulate flow, so no unloading valve is needed.

3 Pressure relief valve
A safety valve that dumps fluid back to return if pressure exceeds a set maximum, protecting the system from over-pressure.

4 Accumulator
A gas-charged vessel that dampens pump pulsations, stores energy for peak demand and gives a short emergency supply.

5 Selector valves
Direct pressure to one side of an actuator and connect the other side to return, so the user moves the chosen way.

6 Actuators
Linear (jacks) or rotary (motors) convert pressure into the force that moves gear, flaps, brakes and flight controls.

Pump raises pressure from the reservoir; a relief valve caps it, an accumulator smooths and stores it, selectors feed the actuators, then fluid returns. Drawn in code.

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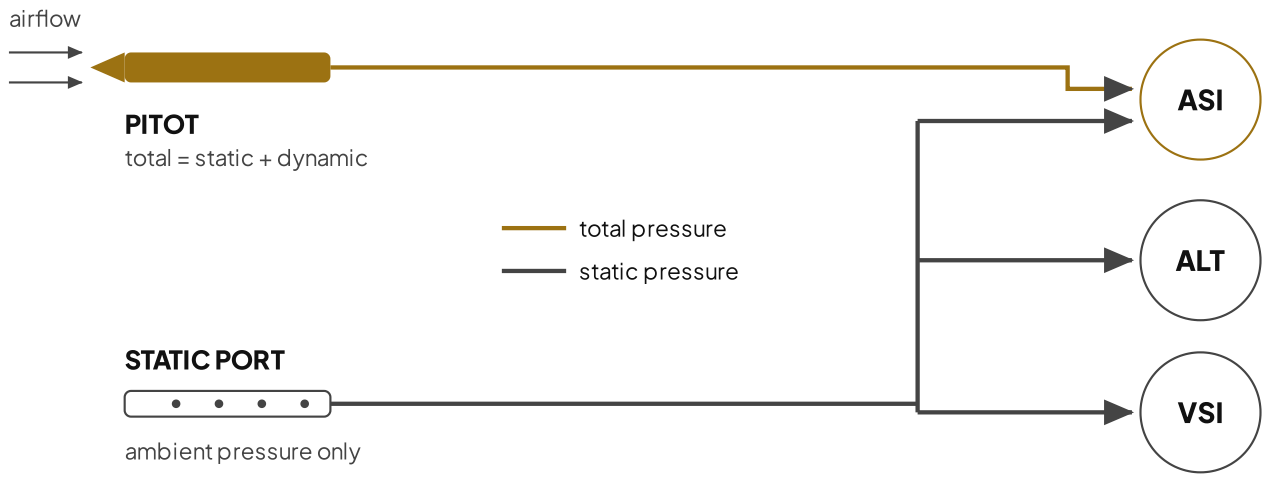
022 Instrumentation

Pitot-static, gyroscopes, magnetic compass, IRS/AHRS, EFIS, warning systems.

PITOT-STATIC SYSTEM AND ITS INSTRUMENTS



ASI needs both total and static; the **altimeter** and **VSI** use static only. Blocked static: altimeter freezes and VSI reads zero, ASI over-reads in a descent and under-reads in a climb. Blocked pitot (drain blocked): the ASI behaves like an altimeter.

MUST-KNOW DEFINITIONS AND CONCEPTS

- Pitot pressure = static (ambient) + dynamic (impact); the pitot tube senses total pressure, static ports sense ambient only.
- **IAS** is the raw reading; **CAS** = IAS corrected for instrument and position error.
- **EAS** = CAS corrected for compressibility (significant only at high speed/altitude).
- **TAS** = EAS corrected for density (temperature and altitude); TAS exceeds CAS increasingly with altitude.
- The altimeter is an aneroid capsule sensing static pressure, calibrated to ISA; QNH reads elevation AMSL, QFE reads zero on the field, QNE (1013.25 set) gives pressure altitude.
- The VSI senses rate of change of static pressure through a calibrated leak; an IVSI adds an accelerometer pump to remove lag.
- The Machmeter compares dynamic to static pressure for Mach number and needs no temperature input, unlike a TAS computation.
- **Rigidity in space**: a spinning mass resists change to its plane of rotation, proportional to spin speed and moment of inertia.
- **Precession**: a force applied to a spinning gyro is felt 90 degrees later in the direction of rotation.
- **Real (Earth) wander** is apparent drift from Earth rotating beneath a space-fixed gyro; **transport wander** is drift from the aircraft moving over the curved Earth.
- The attitude indicator uses an earth gyro with a pendulous erection system for the gravity vertical.
- The directional gyro/HSI uses a tied gyro that must be reset against the magnetic compass because it is not Earth-referenced.
- The turn indicator is a rate gyro precessing against a spring in proportion to turn rate; the slip ball beside it is a simple pendulum, not gyroscopic.
- **Magnetic dip** is the angle between the local field vector and the horizontal; it causes direct-reading compass turning and acceleration errors.
- **IRS** uses strapdown ring-laser or fibre-optic gyros (Sagnac effect, no spinning mass) plus accelerometers, deriving position by double integration.
- **AHRS** gives attitude and heading only (no navigation), using strapdown sensors plus a magnetometer.
- The radio altimeter measures true height above the terrain directly below (AGL), not AMSL.
- The **Air Data Computer** turns pitot, static and total-air-temperature inputs into altitude, CAS, TAS, Mach and VS for displays, autopilot, transponder and FMS.
- **EFIS** splits into the PFD (attitude, speed, altitude) and ND (navigation/map). The FMS adds a nav database and performance computer for lateral and vertical navigation (LNAV/VNAV).

KEY NUMBERS, LIMITS AND VALUES

- ISA sea level: **15 C** (288 K), **1013.25 hPa**, 29.92 inHg, 760 mmHg.
- ISA lapse rate **1.98 C per 1000 ft** (rounded to 2) to the tropopause.
- ISA tropopause: **36,090 ft** (11,000 m), **-56.5 C**, constant above.
- Speed of sound at ISA sea level about **661.5 kt** (340.3 m/s).
- **Rate 1** standard turn = **3 deg/sec** (360 in 2 minutes); Rate half = 1.5 deg/sec at high TAS VERIFY.
- **RVSM**: FL290 to FL410 inclusive, 1000 ft separation; 2000 ft above FL410.
- Magnetic dip: **0 deg at the magnetic equator, 90 deg at the magnetic poles**.
- Compass turning error is maximum turning through **North or South**, zero through East or West.
- Compass acceleration error is maximum on **East/West** headings, zero on North/South.
- Radio altimeter usable range roughly **0 to 2500 ft AGL** VERIFY.
- GPWS classic modes 1 to 6; EGPWS adds a forward-looking terrain database and windshear mode VERIFY.
- TCAS II issues Resolution Advisories in the final seconds, Traffic Advisories earlier; RAs are vertical only VERIFY.
- Stall warning (stick shaker) triggers at a set margin above the stalling angle of attack, not from IAS alone VERIFY.

FORMULAS AND RELATIONSHIPS

- `Mach number = TAS / Local Speed of Sound.`
- `LSS (kt) is about 38.95 x sqrt(absolute temperature in K); it depends on temperature only.`
- `Rule of thumb: TAS is about 2% above CAS per 1000 ft for a constant CAS (an ISA approximation).`
- `Standard-rate (Rate 1) bank angle is about TAS(kt)/10 + 7 degrees.`
- `Precession rate is proportional to applied torque and inversely proportional to angular momentum (spin x moment of inertia); more momentum means more rigidity.`
- `Pressure altitude is what the altimeter reads with 1013.25 set; true altitude equals indicated only in ISA conditions, else high to low, look out below.`

MNEMONICS AND MEMORY ITEMS

- **ONUS**: Overshoot North, Undershoot South, the compass turning error (Northern Hemisphere; reverses in the South).
- **ANDS**: Accelerate North, Decelerate South, the compass acceleration error (Northern Hemisphere; reverses in the South).
- **High to low, look out below**: flying into lower pressure or colder air, true altitude is below indicated.
- Turning error worst on **N/S**, acceleration error worst on **E/W**: complementary, not the same axis.
- **Precession is felt 90 degrees later** in the direction of spin: the key to every gyro-error question.
- **Rigidity** keeps a gyro pointing the same way; **precession** is the only thing that moves it.

COMMON EXAM TRAPS

- A blocked **static** freezes the altimeter and zeroes the VSI; the ASI then under-reads in a climb and over-reads in a descent.
- A blocked **pitot with the drain also blocked** makes the ASI act like an altimeter: it over-reads in a climb, under-reads in a descent.
- A blocked pitot with the **drain clear** lets the ASI fall toward zero.
- Compressibility error depends on speed **and** altitude (a dynamic-to-static pressure ratio), not speed alone.
- The Machmeter needs no temperature correction; do not apply the TAS temperature correction to it.
- Compass dip errors affect the **direct-reading compass only**; gyro instruments suffer real/transport wander and drift instead.
- Do not confuse VSI lag during rapid pitch changes with an actual fault.
- The radio altimeter reads AGL over the terrain below, so over rising or falling ground it will not track the pressure altimeter.
- TCAS/ACAS resolution advisories are **vertical only**; TCAS never gives turn guidance.
- Stall warning triggers from **angle of attack**, not IAS; an iced or mis-rigged AoA vane is the classic failure cause.

EXAM FIGURES FROM THE SKYSTUDY QUESTION BANK

The six-pack: standard flight instruments

Airspeed indicator

Dynamic pressure -> speed; pitot + static

Attitude indicator

Gyro -> pitch & bank; topples on power loss

Altimeter

Static pressure -> altitude; static line

Turn coordinator

Gyro -> turn rate & balance; electric

Heading indicator

Gyro -> heading; drifts, realign to compass

Vertical speed

Static change -> climb/descent; it lags

Standard "basic-T": attitude indicator top-centre; airspeed and altimeter flank it, heading indicator sits directly below. Diagrams drawn to scale in code.

Pitot-static blockages: what each instrument does

022 · AIR DATA

SCENARIO	AIRSPEED (ASI)	ALTIMETER	VERTICAL SPEED
OVER-READS · UNDER-READS · FROZEN · ZERO · normal			
Pitot blocked, drain OPEN	ZERO falls toward 0	normal unaffected	normal unaffected
Pitot+drain blocked, CLIMB	OVER-READS acts like an altimeter	normal unaffected	normal unaffected
Pitot+drain blocked, DESCENT	UNDER-READS acts like an altimeter	normal unaffected	normal unaffected
Static blocked, CLIMB	UNDER-READS trapped static too high	FROZEN stuck at block height	ZERO no static change
Static blocked, DESCENT	OVER-READS trapped static too low	FROZEN stuck at block height	ZERO no static change
Alternate static selected	OVER-READS cabin static lower	OVER-READS reads a bit high	normal brief blip

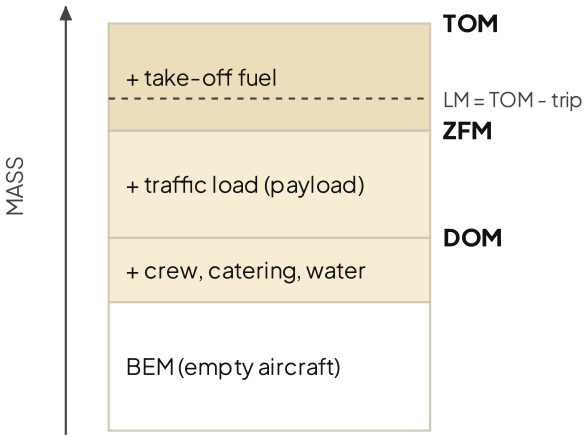
Pitot feeds the ASI only; static feeds all three. A trapped pitot makes the ASI mimic an altimeter; a blocked static freezes the altimeter and zeroes the VSI.

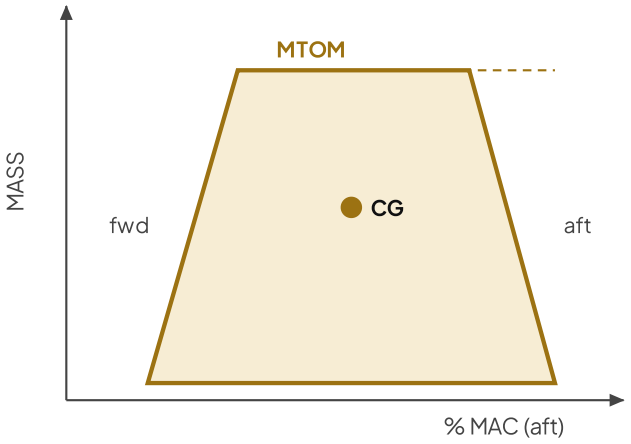
Two of the 369 code-drawn study figures inside the SkyStudy question bank. Try them with the free demo at skystudyatpl.com/demo.

031 Mass and Balance

Mass definitions, centre of gravity, MAC, load and trim, standard masses.

MASS BUILD-UP AND THE CG ENVELOPE





Build-up: BEM to DOM (add crew, catering) to ZFM (add payload) to TOM (add fuel); LM = TOM minus trip fuel. The **CG must stay inside the envelope** at every mass, and no mass may exceed MTOM, MLM or MZFM.

MUST-KNOW DEFINITIONS AND CONCEPTS

- **Basic Empty Mass (BEM)**: airframe, engines, fixed equipment, unusable fuel and fixed ballast; excludes crew, consumables and payload.
- **Dry Operating Mass (DOM/OEM)**: BEM plus crew, crew baggage, catering, potable water and removable operational equipment; excludes payload and usable fuel.
- **Zero Fuel Mass (ZFM)**: DOM plus traffic load; the aircraft with no usable fuel.
- **Take-off Mass (TOM)**: ZFM plus take-off fuel. **Landing Mass (LM)**: TOM minus trip fuel.
- **Traffic load (payload)**: passengers, baggage, cargo and mail; equals ZFM minus DOM.
- **Useful load**: traffic load plus usable fuel; about MTOM minus DOM, subject to the limiting mass.
- **MTOM, MLM, MZFM** are maximum structural/regulatory limits; none may be exceeded whatever the underload elsewhere.
- **Underload**: the margin between the actual mass and the most restrictive limiting mass for that flight.
- **Datum**: a reference point (can even be ahead of the nose) from which all arms are measured; chosen for convenience.
- **Arm**: distance from the datum to an item CG; **moment** = mass x arm (the turning effect about the datum).
- **Centre of Gravity (CG)**: the single point at which total weight is considered to act.
- **Mean Aerodynamic Chord (MAC)**: the reference chord against which CG position is expressed.
- **%MAC**: CG position as a percentage of MAC length, measured aft of the leading edge of MAC (LEMAC).
- **Index unit**: a scaled, dimensionless moment used on loadsheets to keep numbers small and positive.
- Forward CG effects: more longitudinal stability, higher stall speed, more nose-down pitch needing tailplane download (more trim drag), more elevator needed to rotate.
- Aft CG effects: less stability, lower stall speed, less trim drag and better range, but reduced stall/spin recovery margin and lighter control feel.
- Cargo floor loading is limited by a **running load** (kg per metre) and an **area load** (kg per square metre), separate from the compartment mass limit.

KEY NUMBERS, LIMITS AND VALUES

- Standard passenger mass, 20+ seats: male **88 kg**, female **70 kg**, child (2 to under 12) **35 kg**, including hand baggage VERIFY.
- Standard crew mass: flight crew **85 kg**, cabin crew **75 kg**, including crew hand baggage VERIFY.
- Standard checked baggage commonly taught: about **13 kg** short/medium-haul, **15 kg** intercontinental VERIFY.
- Fuel density varies. Training problems commonly use a nominal **0.8 kg/L**, but use the actual density from the docket or gauge when given (Jet A-1 is typically 0.775 to 0.840 kg/L) VERIFY.
- 1 US gallon is about 3.785 L; 1 Imperial gallon is about 4.546 L; 1 kg is about 2.2046 lb.
- MTOM, MLM, MZFM, the CG limits, LEMAC, MAC length and index constants are all aircraft-type specific; never assume a generic value.
- CG limits are often plotted on an envelope and can narrow at low or high mass.

FORMULAS AND RELATIONSHIPS

- Moment = Mass x Arm.
- Combined CG arm = Total moment / Total mass = sum(mass_i x arm_i) / sum(mass_i).
- %MAC = ((CG arm - LEMAC arm) / MAC length) x 100.
- Adding mass: New CG = (Old moment + added mass x its arm) / (Old mass + added mass).
- Removing mass: New CG = (Old moment - removed mass x its arm) / (Old mass - removed mass).
- Shifting mass: CG change = (mass shifted x distance shifted) / Total mass.
- Mass to shift for a required CG change = (Total mass x required CG change) / distance shifted.
- Index = (Mass x Arm / reduction constant) + reference constant (type-specific).
- ZFM = DOM + Traffic load; TOM = ZFM + Take-off fuel; LM = TOM - Trip fuel.
- Underload = limiting mass (MTOM/MLM/MZFM) - actual mass at that stage.

MNEMONICS AND MEMORY ITEMS

- Build-up order **Basic, Dry, Zero, Take-off, Land** (BEM, DOM, ZFM, TOM, LM): each step adds or removes one category.
- Treat every problem as a lever: **Moment = Mass x Arm**, like torque = force x distance.
- **CG = Total moment over Total mass**, never masses alone.
- Forward CG: more stable, higher stall speed, more trim drag. Aft CG: less stable, lower stall speed, less drag.
- **%MAC starts at LEMAC**: always measured aft of the leading edge of the MAC, not from the datum.
- The datum is a choice, not a landmark; the index is just moment, shrunk and shifted.

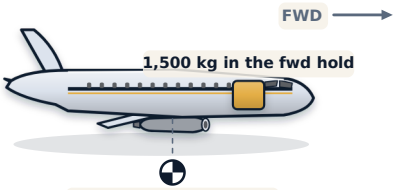
COMMON EXAM TRAPS

- Do not confuse **DOM** (no payload) with **ZFM** (no usable fuel).
- Do not add unusable fuel or fixed ballast again; they are already inside BEM.
- Check the **arm sign convention**: some datums make forward arms negative, others keep all arms positive.
- Use the **given** fuel density, not a fixed 0.8 kg/L, when a docket value is supplied.
- **%MAC and index units** are two different scaled representations of the same CG; they are not interchangeable without the type conversion data.
- Checking only TOM against MTOM can miss that **MLM or MZFM** is the limiting figure.
- Shifting cargo changes CG but not total mass, so ZFM/TOM/MLM checks are unaffected by a shift; only CG/%MAC needs rework.
- Do not double count crew baggage or catering already folded into DOM.
- Do not freely mix **standard and actual mass** methods within one passenger/baggage category on a flight.
- A concentrated load can breach a **floor load** limit while under the compartment mass limit.

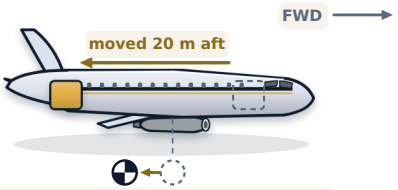
EXAM FIGURES FROM THE SKYSTUDY QUESTION BANK

Moving a mass: CG shift = (m × d) / M

1 **BEFORE the move**



2 **AFTER the move**



CG shift = (mass moved × distance moved) / total mass

= (1,500 kg × 20 m) / 60,000 kg = 0.5 m aft

1 Total mass unchanged

Moving a load between holds or cabin zones changes no total mass: only the moment distribution, and therefore the CG position, changes.

2 Direction of the shift

The CG always shifts in the same direction as the moved mass: 1,500 kg sent 20 m rearward drags the CG 0.5 m aft, from 17.5 m to 18.0 m.

3 The formula

CG shift = (mass moved × distance moved) / total mass: (1,500 × 20) / 60,000 = 0.5 m.

4 Light aircraft shift more

Total mass sits in the denominator, so the identical move on a lighter aircraft produces a larger CG shift; heavy aircraft are less sensitive.

CG shift = (mass moved × distance moved) / total mass, in the direction of the move; the total mass itself never changes.

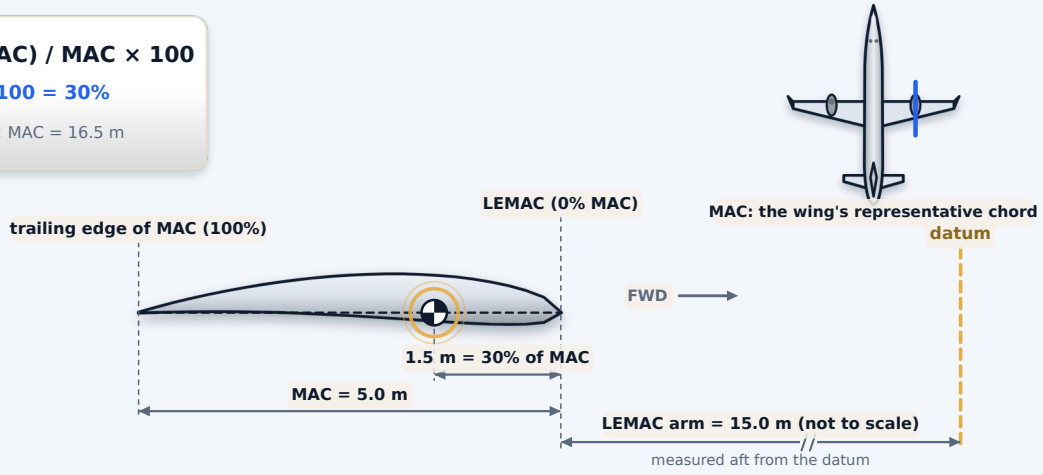
CG as % MAC: LEMAC, MAC, the formula

031 · MASS & BALANCE

% MAC = (CG − LEMAC) / MAC × 100

= (16.5 − 15.0) / 5.0 × 100 = 30%

reverse: CG = LEMAC + 0.30 × MAC = 16.5 m



1 The formula

% MAC = (CG arm − LEMAC arm) / MAC length × 100: the CG's distance past the MAC leading edge as a percentage of the MAC.

2 Two references needed

Converting needs two flight-manual values: the LEMAC arm from the datum and the MAC length; 0% sits at the MAC leading edge and 100% at its trailing edge.

3 Back to an arm

Reverse the formula with CG = LEMAC + (% MAC / 100) × MAC: 15.0 + 0.30 × 5.0 = 16.5 m aft of the datum.

4 Why % MAC at all

Quoting CG in % MAC references the wing that carries the lift, so limits stay comparable between aircraft whatever datum each manufacturer chose.

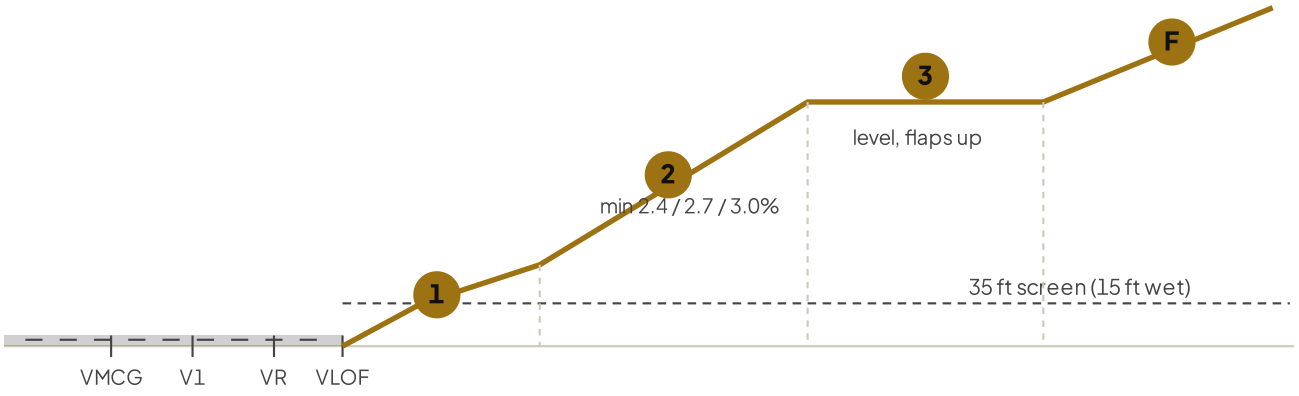
% MAC = (CG arm − LEMAC arm) / MAC × 100, measured from the MAC leading edge (0%) towards its trailing edge (100%).

Two of the 369 code-drawn study figures inside the SkyStudy question bank. Try them with the free demo at **skystudyatpl.com/demo**.

032 Performance

Performance classes, V-speeds, takeoff and landing, climb segments, WAT limits.

CLASS A TAKE-OFF CLIMB SEGMENTS (ONE ENGINE INOPERATIVE)



1 gear retracting, gradient positive. **2** steepest climb, gear up, to at least 400 ft (min 2.4% twin, 2.7% tri, 3.0% quad). **3** level acceleration, flaps retract. **F** en-route climb at MCT (min 1.2 / 1.5 / 1.7%). All one-engine-inoperative for Class A.

MUST-KNOW DEFINITIONS AND CONCEPTS

- **Class A**: multi-engine turbine, MTOM over 5700 kg or over 9 seats, or any turbojet; full engine-failure accountability at every stage.
- **Class B**: propeller aeroplanes, 9 seats or fewer and MTOM 5700 kg or less; simplified rules, no guaranteed OEI climb below the screen height.
- **Class C**: larger aeroplanes not meeting A or B (mostly older large piston types).
- **V1** (decision speed): stop by V1 to remain within ASDA; at or above V1, continue and reach V2 by the screen height after a recognised failure.
- **VR** (rotation): not less than V1, not less than 1.05 x VMCA, set so V2 is reached by the screen height.
- **V2** (takeoff safety speed): target by the screen height with one engine inoperative, giving the certified climb margin above stall and VMCA.
- **VMCG**: minimum ground speed to keep directional control after critical-engine failure using rudder alone.
- **VMCA**: minimum airborne speed to keep directional control with the critical engine out and a limited bank into the live engine.
- **VMU** minimum unstick, **VEF** assumed engine-failure speed, **VLOF** lift-off speed, **VMBE** max brake energy speed.
- **VS/VS0/VS1/VSR**: stall speeds and the reference stall speed used as the basis for V-speed margins.
- **Balanced field**: V1 chosen so the OEI accelerate-go distance equals the accelerate-stop distance, minimising required runway.
- **TORA/TODA/ASDA/LDA**: the four declared distances. **Clearway** extends TODA only; **stopway** extends ASDA only.
- Class A takeoff segments: 1st (gear retracting, one engine inoperative), 2nd (gear up, steepest, OEI), 3rd (level acceleration, flaps up), final (climb to safe en-route altitude, MCT, OEI).
- **Gross** flight path is demonstrated performance; **net** is gross reduced by a certification decrement and is what obstacle clearance is checked against.
- **WAT limit** (Weight, Altitude, Temperature): the maximum mass at which the required climb gradient is still met.
- **Drift-down**: the planned descent schedule flown after an engine failure in cruise when altitude cannot be held, checked against the net flight path.
- **PNR** is the last point a return is possible with required reserves; **ETP/PET** is where time to continue equals time to turn back.

KEY NUMBERS, LIMITS AND VALUES

- Takeoff screen height **35 ft dry**; a reduced **15 ft** is allowed on a wet runway under certain provisions VERIFY.
- VR not less than **1.05 x VMCA**; V2 not less than about **1.13 x VSR** for most turbojets VERIFY.
- VMCG lateral deviation limit about **30 ft** from centreline; VMCA demonstration bank angle limited to about **5 degrees** into the live engine VERIFY.
- **2nd segment** minimum climb gradient about **2.4%** twin, **2.7%** three-engine, **3.0%** four-engine VERIFY.
- **Final segment** minimum about **1.2%** twin, **1.5%** three-engine, **1.7%** four-engine VERIFY.
- **Approach climb** (OEI, go-around) about **2.1%** twin, **2.4%** three-engine, **2.7%** four-engine; **landing climb** (all engines) about **3.2%** VERIFY.
- 1st segment gradient must be **positive**; 3rd segment is a level acceleration with no gradient requirement, commonly around 400 ft AGL VERIFY.
- Dispatch landing factor, turbojet: about **x1.67 dry**, **x1.92 wet**. Turboprop: about **x1.43 dry**, **x1.64 wet** VERIFY.
- Landing distance is measured from a **50 ft** screen over the threshold to a full stop (distinct from the takeoff screen).
- ASDA = TORA + stopway; TODA = TORA + clearway.
- En-route OEI obstacle corridor commonly taught as about **5 NM** either side of track, with at least **1000 ft** net vertical clearance (more in mountainous areas) VERIFY.
- Wind rule of thumb: about **50% credit** for headwind, **150% penalty** for tailwind.

FORMULAS AND RELATIONSHIPS

- Climb gradient (%) is about (Rate of Climb / TAS) x 100, both in the same units (1 kt is about 101.3 ft/min).
- Specific air range is about TAS / fuel flow (distance per unit fuel).
- ETP distance from departure = (total distance x GS toward the point) / (GS out + GS back).
- As chosen V1 increases, accelerate-stop distance grows while accelerate-go shrinks; balanced V1 is where they cross.
- Required takeoff distance (Class A) is the greater of the OEI distance to the screen or a factored all-engine distance.
- V-speeds and stall speed rise with the **square root of weight**, so higher mass raises V1/VR/V2 and lengthens all distances.
- For fixed altitude and temperature, the WAT-limited mass is the mass at which the required gradient is exactly met.

MNEMONICS AND MEMORY ITEMS

- Ground-run order: **VMCG, V1, VR, VLOF, V2** = control, decide, rotate, lift, safety.
- Segment shape: **Up, Steep-Up, Level-Out, Up-Again** (1st climbs, 2nd steepest, 3rd level, final climbs).
- Gradient: **rate over speed, times a hundred**.
- Things that hurt performance, **HATS**: High density altitude, Aft/heavy mass, Tailwind, Slope (uphill takeoff, downhill landing).
- **Net** is what you may plan on, **gross** is what the aeroplane actually did; net is the conservative figure.
- **Clearway helps you go (TODA), stopway helps you stop (ASDA).**
- **Half the headwind helps, one and a half times the tailwind hurts.**

COMMON EXAM TRAPS

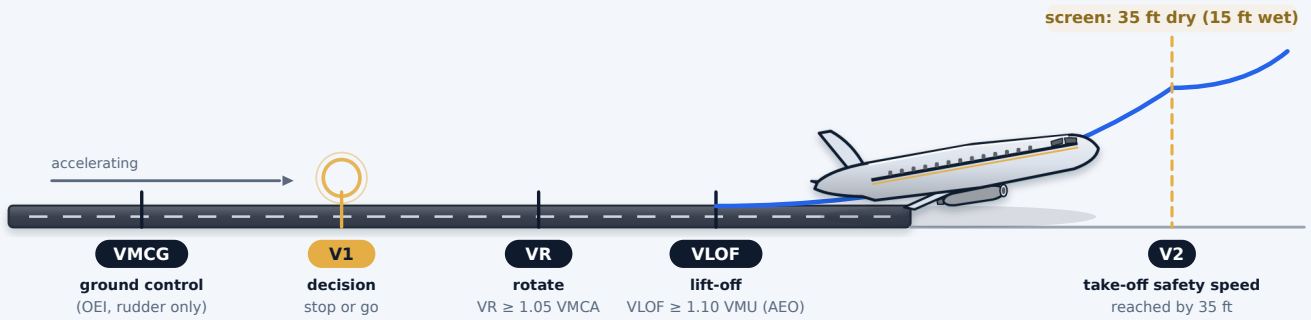
- Do not mix **V1** (decision, tied to distance) with **VR** (rotation, tied to reaching V2); V1 can never exceed VR.
- VMCG uses **rudder alone**, not nosewheel steering, which is why it floors V1.
- Obstacle clearance and WAT questions use the **net** flight path, never the gross.
- **Clearway** cannot be used for stopping (ASDA); **stopway** cannot be used for the continued takeoff (TODA).
- A factored **all-engine** takeoff distance can be the limiting case, not just the OEI cases.
- Do not apply the landing dispatch factors to the takeoff phase; they are for landing distance planning.
- Do not confuse the **35 ft** (15 ft wet) takeoff screen with the **50 ft** landing screen.
- Downhill slope shortens takeoff but hurts landing; uphill slope lengthens takeoff but helps landing braking.
- Drift-down is a defined procedure with its own speed schedule and net-flight-path obstacle check, not just an engine-out descent.
- Class B does not guarantee the same OEI climb-segment structure as Class A.
- VMCA is defined with a limited bank (about 5 degrees) into the live engine; wings-level gives an artificially high value.

Take-off V-speeds: the sequence

032 · PERFORMANCE

the order that must always hold

VMCG ≤ V1 ≤ VR < VLOF, then V2 by 35 ft



Failure recognised before V1: reject (RTO) and stop on what is left. At or after V1: continue, the speed set guarantees the screen.

1 V1, the decision speed

V1 is the decision speed: engine failure recognised at or above V1 means GO, and V1 can never sit below VMCG nor above VR or the brake-energy limit VMBE.

2 VR, rotation

VR is where the nose is raised; it must be at least 1.05 VMCA and at least V1, and high enough that V2 is reached at or before 35 ft with an engine out.

3 VLOF and VMU

VLOF is where the main wheels actually leave the ground: at least 1.10 VMU with all engines running, or 1.05 VMU with one engine inoperative (VMU is the minimum demonstrated unstick speed).

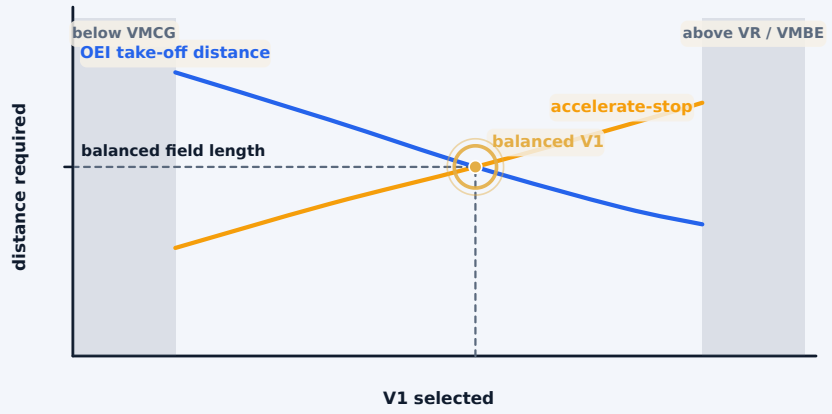
4 V2, the safety speed

V2 must be at least 1.13 VSR for two- and three-engine aeroplanes (1.08 VSR with four engines) and is the speed flown from the 35 ft screen through the second segment.

The take-off speed order always holds: VMCG ≤ V1 ≤ VR < VLOF, and V2 is reached by the 35 ft screen.

Balanced field: the V1 trade

032 · PERFORMANCE



the V1 trade

raise V1: go shrinks, stop grows

lower V1: go grows, stop shrinks

V1 window:
VMCG ≤ V1 ≤ VR and V1 ≤ VMBE

On a longer runway both distances fit over a spread of speeds, so V1 becomes a range instead of a single value.

1 Raise V1

A higher V1 shortens the engine-out take-off distance (the failure is recognised at a higher speed, less is left to accelerate) but lengthens the accelerate-stop distance: more kinetic energy to destroy.

2 The balance

The field is balanced when the take-off distance required equals the accelerate-stop distance required: one V1 makes the go and the stop need exactly the same field length.

3 Balanced field length

The balanced field length is the shortest field that covers both decisions, which is why it is used for quick runway-adequacy checks.

4 Set V1 wrong

If the engine fails at a V1 set below the balanced value and the take-off is continued, the go distance grows; a V1 set too high risks the stop running off the end.

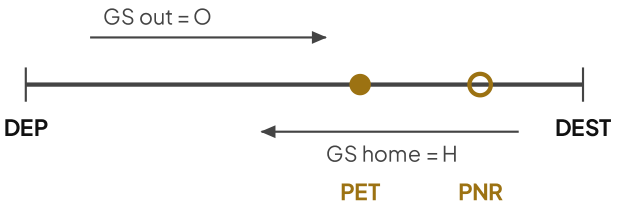
One V1 balances the field: the engine-out go distance falls and the accelerate-stop distance rises until they cross.

Two of the 369 code-drawn study figures inside the SkyStudy question bank. Try them with the free demo at skystudyatpl.com/demo.

033 Flight Planning and Monitoring

Fuel policy, PET and PNR, ICAO flight plan, cruise techniques, altimetry.

PET AND PNR, AND THE FUEL BUILD-UP

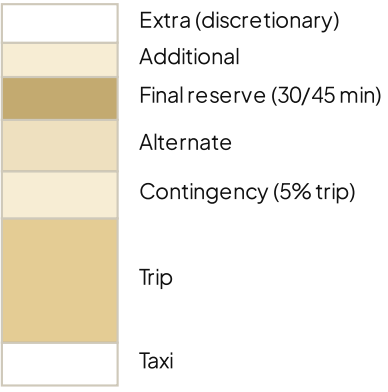


PET distance = D x H / (O + H)

PNR time = E x H / (O + H)

PET: equal-time point (geometry). PNR: last point a safe return fits the endurance E.

Block (ramp) fuel



PET depends on geometry only; a headwind out moves it toward the destination. **PNR** depends on endurance; any wind reduces its range. Fuel order upward: Taxi, Trip, Contingency, Alternate, Final reserve, Additional, Extra.

MUST-KNOW DEFINITIONS AND CONCEPTS

- **Trip fuel**: brake release at departure to touchdown at destination (takeoff, climb, cruise, descent, approach, landing).
- **Taxi fuel**: fuel used before takeoff, including APU and expected delay.
- **Contingency fuel**: covers deviations from plan; normally the higher of a percentage of trip fuel or a time-based allowance VERIFY.
- **Alternate fuel**: from the missed approach at destination to landing at the destination alternate, including one approach and landing.
- **Final reserve**: a fixed holding time at 1500 ft above the alternate (or destination if none), at estimated landing mass.
- **Additional fuel**: for engine or pressurisation failure at the critical point, or flight to an isolated aerodrome with no usable alternate.
- **Extra/discretionary fuel**: carried at the commander's discretion above the required minimum.
- **Block (ramp) fuel**: taxi + trip + contingency + alternate + final reserve + additional + extra.
- **Isolated aerodrome**: no suitable alternate in range, needing additional fuel instead of alternate fuel.
- **Point of Equal Time (PET)** / Critical Point: the point from which time to continue equals time to return.
- **Point of No Return (PNR)**: the furthest point from which a safe return to departure is still possible with the endurance available.
- **Redispatch/reclearance**: dispatch to an intermediate point with a new plan filed for continuation once airborne, to reduce the required fuel load.
- **ICAO flight plan (FPL)**: the standardised ATC/ATFM form; distinct from the operational (company) flight plan used for fuel and performance.
- **Network Manager (Eurocontrol)**: manages European flow, issues ATFM slots (CTOT); the **RAD** publishes permitted and prohibited route segments.
- **Conditional Route (CDR)**: usable only under stated conditions (CDR1 always plannable, CDR2 per AUP/NOTAM, CDR3 tactical only).
- **LRC** gives about 99% of maximum range for a useful speed gain; **max range** gives the greatest still-air distance per fuel; **max endurance** gives minimum fuel flow.
- **Transition altitude/level/layer**: at or below the TA use altitude on QNH; above the TL use flight levels on 1013.25; do not level in the layer between.

KEY NUMBERS, LIMITS AND VALUES

- Contingency: the higher of **5% of trip fuel** or a time-based holding allowance VERIFY.
- Final reserve: **30 minutes** for turbine (jet/turboprop), **45 minutes** for piston, holding at 1500 ft in standard conditions VERIFY.
- Standard pressure setting (QNE) for flight levels: **1013.25 hPa** (29.92 inHg).
- **MINIMUM FUEL** call: committed to an aerodrome where any extra delay would land below final reserve; it is not a distress call.
- **MAYDAY FUEL** call: predicted usable fuel on landing at the nearest suitable aerodrome will be below final reserve; this is distress.
- FPL wake categories (Item 9): **L** Light, **M** Medium, **H** Heavy, **J** Super.
- FPL flight rules (Item 8): I (IFR), V (VFR), Y (IFR then VFR), Z (VFR then IFR).
- FPL type of flight (Item 8): S scheduled, N non-scheduled, G general aviation, M military, X other.
- Semicircular levels: odd for magnetic track roughly 000 to 179, even for 180 to 359 VERIFY .

FORMULAS AND RELATIONSHIPS

- `PET distance from departure = D x H / (O + H), where D = total distance, O = groundspeed out, H = groundspeed home.`
- `PNR time from departure = E x H / (O + H), where E = safe endurance as time, O = groundspeed out, H = groundspeed home.`
- `Time to PET = PET distance / O; PNR distance = PNR time x O.`
- `With no wind (O = H), PET is at the mid-point D/2 and PNR is at maximum range for the endurance.`
- `A headwind out / tailwind home moves PET toward the destination; any wind (versus still air) moves PNR closer to departure, reducing range.`
- `Specific air range (SAR) = distance per unit fuel; LRC and max-range speeds sit at or near the peak of the SAR curve.`

MNEMONICS AND MEMORY ITEMS

- Fuel build-up **Taxi, Trip, Contingency, Alternate, Final reserve, Additional, Extra**.
- **PET splits the trip in time; PNR is the last chance to turn back.**
- Keep the letters straight: **O** is Out, **H** is Home; swap them and the answer flips.
- **Minimum fuel is a heads-up; Mayday fuel is an emergency.**
- **LRC = a little less range, a lot more speed** (about 1% range traded).
- Going up: QNH to QNE at the transition altitude. Coming down: QNE to QNH at the transition level.

COMMON EXAM TRAPS

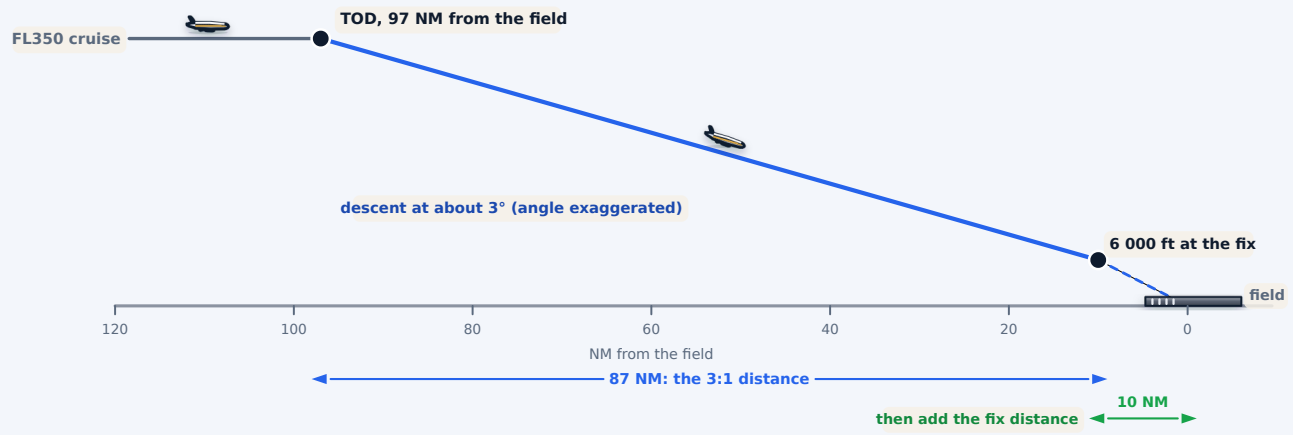
- PET is a **time-equality** point (independent of fuel); PNR is **endurance-limited**. Do not conflate them.
- Do not swap **O** and **H**; confirm which groundspeed is outbound and which is the return.
- PET is at the mid-point **only** in zero wind; wind shifts it toward the less favourable leg.
- Final reserve is the minimum fuel **on landing**, not a planning allowance to dip into en route.
- Do not mix the **30 min** (turbine) and **45 min** (piston) reserves; a turboprop uses the turbine figure VERIFY.
- Contingency is normally the **higher** of the two methods, not always 5%.
- Do not confuse **QNH** (altitude AMSL), **QFE** (height above aerodrome) and **QNE** (flight levels on 1013.25).
- FPL Item 10a is COM/NAV/approach equipment; Item 10b is surveillance equipment (transponder, ADS: Automatic Dependent Surveillance); do not merge them.
- Restricted route segments in the RAD will get the plan rejected or delayed by ATFM.
- Redispatch reduces the **required minimum**, it does not exempt the flight from carrying adequate fuel for the routing actually flown.
- Max endurance speed is lower than max range speed; a MAYDAY FUEL situation needs the MAYDAY call, not MINIMUM FUEL.

EXAM FIGURES FROM THE SKYSTUDY QUESTION BANK

Top of descent: the 3:1 rule

100 · KSA

FL350, reach 6 000 ft at a fix 10 NM from the field



FL350 down to 6 000 ft at the fix

altitude to lose = 35 000 − 6 000 = 29 000 ft

in thousands = 29

29 × 3 = 87 NM, then 87 + 10

× 3

3 NM per 1 000 ft

TOP OF DESCENT

97 NM

The three printed errors

- Multiplying the cruise level instead of the altitude to lose: FL320 down to FL100 needs 22 × 3 = 66 NM, but 32 × 3 prints 96 NM
- Dropping the fix distance leaves the raw 87 NM, which arrives at the fix still high and still descending
- Adding a buffer the question did not ask for: when the stem says the 3:1 rule only, the raw answer is the printed one

red: the bank's own distractor rationales

Three miles for every thousand feet, and the fix distance is added to that answer, never folded into it.

1 Three miles per thousand feet

The 3:1 rule gives three nautical miles of track for every thousand feet the aircraft has to lose. Twenty nine thousand feet therefore needs eighty seven nautical miles.

2 The altitude to lose, not the level

Subtract the target altitude from the cruise level first. From FL350 to six thousand feet the figure is twenty nine thousand feet, not the thirty five thousand feet of the cruise level itself.

3 Then add the fix distance

A constraint at a fix ten nautical miles from the field means the descent must finish there, so the top of descent lies eighty seven plus ten, ninety seven nautical miles from the field.

4 Awkward levels still work

FL283 down to three thousand feet is twenty five thousand three hundred feet, so 25.3 times three is 75.9 nautical miles, and the closest printed answer is seventy six.

5 The named errors

Multiplying the cruise level rather than the altitude to lose, and forgetting the fix distance, are both printed options. So is a buffer that the rule-only question never asked for.

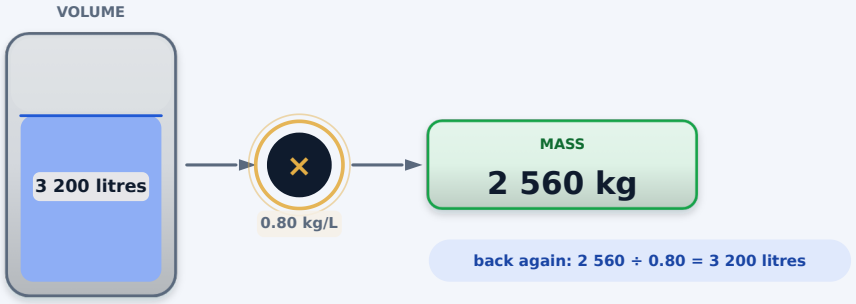
6 Comparing, not just computing

Asked whether a crossing restriction can be met, work the distance the descent needs and compare it with the track available. Twenty two thousand feet needs sixty six miles, so eighty miles will do.

The 3:1 rule multiplies the altitude to lose in thousands of feet by three, and any fix distance is added to that answer.

Fuel volume to mass: litres and kilograms

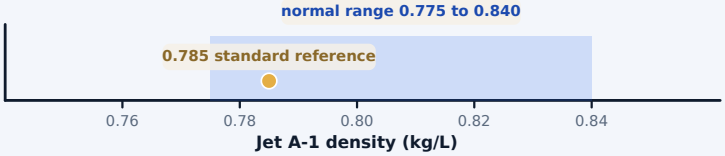
100 · KSA



The inversions

- Volume × density gives mass. Mass ÷ density gives volume. Swapping them is the error the bank names most
- Leaving litres unchanged as kilograms assumes a density of 1.00 kg/L, which is water
- Use the density printed in the question, never the standard value

red: the named errors



Cold fuel is denser, so a given mass fills fewer litres.

The units the bank quotes

1 US gallon	**3.785 litres**
1 Imperial gallon	**4.546 litres**
1 lb	**0.4536 kg**
Jet-A	**6.7 lb per US gallon**

1 Mass from volume

Mass in kilograms is the volume in litres multiplied by the density in kilograms per litre. Three thousand two hundred litres at 0.80 kg/L is 2 560 kg.

2 Volume from mass

Volume in litres is the mass in kilograms divided by the density. Two thousand one hundred kilograms at 0.84 kg/L occupies 2 500 litres.

3 Specific gravity is the density

The bank writes specific gravity and density interchangeably, so a specific gravity of 0.80 is a density of 0.80 kg/L and multiplies litres straight into kilograms.

4 A density of 1.00 is water

Leaving a litre figure unchanged treats fuel as water. Three thousand two hundred litres would become 3 200 kg instead of 2 560 kg, and no aviation fuel is that dense.

5 Use the density you are given

Jet A-1 runs about 0.775 to 0.840 kg/L because cold fuel is denser. 0.785 kg/L is the standard reference, but the figure printed in the question always wins.

6 Mind the gallon

A US gallon is 3.785 litres and an Imperial gallon is 4.546. Convert the gallons to litres first, then apply the density: 2 500 US gallons at 0.80 kg/L is 7 570 kg.

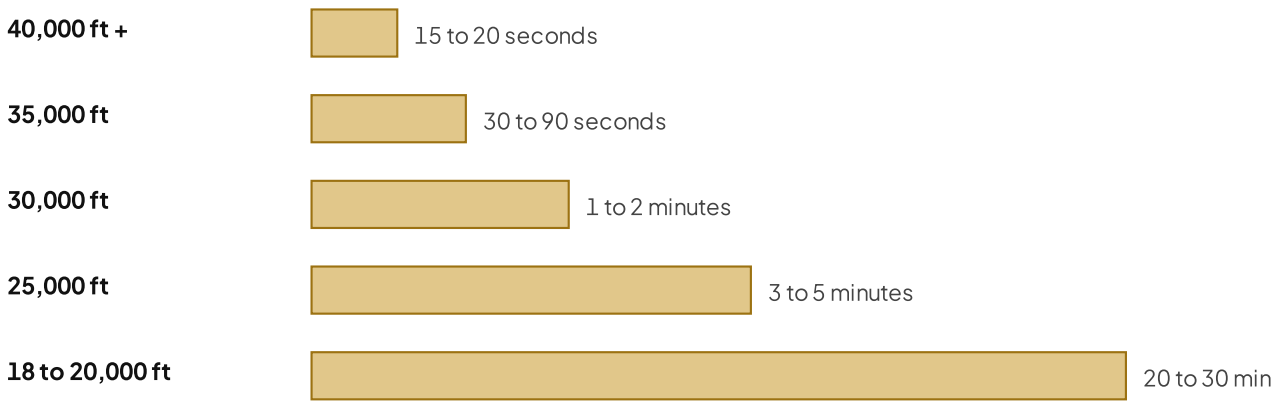
Multiply litres by density for kilograms and divide kilograms by density for litres: a litre figure must never walk into a mass box unchanged.

These two come from SkyStudy's KSA (100) mental-maths set; they are the exact methods 033 planning questions test. Two of the 369 code-drawn study figures inside the SkyStudy question bank. Try them with the free demo at **skystudyatpl.com/demo**.

040 Human Performance and Limitations

Physiology, hypoxia, vision, illusions, sleep and fatigue, CRM and error.

TIME OF USEFUL CONSCIOUSNESS VERSUS ALTITUDE



Approximate, seated at rest. A rapid or explosive decompression roughly halves these times. TUC is the time to loss of useful action, not the time to unconsciousness. Values vary by individual, so confirm against current teaching.

MUST-KNOW DEFINITIONS AND CONCEPTS

- Atmosphere by volume: about **21% oxygen, 78% nitrogen**, roughly 1% other gases.
- Partial pressure of a gas = total pressure x fractional concentration (Dalton's Law); alveolar oxygen partial pressure falls with altitude even though the 21% fraction is constant.
- **Hypoxic hypoxia**: too little oxygen reaching the blood from reduced ambient partial pressure (the classic altitude hypoxia).
- **Hypemic (anaemic) hypoxia**: reduced oxygen-carrying capacity (anaemia, blood loss, or carbon monoxide binding to haemoglobin).
- **Stagnant hypoxia**: enough oxygen in the blood but poor circulation (cold, positive G, shock, poor posture).
- **Histotoxic hypoxia**: oxygen delivered but tissues cannot use it (alcohol, some drugs, cyanide).
- **Hyperventilation**: over-breathing washes out CO2 (hypocapnia), mimicking hypoxia but with normal or high oxygen.
- Stages of hypoxia: indifferent, compensatory, disturbance, critical.
- **Time of Useful Consciousness (TUC)**: time from onset of hypoxia to the loss of effective corrective action.
- Pressurised cabins are typically held around **6,000 to 8,000 ft** equivalent, not sea level.
- Explosive/rapid decompression is more dangerous than gradual because TUC is shortened and lung barotrauma risk rises.
- G-force sequence with increasing positive G: **grey-out** (peripheral vision loss), **blackout** (total vision loss, still conscious), then **G-LOC** (loss of consciousness). Negative G gives redout.
- The retina has **rods** (peripheral, low light, motion, no colour) and **cones** (central, colour, detail, need light).
- Dark adaptation of rods takes around **30 minutes** and is lost quickly in bright light; use off-centre viewing at night.
- **Empty-field myopia**: in a featureless field the eyes default-focus short (about arm's length), reducing distant traffic detection.
- The vestibular system (semicircular canals plus otoliths) senses angular acceleration (canals) and linear acceleration/gravity (otoliths), not attitude directly.
- **The leans**: a slow roll below the canals' detection threshold is not sensed, so the pilot feels wings-level when banked.
- **Coriolis illusion**: a head movement during a sustained turn stimulates several canals at once, causing strong disorientation.
- **Somatogravic illusion**: forward acceleration (e.g. takeoff) feels like a nose-up pitch, tempting a nose-down input.
- **Somatogyral illusion**: a sustained turn feels to slow or stop, so rolling level feels like a turn the other way (graveyard spiral risk).
- **Black hole approach**: over dark, featureless terrain with only runway lights, pilots feel too high and fly dangerously low.
- Middle ear and sinus barotrauma is worse on **descent**. Decompression sickness (DCS) is a separate problem: nitrogen leaving solution as pressure falls.
- **Circadian rhythm** is the roughly 24-hour body clock; the **WOCL** (window of circadian low) is the least-alert period, roughly 02:00 to 06:00 body time.
- **Yerkes-Dodson law**: performance rises with arousal to an optimum, then falls (inverted-U).
- Memory has three stores: sensory (very brief), short-term/working (limited), and long-term (large, durable).

- The **SHELL model** describes the interfaces around the central Liveware (Software, Hardware, Environment, other Liveware).
- **Reason's Swiss cheese** model: accidents happen when weaknesses in successive defences line up.
- Error types: **slips** (attention, right intent wrong action), **lapses** (memory), **mistakes** (wrong plan), **violations** (deliberate rule deviation).
- **CRM** is the effective use of all resources (people, procedures, equipment) through communication, teamwork and workload management, not stick-and-rudder skill.

KEY NUMBERS, LIMITS AND VALUES

- Sea level composition about 21% oxygen, 78% nitrogen; sea level pressure 1013.25 hPa VERIFY.
- Typical maximum cabin altitude around **8,000 ft** VERIFY.
- TUC (seated, at rest, approximate, verify): **18,000 to 20,000 ft** about 20 to 30 min; **25,000 ft** about 3 to 5 min; **30,000 ft** about 1 to 2 min; **35,000 ft** about 30 to 90 s; **40,000 ft+** about 15 to 20 s.
- Sudden/explosive decompression roughly **halves** TUC versus gradual VERIFY.
- Dark adaptation to near-maximum rod sensitivity takes up to about **30 minutes** VERIFY.
- WOCL roughly **02:00 to 06:00** body-clock time; a sleep cycle is about **90 minutes** VERIFY.
- Adults need about **7 to 8 hours** sleep per 24 hours VERIFY.
- Working memory capacity is classically **7 plus or minus 2** chunks, held for about 15 to 30 seconds without rehearsal VERIFY.
- Flying after diving: commonly at least **12 hours** after a single no-decompression dive, at least **24 hours** after repetitive or decompression dives VERIFY.
- Alcohol is metabolised at roughly **one unit per hour**; a commonly cited minimum is 8 hours bottle to throttle VERIFY.
- Unprotected positive-G tolerance before G-LOC is roughly **4 to 6 G** depending on onset rate and the individual VERIFY.

MNEMONICS AND MEMORY ITEMS

- Hypoxia types **HHSH**: Hypoxic, Hypemic, Stagnant, Histotoxic (ambient, blood, circulation, cellular).
- **Hypoxia hides, hyperventilation hurries**: hypoxia creeps in unnoticed, hyperventilation shows a fast breathing rate.
- **SHELL**: Liveware in the centre, surrounded by Software, Hardware, Environment and other Liveware.
- **Swiss cheese**: the holes must line up; single failures rarely cause the accident.
- **Grey before Black**: grey-out precedes blackout before full G-LOC.
- **Gravic** tricks you on acceleration (false pitch); **gyral** tricks you on turn rate.
- Yerkes-Dodson inverted-U: too little arousal is slow, too much is sloppy, the middle is best.
- DCS signs: **bends** (joints), **chokes** (breathing), **creeps** (skin), **staggers** (neurological).

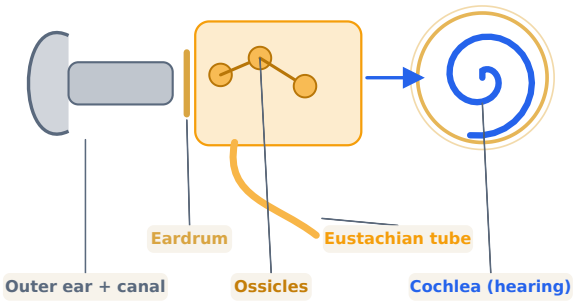
COMMON EXAM TRAPS

- Do not confuse **hypoxia** (low oxygen) with **hyperventilation** (low CO_2); symptoms overlap heavily.
- **Blackout** keeps consciousness; **G-LOC** is loss of consciousness. They are different events.
- The 21% oxygen fraction does **not** change with altitude; the **partial pressure** falls.
- TUC is shorter with **rapid** decompression; altitude alone does not set it.
- **Rods** handle night and peripheral vision; **cones** handle central, colour, daylight vision.
- Use **off-centre** viewing at night; looking straight at a target uses cone-poor central vision.
- The **leans** comes from a slow undetected roll; distinguish it from the **Coriolis** head-movement illusion.
- **Somatogravic** is a false pitch-up on acceleration; **somatogyral** is a misperceived turn rate.
- Eustachian tube blockage hurts more on **descent** than climb.
- A **slip** is an attention failure with correct intent; a **lapse** is a memory failure; do not swap them.
- A **mistake** follows a wrong plan; a **violation** is a deliberate rule deviation.
- **Chronic fatigue** is not fixed by one night's sleep the way acute fatigue is.
- The **WOCL** follows body-clock (home-base) time, not local night, which matters for jet-lagged crews.
- CRM is resource management and teamwork, not technical proficiency.

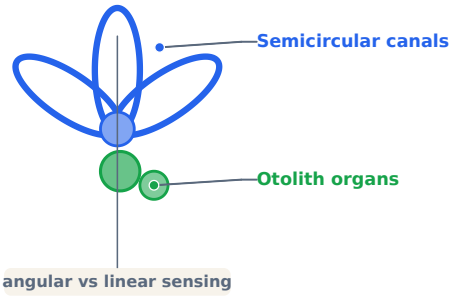
The ear: hearing and the vestibular balance organs

040 · PHYSIOLOGY

1 Hearing: the conduction path



2 Balance: the vestibular organs



1 Hearing

Sound moves the eardrum, the three ossicles amplify it and the fluid-filled cochlea turns it into nerve signals. Loud noise and age cause permanent high-tone loss.

2 Balance organs

The three semicircular canals sense angular (rotational) acceleration; the otolith organs sense linear acceleration and the pull of gravity.

3 Equalising pressure

The Eustachian tube vents the middle ear. It opens easily on climb but must be actively cleared on descent, which a head cold makes painful (otic barotrauma).

4 False sensations

The balance organs are easily fooled without outside vision, so sub-threshold rolls and head turns cause disorientation. Trust the instruments, not the seat.

The cochlea hears; the semicircular canals sense angular and the otoliths linear acceleration; the Eustachian tube equalises the middle ear, hardest on descent. Drawn in code.

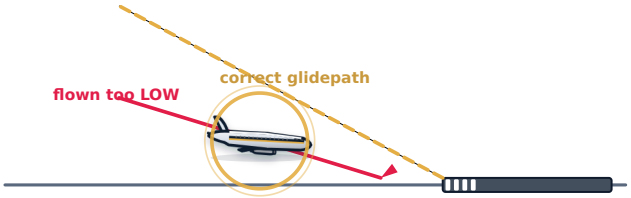
Visual illusions on the approach

040 · ILLUSIONS

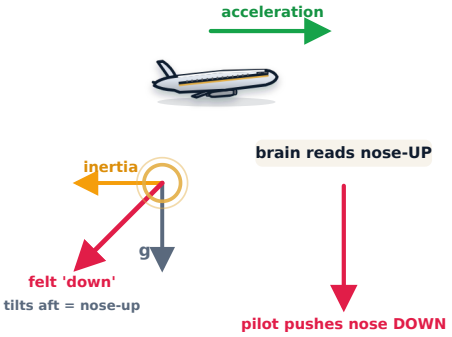
1 Glidepath illusions: feel HIGH, fly LOW

All make you fly too LOW:

- narrow runway
- up-slope
- black hole (night)
- haze



2 Somatogravic: feel PITCH-UP, push DOWN



1 Runway width & slope

A narrow OR up-sloping runway looks too high, so the pilot flies a low approach (undershoot). A wide OR down-sloping runway looks too low, so the pilot flies high (overrun). Cross-check the PAPI.

2 Black-hole approach

At night over dark ground or water with only runway lights, the eye builds a slope lower than the real one, so the pilot flies dangerously low. Use PAPI, a stabilised instrument approach and the radio altimeter.

3 Somatogravic illusion

Forward acceleration (go-around) feels like pitch-up, so the pilot pushes down into the ground; deceleration feels like pitch-down and invites a pull-up and stall. Fly the attitude indicator.

4 Night visual traps

Autokinesis: a fixed light seems to drift after 6 to 12 s, so scan, never stare. A sloping cloud or shore-light line makes a false horizon; empty-field myopia rests the eyes at 1 to 2 m.

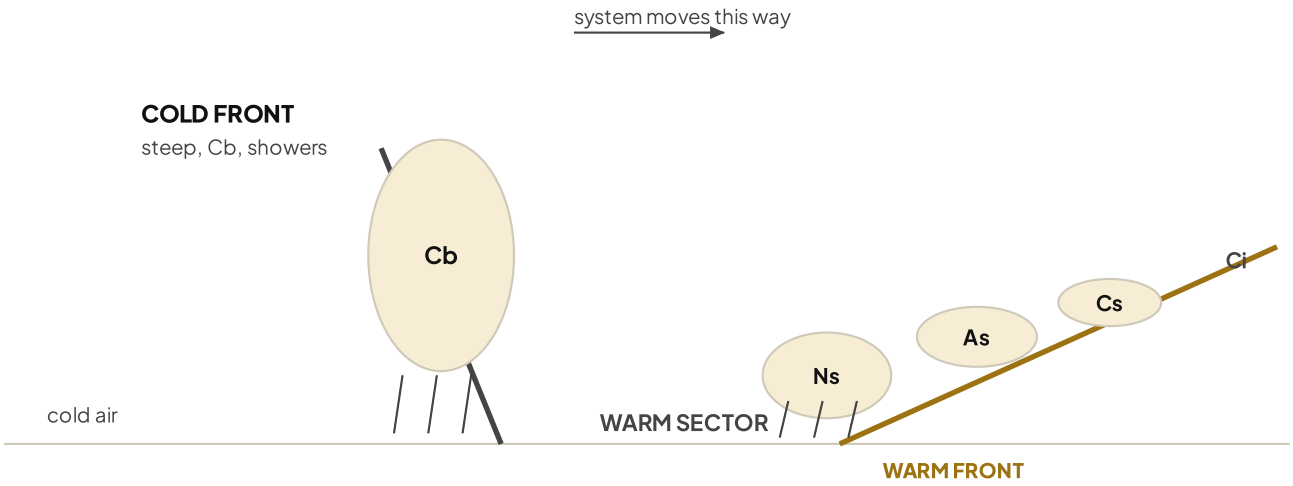
Most approach illusions make the runway look too high, so the pilot flies dangerously low, and forward acceleration feels like pitch-up; fly the PAPI and the attitude indicator, not the view or the seat. Drawn in code.

Two of the 369 code-drawn study figures inside the SkyStudy question bank. Try them with the free demo at **skystudyatpl.com/demo**.

050 Meteorology

ISA, pressure and altimetry, cloud, wind, fronts, icing, thunderstorms.

WARM AND COLD FRONTS IN A DEPRESSION



Cold front (behind): steep slope, cumuliform Cb, showery and squally, passes quickly. **Warm front** (ahead): shallow slope, layered Ns, As, Cs, Ci with prolonged steady rain. Between them lies the mild, moist **warm sector**.

MUST-KNOW DEFINITIONS AND CONCEPTS

- **ISA** is a fixed reference atmosphere for altimetry, performance and calibration; it is not the real atmosphere.
- The **troposphere** is where temperature falls with height (the ELR) and almost all weather occurs; the **tropopause** caps it and is higher/warmer over the tropics, lower/colder over the poles.
- **ELR** (Environmental Lapse Rate) is the actual measured rate on the day; it varies constantly.
- **DALR** (Dry Adiabatic Lapse Rate) is how fast an unsaturated parcel cools when it rises, from expansion alone.
- **SALR** (Saturated Adiabatic Lapse Rate) is less than the DALR because condensation releases latent heat.
- Stability compares ELR to DALR/SALR: a displaced parcel warmer than its surroundings keeps rising (unstable), colder sinks back (stable).
- A **temperature inversion** (temperature rising with height) is very stable and traps moisture, smoke and haze below it.
- **Dewpoint (Td)** is the temperature to which air must cool to become saturated; the **dewpoint spread** (T minus Td) shrinks toward saturation.
- **Geostrophic wind**: balance of pressure gradient and Coriolis force, parallel to straight isobars (above the friction layer).
- **Gradient wind** adds centripetal force for curved isobars; surface **friction** backs and slows the wind, so it crosses isobars toward low pressure.
- **Thermal wind** is the vector difference between geostrophic winds at two levels, from horizontal temperature gradients.
- A **col** is a flat-gradient saddle between two highs and two lows; a **trough** is elongated low pressure, a **ridge** elongated high pressure.
- An **air mass** has fairly uniform temperature and humidity from its source region; a **front** is the boundary between two air masses.
- A **warm front** has a shallow slope: long, gradual cloud (Ci, Cs, As, Ns) and prolonged steady rain. A **cold front** has a steep slope: narrower, vigorous cumuliform cloud with showery, squally rain.
- An **occlusion** forms when the cold front catches the warm front and lifts the warm sector aloft.
- **Radiation fog** forms over land on clear, calm, humid nights; **advection fog** forms when warm moist air moves over a colder surface and needs some wind to persist.
- **Rime ice** (small supercooled droplets, stratiform) is rough and opaque; **clear ice** (large droplets, freezing rain, cumuliform) is smooth, hard and more hazardous.
- A thunderstorm needs **moisture, instability and a trigger**; its life cycle is cumulus (updrafts), mature (up and down drafts, heaviest weather), dissipating (downdrafts).
- A **gust front** is the leading edge of the cold downdraft outflow; a **microburst** is a small, intense downdraft giving sudden severe windshear on takeoff and landing.
- **CAT** (Clear Air Turbulence) occurs in cloud-free air, most often near jet streams and the tropopause; **mountain waves** form downwind of a ridge (lenticular clouds, rotor turbulence).
- The **ITCZ** is a belt of converging trade winds and rising air near the equator; tropical revolving storms need sea temperatures above about 26 to 27 C and enough Coriolis, so none form within about 5 degrees of the equator.

KEY NUMBERS, LIMITS AND VALUES

- ISA MSL: **1013.25 hPa**, **15 C** (288.15 K), density **1.225 kg/m3**.
- ISA lapse rate **1.98 C per 1000 ft** (rounded to 2), equal to 6.5 C per km.
- ISA tropopause: **36,090 ft** (11 km), **-56.5 C**, constant above in the model.
- Real tropopause: roughly 16 km over the equator down to about 8 km over the poles VERIFY.
- Pressure change near MSL about **1 hPa per 27 ft**; the height per hPa increases with altitude.
- **DALR = 3 C per 1000 ft** (about 1 C per 100 m).
- **SALR** about **1.5 C per 1000 ft** on average, variable roughly 1.1 to 2.8 depending on temperature and moisture.
- Dewpoint lapse for cloud-base estimation: about **2.5 C per 1000 ft** difference from the DALR.
- Icing is significant roughly between **0 and -40 C**, most severe clear/mixed ice around 0 to -20 C VERIFY.
- Jet streams sit near the tropopause, roughly FL300 to FL400, cores commonly 60 to 150+ kt, sometimes over 200 kt VERIFY.
- Tropical revolving storms develop about 5 to 20 degrees latitude over sea temperatures above 26 to 27 C.
- METAR is routine (half-hourly or hourly); SPECI is issued on specified changes; TAF validity is commonly 9, 24 or 30 hours VERIFY.

FORMULAS AND RELATIONSHIPS

- Convective cloud base (ft AGL) is about (surface T minus surface Td, in C) x 400, i.e. (T minus Td)/2.5 x 1000.
- Stability test: ELR less than SALR = absolutely stable; between SALR and DALR = conditionally unstable; greater than DALR = absolutely unstable.
- Buys Ballot's Law (Northern Hemisphere): back to the wind, low pressure is on your left, high on your right (reversed in the South).
- Thermal wind blows parallel to the thickness lines with cold air to the left in the Northern Hemisphere.
- Coriolis force is proportional to wind speed and the sine of latitude, so it is zero at the equator and maximum at the poles.
- Temperature error rule of thumb: flying from warm/high pressure into cold/low pressure without correction means true altitude is below indicated.

MNEMONICS AND MEMORY ITEMS

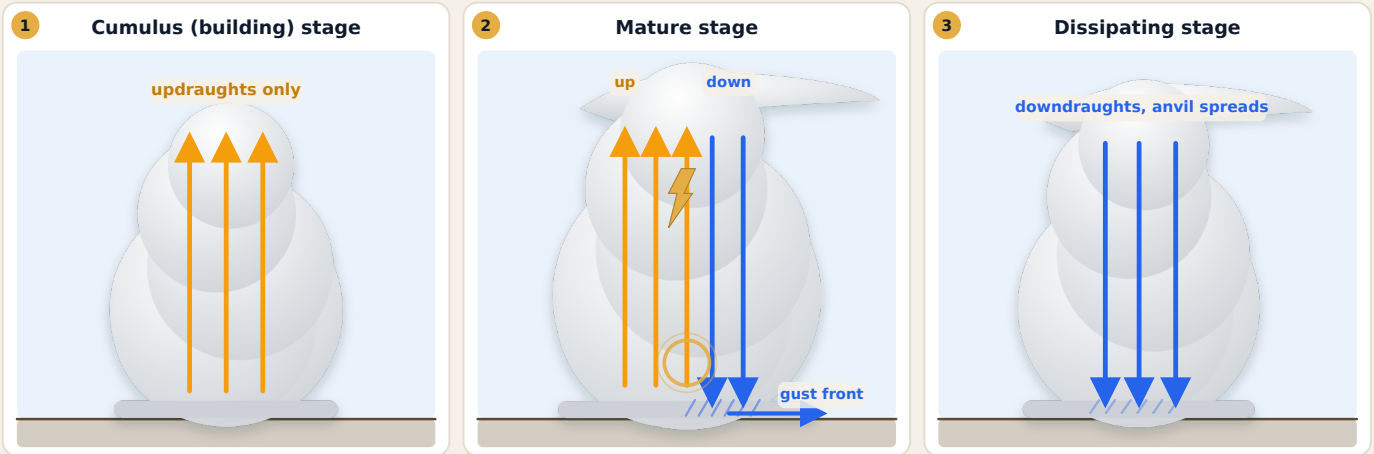
- **High to Low, Look out Below**: into lower pressure or colder air, true altitude is below indicated.
- **Dry is faster**: DALR (3 C/1000 ft) is always greater than SALR (about 1.5), because condensation releases latent heat.
- Cold front **CCCC**: Cumuliform cloud, Colder air, Choppy showers, quiCk passage.
- Warm front: **long and slow** (shallow slope, gradual cloud, prolonged rain).
- Fog needs: cool, calm, clear, near-saturated air (light wind still needed to stir radiation fog).
- Thunderstorm ingredients **MIT**: Moisture, Instability, Trigger.
- **Katabatic down at night, Anabatic up by day.**
- **Rime is Rough and Rapid** from small droplets in stratiform cloud; **Clear ice** is denser and more hazardous from big droplets in cumuliform cloud.

COMMON EXAM TRAPS

- Do not confuse **ELR** (measured on the day) with **DALR/SALR** (parcel rates); stability compares ELR against the adiabatic rates.
- **1 hPa is about 27 ft only near MSL**; the height per hPa increases with altitude.
- Do not swap **QNH** (sea level, altitude) and **QFE** (aerodrome, height); **QNE** is the fixed 1013.25 for flight levels.
- The tropopause is **not constant**; 36,090 ft is the model value, the real one is higher over the tropics.
- **Cold fronts** usually bring the more intense, showery, turbulent weather despite passing faster.
- **Clear ice** (cumuliform, large droplets) is generally more hazardous than **rime** (stratiform, small droplets).
- Icing can persist toward **–40 C** in cloud, not only near 0 C.
- **CAT** is by definition cloud-free turbulence near jet streams, not a thunderstorm phenomenon.
- The **SALR is variable**; only the **DALR** is treated as a constant.
- Use pure Buys Ballot for the **geostrophic/upper** wind; the surface wind is backed and crosses isobars toward low pressure.
- **SIGMET** covers severe en-route hazards; **AIRMET** covers less severe, lower-level phenomena.
- A **METAR** is an observation, a **TAF** is a forecast; they can legitimately disagree.

The thunderstorm (CB) life cycle in three stages

050 · METEOROLOGY



Each cell lasts 20 to 30 minutes; the mature stage holds the worst hazards.

1 Cumulus stage

Warm moist air rises in updraughts only. The cloud builds rapidly and no precipitation yet reaches the ground.

2 Mature stage

Updraughts and downdraughts now coexist. This is the worst stage: heavy rain and hail, lightning, a gust front, severe turbulence and low-level windshear.

3 Dissipating stage

Downdraughts spread through the whole cell and cut off the inflow. The anvil of ice crystals remains as the rain and turbulence ease.

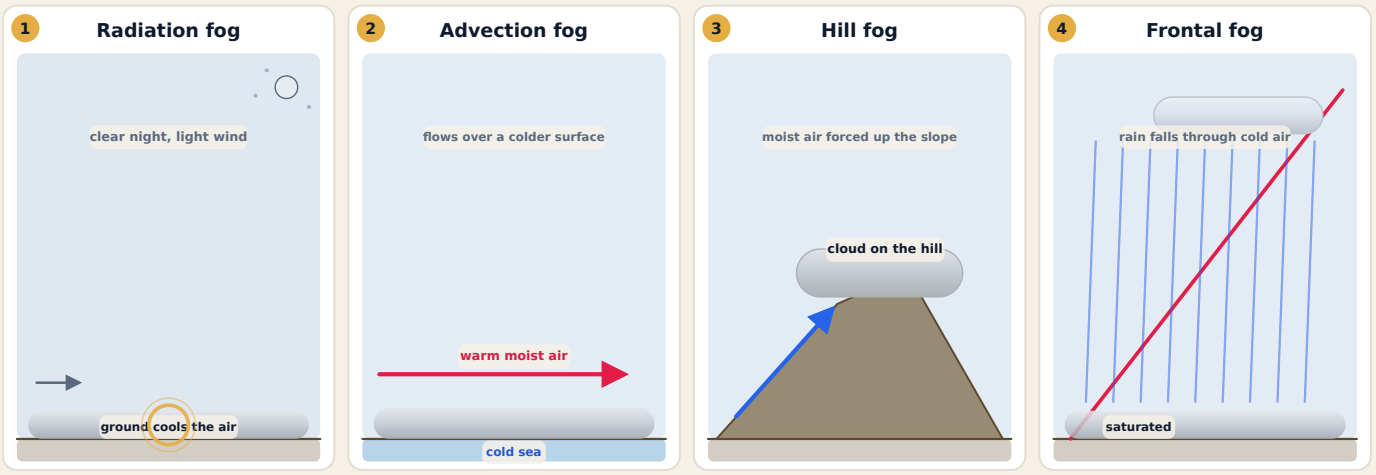
4 What it needs

A thunderstorm needs unstable air, high humidity and a trigger to lift it (heating, a front or high ground). Remove any one and it cannot grow.

A thunderstorm is worst in the mature stage, where updraughts and downdraughts coexist with hail, lightning, the gust front and severe windshear. Drawn in code.

The four fog types and how each saturates the air

050 · METEOROLOGY



Fog is cloud on the ground, visibility below 1000 m. Each type reaches saturation differently: by cooling the air, or by adding moisture to it.

1 Radiation fog

Forms on a clear night with light wind over land: the ground radiates heat and cools the moist air to its dew point. Calm gives dew, strong wind gives stratus; it clears with daytime heating.

2 Advection fog

Warm, moist air flows over a colder surface (often the sea) and is cooled to its dew point. It can form and persist in a stronger wind, by day or night. Sea fog is advection fog.

3 Hill (upslope) fog

Moist air is forced up rising ground and cools adiabatically to saturation. It is really stratus cloud sitting on the high ground, clearing the valleys below.

4 Frontal fog

Rain from the warm air aloft falls through the colder air below a front and evaporates, saturating it. It forms in the frontal rain belt (precipitation fog).

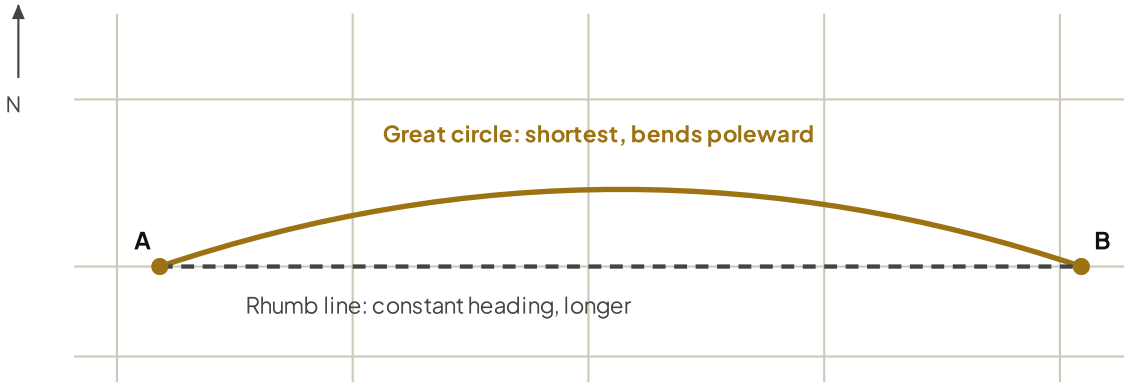
Fog forms when air is cooled to its dew point (radiation, advection, upslope) or moistened by evaporating rain (frontal): the result is cloud on the ground with visibility below 1000 m. Drawn in code.

Two of the 369 code-drawn study figures inside the SkyStudy question bank. Try them with the free demo at skystudyatpl.com/demo.

061 General Navigation

The Earth, great circles, charts and projections, dead reckoning, the compass.

GREAT CIRCLE VERSUS RHUMB LINE (MERCATOR)



Meridians drawn parallel here; in reality they converge poleward.

Great circle is the shortest path and cuts each meridian at a changing angle; the **rhumb line** holds one heading but is longer. They coincide only along the equator or a meridian. Convergency = d.long x sin(mean lat); conversion angle is half of it.

MUST-KNOW DEFINITIONS AND CONCEPTS

- A **great circle** has its plane through the Earth's centre and is the shortest distance between two points on a sphere.
- A **rhumb line** (loxodrome) crosses every meridian at the same angle; it is not the shortest route except along the equator or a meridian.
- **Convergency** is the angle between two meridians at a given latitude; **conversion angle** is the angle between the great circle and the rhumb line joining the same two points.
- **Latitude** is 0 to 90 N/S; **longitude** is 0 to 180 E/W from Greenwich.
- 1 nautical mile equals **1 minute of arc of latitude**; 1 degree of latitude equals 60 nm.
- 1 minute of longitude equals 1 nm **only at the equator**, decreasing with cos(latitude).
- **Departure** is the east-west distance in nm between two meridians at a given latitude.
- **Variation** is the angle between true and magnetic north (changes slowly, secular change); **deviation** is between magnetic and compass north (aircraft-specific, varies with heading).
- **IAS to CAS to EAS to TAS**: instrument/position, then compressibility, then density corrections.
- **Groundspeed** is TAS combined with wind; **track** is the actual path over the ground.
- The **triangle of velocities** relates the air vector (heading and TAS), the wind, and the ground vector (track and groundspeed).
- **1-in-60 rule**: a 1 degree displacement subtends about 1 nm after 60 nm.
- **Dead reckoning** finds position from heading, TAS, wind and time from a known start; a **fix** corrects the DR position from external references.
- **GMT/UTC** is based on the Greenwich meridian; **LMT** is based on the observer's own meridian.
- **Grid navigation** uses a fixed grid north instead of true/magnetic north at high latitudes where meridians converge fast.
- **Isogonals** are lines of equal variation; the **agonic** line is zero variation. **Magnetic dip** is 0 at the magnetic equator and 90 at the magnetic poles.
- **GNSS** fixes position by satellite ranging; **INS** integrates sensed accelerations from a known start and drifts over time.

KEY NUMBERS, LIMITS AND VALUES

- 1 international nautical mile = **1852 m** exactly, about 6076 ft.
- 1 degree of latitude = **60 nm**; 1 minute of latitude = 1 nm.
- Mean radius of the Earth about **3440 nm** (6371 km) VERIFY.
- Convergency is **0 at the equator** and equals the change of longitude **at the pole** (factor 1 at the pole).
- The sun moves **15 degrees of longitude per hour**, so 1 degree of longitude = 4 minutes of time.
- **Lambert** standard parallels are typically at about 1/6 and 5/6 of the chart's latitude span VERIFY; scale is correct only along them.
- A rhumb line and great circle coincide only along the **equator or a meridian**.
- **Mercator** scale expands with sec(latitude); it is correct only at the chart's construction latitude (or the equator).
- **Polar stereographic** charts are conformal and can show the pole; a standard Mercator cannot.
- TAS rises roughly **2% above CAS per 1000 ft** as a quick estimate VERIFY.
- A 3 degree glidepath is about **300 ft per nm** (a rule of thumb: roughly 100 ft per nm for each degree of glide angle) VERIFY.

FORMULAS AND RELATIONSHIPS

- `Convergency (deg) = change of longitude (deg) x sin(mean latitude).`
- `Conversion angle = 1/2 x convergency.`
- `Departure (nm) = change of longitude (minutes) x cos(latitude).`
- `Difference of latitude (minutes) = distance in nm along a meridian.`
- `1-in-60 rule: angle (deg) is about (distance off track / distance run) x 60.`
- `Chart scale (representative fraction) = chart length / earth distance, same units.`
- `Mach number = TAS / local speed of sound (LSS depends on temperature only).`
- `True heading = Magnetic heading + Variation (East positive, West negative).`
- `Compass heading = Magnetic heading - Deviation (East positive, West negative, from the deviation card).`
- `LMT = GMT + longitude in time (add East, subtract West).`
- `On a Lambert chart the constant of the cone n is about sin(standard-parallel latitude); chart convergency = change of longitude x n.`

MNEMONICS AND MEMORY ITEMS

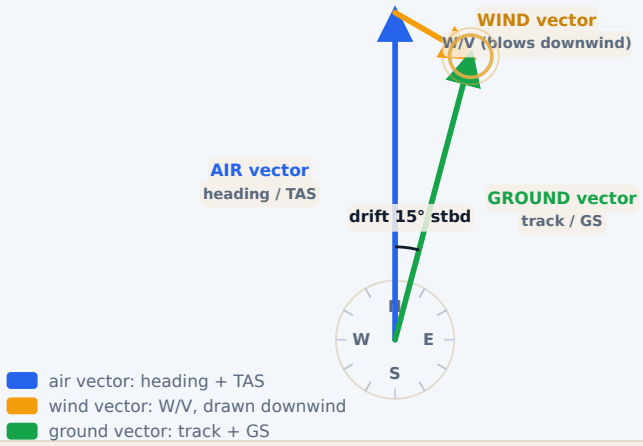
- **CADET**: Compass, Add East, to get True (add easterly deviation and variation; subtract westerly).
- **Variation West, Magnetic Best (add); Variation East, Magnetic Least (subtract)** for True to Magnetic.
- **Error West, Compass Best; Error East, Compass Least** for Magnetic to Compass via deviation.
- **Longitude East, GMT least (subtract); Longitude West, GMT best (add)** for GMT to LMT.
- Conversion angle is always **half** the convergency: a quick sanity check.
- **Mercator**: straight line is a rhumb line; **Lambert**: straight line is about a great circle.

COMMON EXAM TRAPS

- Do not swap **convergency** (full angle) with **conversion angle** (half of it).
- Departure uses **cos(latitude)**, not sin.
- Use the **mean latitude** for departure, convergency and conversion angle over a significant distance.
- 1 minute of **longitude** is 1 nm only at the equator; only 1 minute of **latitude** is always 1 nm.
- **CADET** applies Compass to True; the reverse direction reverses the sign logic.
- **Variation** is geographic (same for all aircraft at a place); **deviation** is aircraft-specific and changes with heading.
- A rhumb line is shortest **only** along the equator or a meridian; otherwise the great circle is shorter.
- On a **Lambert** chart great circles are only near-straight, best between the standard parallels.
- A **Mercator** cannot sensibly show or navigate the poles.
- Correct CAS to **EAS** (compressibility) before the density correction to TAS at high speed/altitude.
- Do not use the 2%-per-1000-ft rule for a precise calculation; use the flight computer or ISA tables.
- The **agonic** line is zero variation; an **isogonal** is any line of constant variation.
- Compass indications are unreliable through dip errors near the poles and on headings near north/south.

The triangle of velocities: heading/TAS + W/V = track/GS

061 · NAVIGATION



GIVEN -> FIND	
Heading (T)	000°
TAS	150 kt
W/V	300° / 40
Track (T)	015°
GS	135 kt
Drift	15° stbd

1 The three vectors

Air vector (heading and TAS) plus wind vector (the W/V) gives the ground vector (track and GS). It is one vector sum: two knowns fix the third.

2 Draw the wind downwind

The wind vector starts at the head of the air vector and points the way the air is going: a wind FROM 300° is drawn towards 120°.

3 Drift

Drift is the angle between heading and track. A wind from the left gives starboard (right) drift, so the aircraft tracks right of its heading.

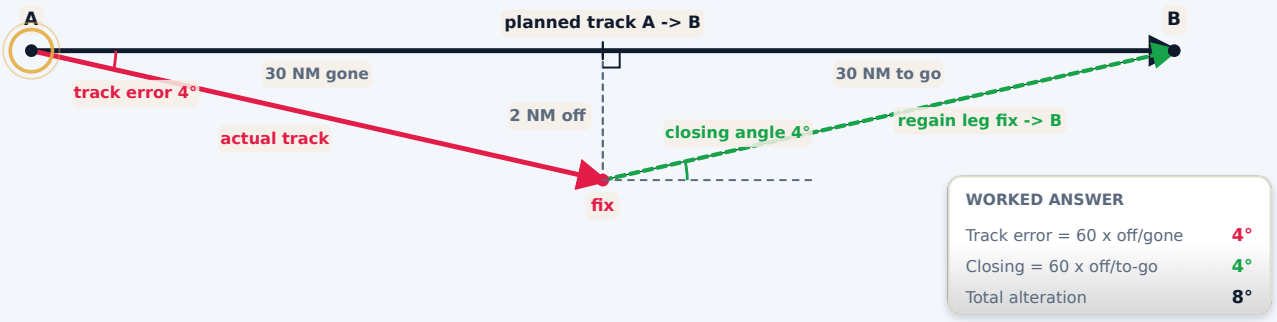
4 Heading vs track

To make good a desired track you turn the heading into wind by the wind correction angle, which equals the drift but is applied the opposite way.

Heading/TAS plus W/V equals track/GS: the wind vector, drawn downwind from the head of the air vector, closes the triangle and the drift is track minus heading.

The 1-in-60 rule: track error and the closing angle

061 · NAVIGATION



1 Track error

Track error in degrees is 60 times distance off divided by distance gone. Here 60 times 2 over 30 is 4°, the angle already opened up between planned and actual track.

2 Parallel the track

Turn by the track error alone and the aircraft flies parallel to the planned track, holding the same 2 NM offset but no longer diverging.

3 Closing angle

To arrive at the destination add the closing angle, 60 times off divided by distance to go: 60 times 2 over 30 is another 4°.

4 Total correction

Turn by track error plus closing angle, here 8°, to regain track at B. When gone equals to-go, simply double the track error.

Track error equals 60 times distance off over distance gone; add the closing angle, 60 times off over distance to go, to regain track at the destination.

Two of the 369 code-drawn study figures inside the SkyStudy question bank. Try them with the free demo at skystudyatpl.com/demo.

062 Radio Navigation

Radio waves, NDB, VOR, DME, ILS, radar, SSR, GNSS.

ILS: LOCALISER, GLIDE PATH AND MARKERS

Localiser 108.10 to 111.95 MHz (odd first decimals) gives the centreline; **glide path** 328.6 to 335.4 MHz UHF is auto-paired, nominal 3 degrees. **Markers** all on 75 MHz: **O**uter blue low tone, **M**iddle amber medium, **I**nner white high. Localiser full-scale is about plus or minus 2.5 degrees.

MUST-KNOW DEFINITIONS AND CONCEPTS

- **Ground (surface) wave** follows the Earth's curvature by diffraction (LF/MF), with greater range over sea than over land; it does not depend on the ionosphere.
- **Sky wave** is refracted back by the ionosphere (mainly HF); range varies with day/night, season and solar activity.
- **Space (direct) wave** is line-of-sight (VHF/UHF/SHF), limited by Earth curvature and height, not the ionosphere.
- **D layer** (daytime only) absorbs MF/HF; its disappearance at night lets sky waves travel much farther. **E and F layers** reflect HF sky waves; F splits into F1/F2 by day.
- **Skip distance** is the dead zone between the ground-wave limit and where the first sky wave returns.
- **ADF/NDB**: the needle shows Relative Bearing (RB) to the station, clockwise from the nose.
- **QDM** (magnetic bearing to the station) = RB + magnetic heading; **QDR** (bearing from the station) = QDM plus or minus 180.
- **VOR reference phase**: 30 Hz FM, omnidirectional, constant everywhere. **VOR variable phase**: 30 Hz AM, its phase changes with azimuth.
- A **VOR radial** is the phase difference, read as the magnetic bearing **from** the station. The **cone of confusion** is unreliable indications directly overhead.
- **DME** measures **slant range** (line of sight), largest error overhead and negligible far out.
- **ILS**: the localiser gives lateral guidance on the extended centreline, the glide path gives vertical guidance at nominally 3 degrees; **marker beacons** cross the approach at set points.
- **SSR Mode S** assigns a unique 24-bit address for selective interrogation and data link, reducing garbling versus Mode A/C.
- **RNAV** allows any desired path within coverage; **RNP** adds onboard performance monitoring and alerting; **PBN** is the ICAO framework of numbered specifications.
- **WGS-84** is the geodetic datum in which GPS positions are expressed.

KEY NUMBERS, LIMITS AND VALUES

- Speed of radio waves **c = 300,000,000 m/s** (3 x 10^8).
- Bands: VLF 3 to 30 kHz, LF 30 to 300 kHz, MF 300 to 3000 kHz, HF 3 to 30 MHz, VHF 30 to 300 MHz, UHF 300 to 3000 MHz, SHF 3 to 30 GHz.
- NDB operates in LF/MF, roughly 190 to 1750 kHz VERIFY.
- VOR band **108.00 to 117.95 MHz**, 50 kHz spacing; 108.00 to 111.95 shared with the ILS localiser.
- ILS localiser **108.10 to 111.95 MHz** on **odd** first-decimal channels; glide slope **UHF 328.6 to 335.4 MHz**, auto-paired to the localiser.
- DME **UHF 962 to 1213 MHz**, auto-paired to the VOR/ILS.
- Marker beacons all on **75 MHz**: Outer blue low tone, Middle amber medium tone, Inner white high tone.
- SSR: interrogation **1030 MHz**, reply **1090 MHz**. Radio altimeter **4200 to 4400 MHz** (SHF, frequency modulated continuous wave).
- Nominal ILS glide path **3 degrees** (about 2.5 to 3.5 depending on airfield).
- CDI full-scale: **VOR plus or minus 10 degrees** (each dot about 2), **ILS localiser plus or minus 2.5 degrees**.
- VOR aggregate accuracy about plus or minus 5 degrees; DME accuracy about the better of 0.5 nm or 3% of range VERIFY.
- Transponder codes: 7700 emergency, 7600 comms failure, 7500 hijack, 7000 VFR conspicuity (Europe), 2000 entering radar with no assigned code.
- ILS minima by category: **CAT I** DH 200 ft or above, RVR 550 m or above; **CAT II** DH 100 to 200 ft, RVR 300 m or above; **CAT IIIA** DH under 100 ft, RVR 200 m or above; **CAT IIIB** DH under 50 ft, RVR down to about 50 to 75 m VERIFY.
- GPS: nominally **24 satellites**, 6 planes, about 20,200 km, period about 12 hours VERIFY. A 3D fix needs **4 satellites** (3 gives 2D if altitude is known).
- RAIM: **5 satellites to detect** a fault, **6 to exclude** it.

FORMULAS AND RELATIONSHIPS

- `Wavelength (m) = c / f; shortcut wavelength (m) is about 300 / f(MHz).`
- `QDM (to the station) = Relative Bearing + Magnetic Heading (plus or minus 360 as needed).`
- `QDR (from the station) = QDM plus or minus 180.`
- `Radar range R = (c x t) / 2, t = total there-and-back time.`
- `Ground range = sqrt(slant range^2 minus height^2), same units.`
- `VHF/UHF line-of-sight horizon (nm) is about 1.23 x sqrt(height in ft); add both stations' terms for two heights` VERIFY.

MNEMONICS AND MEMORY ITEMS

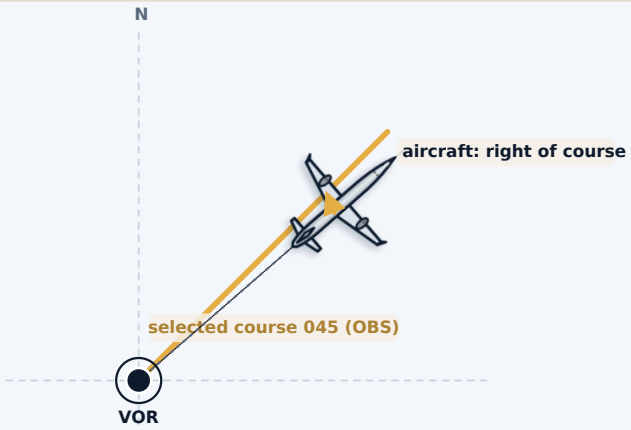
- **RB + MH = MB**: Relative Bearing plus Magnetic Heading gives the bearing to the station (watch the 360 wrap).
- **A radial is always FROM** the station, never to it.
- VOR: **Reference is Fixed (FM), Variable is AM**.
- Localiser channels have an **odd first decimal** (108.10, 108.30); even tenths are VOR.
- Marker colour and tone step up toward the runway: **blue–low, amber–medium, white–high**.
- GPS segments: **Space, Control, User** (who transmits, who manages, who uses). RAIM: **5 to detect, 6 to correct**.

COMMON EXAM TRAPS

- **Lower** frequency gives longer ground-wave range, and it is greater over sea than land.
- **Night effect** on the NDB is worst around dawn and dusk, when sky and ground waves interfere.
- **Coastal refraction** is zero when the path crosses the coast at 90 degrees and grows at oblique angles.
- **Quadrantal error** is maximum on the 045/135/225/315 relative bearings, zero on the cardinals.
- The **cone of confusion** (overhead geometry) is not the same as the VOR aggregate accuracy figure.
- **DME slant range** error is largest close in/overhead and negligible when range is much greater than height.
- The DME channel is **auto-paired** with the VOR/ILS, not tuned separately.
- **Mode C** reports pressure altitude on 1013.25, not QNH; ATC applies the correction.
- A GPS **3D** fix needs 4 satellites; 3 gives only a 2D fix if altitude is known.
- RAIM depends on satellite **geometry** as well as count.
- The 3 degree glide path is nominal, not universal.
- Do not mix up marker beacon colour/tone/pattern between Outer, Middle and Inner.
- Treat the CAT I/II/III minima as reference points; exact operational minima vary by aircraft, runway and approval.

VOR: the CDI shows POSITION vs the selected course

062 · RADIO NAV AIDS



CDI: 2 dots left, FROM

1 Position, not heading

The CDI deflection and the TO/FROM flag depend only on where the aircraft is relative to the selected course. Turning the aircraft does not move the needle.

2 2 degrees per dot

Full-scale deflection is 10 degrees off the selected course, so each dot is 2 degrees: the bar 2 dots left here means the aircraft is about 4 degrees right of the 045 course.

3 TO / FROM by the abeam line

The flag shows FROM when the station is behind the abeam line for the set course and TO when it is ahead. It is not a command to fly toward or away from the station.

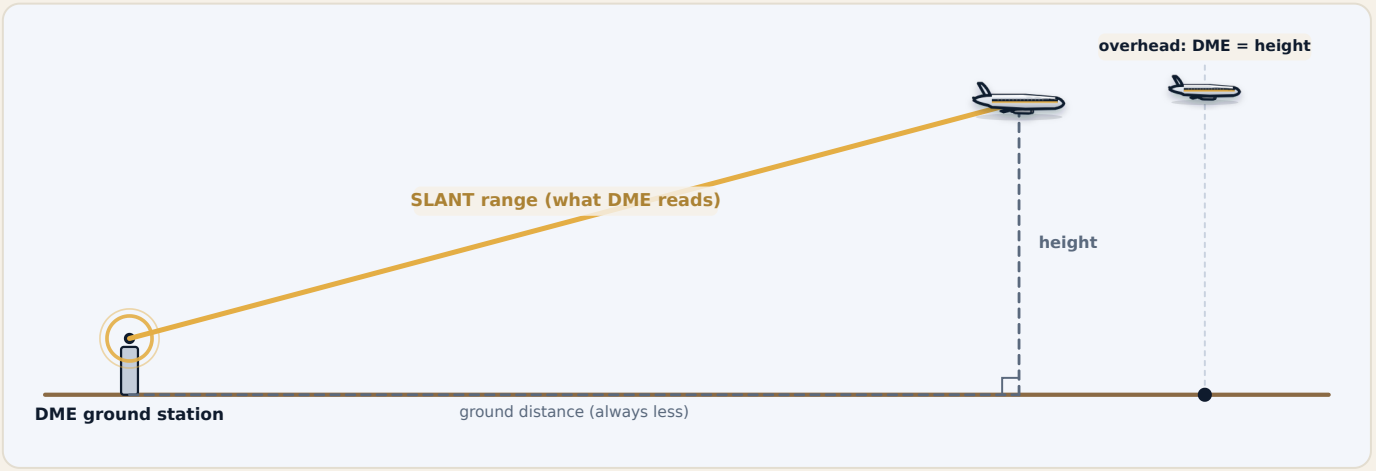
4 OBS selects the course

The Omni Bearing Selector sets the reference course. Fly toward the bar to regain it: the needle is on the side the wanted course lies. An unrelated OBS gives a fixed off-centre bar.

A VOR CDI shows the aircraft's position relative to the OBS-selected course, 2 degrees per dot to 10 degrees full scale, and never responds to heading. Drawn in code.

DME measures SLANT range, not ground distance

062 · RADIO NAV AIDS



1 Slant range, not ground range

DME times a pulse pair to the station and back, so it reads the straight-line SLANT distance. That is always a little more than the distance measured across the ground.

2 Overhead reads your height

Directly over the station the slant range equals the aircraft height, so a DME overhead shows your height in nautical miles, never zero. The error is largest high and close in.

3 Ground-speed read-out error

DME-derived ground speed is the rate of change of slant range, so it reads low near the station and zero overhead, even though the true ground speed is unchanged.

4 Paired and busy

DME is paired with a VOR or ILS frequency and auto-tunes with it. A beacon answers interrogations from many aircraft, so it serves about 100 at once before saturating.

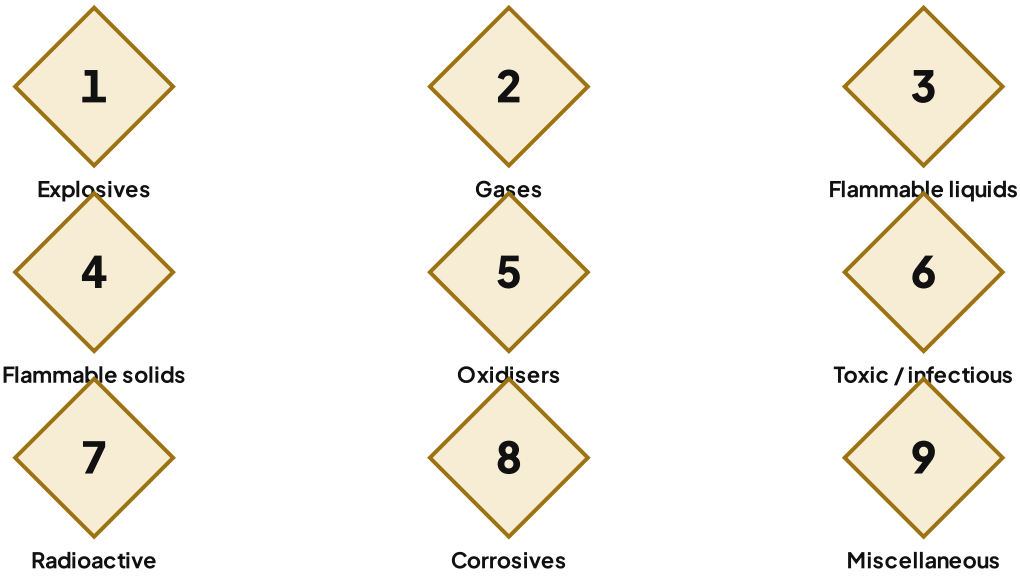
DME reads slant range from a timed pulse pair, so overhead it shows the aircraft height and its ground-speed read-out falls to zero: slant range is never the ground distance. Drawn in code.

Two of the 369 code-drawn study figures inside the SkyStudy question bank. Try them with the free demo at skystudyatpl.com/demo.

070 Operational Procedures

Ops documents, dangerous goods, low-visibility ops, wake turbulence, MEL.

THE 9 DANGEROUS GOODS CLASSES



The numeric order is the exam-testable sequence. Class 9 (miscellaneous) includes lithium batteries, dry ice and magnetised material. The **NOTOC** informs the commander of all dangerous goods loaded.

MUST-KNOW DEFINITIONS AND CONCEPTS

- The **operator** holds primary responsibility for safe operation; the **commander** has final authority in flight and may deviate from any procedure in an emergency.
- The **Operations Manual** has Parts A (general), B (aircraft operating), C (route/aerodrome) and D (training).
- **Aerodrome operating minima** (RVR/visibility and cloud base) depend on runway facilities, approach category and aircraft category.
- **Aircraft category A/B/C/D** (based on Vat, the reference landing speed) sets the applicable minima and protected airspace.
- **Low Visibility Operations (LVO)** cover takeoff and approach/landing below standard CAT I, needing Low Visibility Procedures (LVP), training and approval.
- **Clean aircraft**: no takeoff with frost, ice or snow adhering to critical surfaces.
- **Holdover time (HOT)** is the estimated time anti-icing fluid protects surfaces, given as a range; a pre-takeoff check confirms whether protection has run out.
- **MEL** is the operator's list of equipment that may be inoperative for dispatch; it can never be less restrictive than the manufacturer's **MMEL**.
- **CDL** (Configuration Deviation List) permits dispatch with certain external parts missing, usually with a performance penalty.
- **NOTOC** notifies the commander of all dangerous goods loaded.
- Decompression is **explosive, rapid or gradual** by rate of pressure loss; the crew response depends on the classification.
- **TCAS** gives Traffic Advisories then Resolution Advisories (climb/descend); **GPWS/EGPWS** gives terrain warnings.
- **Wake turbulence** categories by maximum takeoff mass: Light, Medium, Heavy, Super (the A380 is the classic Super).
- **ETOPS/EDTO** governs operations beyond a set single-engine diversion time from an adequate aerodrome, needing specific approval and planning.
- A **contaminated runway** has more than **25%** of the assessed surface covered by water, slush, snow, ice or frost.
- **Noise abatement** departures (NADP 1 and NADP 2) reduce noise near airports while staying safe.
- **Fuel jettison** reduces mass below max landing mass before an emergency landing; not all types are fitted for it.
- **Volcanic ash** is a serious hazard (engine flameout, airframe, systems); operators must avoid it and exit if encountered.

KEY NUMBERS, LIMITS AND VALUES

- **90-second rule**: certification must show all occupants can evacuate through half the exits, in darkness, within 90 seconds.
- MEL rectification categories (letters and order are standard; day counts vary, verify): **A** per the MEL condition; **B** within 3 days; **C** within 10 days; **D** within 120 days (excluding the day of discovery).
- **9 dangerous goods classes**: 1 Explosives, 2 Gases, 3 Flammable liquids, 4 Flammable solids/spontaneous/water-reactive, 5 Oxidisers and organic peroxides, 6 Toxic and infectious, 7 Radioactive, 8 Corrosives, 9 Miscellaneous (includes lithium batteries, dry ice, magnetised material).
- Wake turbulence separation grows when a lighter category follows a heavier one; the largest gap is Light behind Super/Heavy VERIFY.
- CAT I is generally to about **200 ft DH and 550 m RVR** VERIFY; CAT II/III progressively reduce DH and RVR, CAT IIIB allows very low or no DH and very low RVR.
- Normal cabin altitude around **6,000 to 8,000 ft**; cabin altitude warning around 10,000 ft VERIFY.
- Contaminated runway threshold: more than **25%** of the assessed surface covered.

MNEMONICS AND MEMORY ITEMS

- Learn the **9 DG classes by number** (1 to 9); the numeric order is the exam-testable sequence.
- TCAS RA: **comply, do not delay, do not fight it**; the RA overrides the ATC clearance.
- Wake turbulence size order: **Super, Heavy, Medium, Light** (the bigger they are, the more they stir).
- **MEL A to D** runs from most urgent (A, no fixed limit) to least urgent (D, longest interval).
- **Low Vis = less freedom, more procedure**: protected areas, extra spacing and low-vis taxi routes all activate together.
- **HOT tells you when to worry, not when it is safe**: always pair it with a pre-takeoff check.

COMMON EXAM TRAPS

- Do not confuse **MEL** (inoperative systems) with **CDL** (missing external parts, usually with a performance penalty).
- MEL categories are binding limits, not commander discretion, except in a genuine emergency.
- A **TA** is advisory; an **RA** requires an immediate manoeuvre and takes priority over ATC.
- **Holdover time** is a statistical range, not a guarantee; a pre-takeoff check can still be required within it.
- The **90-second** rule is a certification demonstration (half the exits blocked), not a guaranteed real-world outcome.
- **Explosive** decompression is under a second from a large opening; **rapid** is slower but still fast; do not swap them.
- Wake separation also applies to **Medium behind Heavy/Super**, not only Light categories.
- **LVO** applies to both takeoff and landing, not just approach minima.
- **EDTO** terminology now extends the ETOPS concept to some aircraft with more than two engines.
- Dangerous goods also cover **passenger and crew** items (spare lithium batteries), not only cargo.
- **Volcanic ash** also abrades windscreens and blocks pitot/static, not only engines.
- A **contaminated** runway is a distinct, more severe category than merely wet, with different performance calculations.

EXAM FIGURES FROM THE SKYSTUDY QUESTION BANK

Fire classes and the right extinguisher agent

agent (down) / fire class (across)	A solids (wood, paper, fabric, seats)	B liquids (fuel, oil, hydraulic fluid)	C electrical (avionics, wiring, motors)	D metals (magnesium, titanium)
Water / water-glycol	✓ use	✗ never	✗ never	✗ never
Halon 1211 (BCF)	~ limited	✓ use	✓ use	✗ never
CO2	~ limited	✓ use	✓ use	✗ never
Dry powder (ABC)	✓ use	✓ use	✓ use	✗ never

- use: suitable agent for this class
- limited: suppresses briefly, may re-ignite (no deep cooling)
- never: unsafe (spreads fire or conducts current)
- Class D metals: a dedicated metal-fire agent only, no standard aircraft extinguisher qualifies

1 Class A: cool it

Solids (seats, paper, fabric). Water or water-glycol is best: it cools below ignition and soaks in to stop re-ignition. Aim a fine mist at the base.

2 Class B: smother it

Flammable liquids (fuel, oil, hydraulic fluid). Halon, CO2 or dry powder break the flame; water is banned because it spreads the burning liquid.

3 Class C: kill the current

Electrical fires. Use a non-conductive agent (Halon or CO2) and remove power. Never use water or foam on live equipment: it conducts and can electrocute.

4 Halon is the aircraft agent

Halon 1211 (BCF) works on B and C with a surface effect on A, so one bottle covers most cabin fires. It is a CNS depressant above about 5%, so ventilate after use.

Match the agent to the class: water only on Class A solids, never on electrical or flammable-liquid fires. Drawn in code.

Contaminated runway and hydroplaning

071 · RUNWAY OPS

1 Dynamic (standing water)

rides on a water film

needs about 3 mm of water

2 Viscous (thin film)

thin film on a smooth surface

the lowest speed of the three

3 Reverted rubber (steam)

locked wheel makes a steam seal

square patch

Dynamic hydroplaning speed: $Vp = k \times \sqrt{P}$ (P = tyre pressure, psi)

spin-up at touchdown (tyre not yet rotating): k = 7.7 | spin-down on the braking rollout: k = 9

e.g. P = 200 psi gives spin-up about 109 kt and spin-down about 127 kt; lower tyre pressure lowers the speed.

1 Dynamic hydroplaning

On standing water (about 3 mm or more) the water pressure under the tyre lifts it clear of the surface, so it rides on a water film and braking and steering fall to near zero.

2 Viscous hydroplaning

A thin film of water, oil or rubber on a smooth or rubber-coated surface acts as a lubricant. It needs no depth and happens at the lowest speed, so the touchdown zone is prone to it.

3 Reverted-rubber hydroplaning

A locked, skidding tyre heats the water to steam; the rubber reverts and seals a near-frictionless steam cushion. It leaves a square patch and white marks, and needs anti-skid or gentle braking to avoid.

4 Wet vs contaminated runway

Wet means soaked with standing water no deeper than 3 mm. Contaminated means water deeper than 3 mm, or slush, snow or ice, over more than 25% of the required area; report braking action.

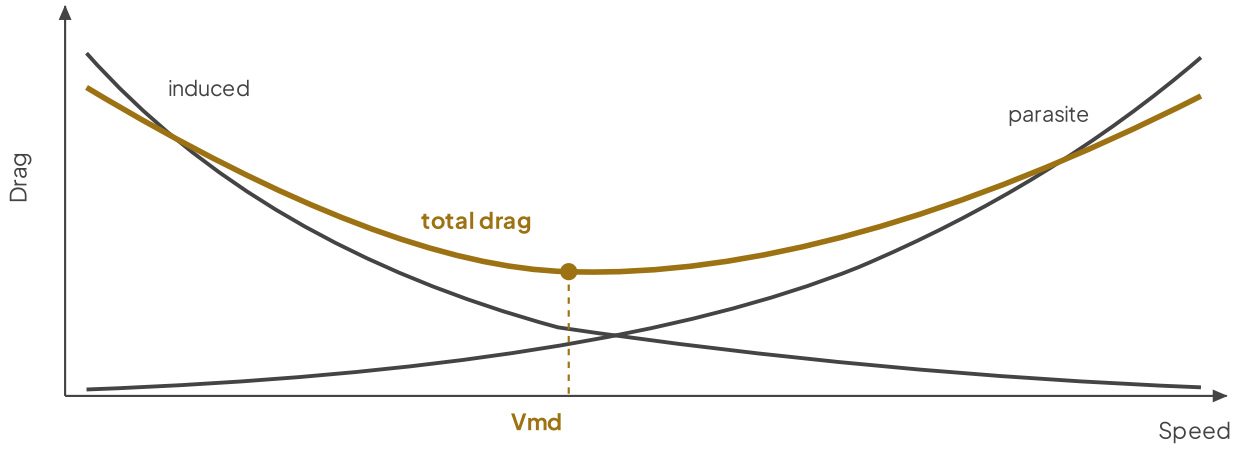
Three hydroplaning types: dynamic (standing water lifts the tyre, Vp = 7.7 to 9 × √P), viscous (thin film, lowest speed) and reverted-rubber (locked wheel makes steam). Drawn in code.

Two of the 369 code-drawn study figures inside the SkyStudy question bank. Try them with the free demo at skystudyatpl.com/demo.

081 Principles of Flight

Lift and drag, the stall, stability and control, high-speed flight, propellers.

THE DRAG CURVE AND VMD



Induced drag falls with speed, **parasite drag** rises with speed; total drag is a U-shape with its minimum at **Vmd** (L/Dmax). Vmd is best glide and propeller max range; a jet's max range is faster, around 1.3 x Vmd.

MUST-KNOW DEFINITIONS AND CONCEPTS

- **Chord line** joins the leading and trailing edges; **camber** is the curvature relative to the chord.
- **Angle of attack (AoA)** is between the chord and the relative airflow, not the horizon; **angle of incidence** is the fixed rigged angle to the longitudinal axis.
- **Relative airflow** is parallel to and opposite the flight path.
- **Aspect ratio** = span^2 / area; high aspect ratio gives lower induced drag at the cost of weight and roll rate.
- **Centre of pressure** moves forward as AoA increases, then snaps aft right at the stall; the **aerodynamic centre** (near quarter chord subsonically) keeps a constant pitching moment instead.
- The **lift/AoA curve** rises nearly linearly to CLmax at the critical AoA, then falls sharply.
- **Boundary layer**: the thin layer slowed by viscosity; laminar (low friction, separates early) or turbulent (higher friction, resists separation).
- **Flow separation** is the boundary layer breaking away: the physical mechanism of the stall.
- **Downwash** and **wingtip vortices** (high pressure curling to low pressure at the tip) are the source of induced drag.
- **Washout**: decreasing incidence toward the tip so the root stalls first, keeping the ailerons effective.
- **Ground effect**: reduced induced drag and downwash within about one wingspan of the surface, causing float and a lower stall speed.
- **Static stability** is the initial tendency to return to trim; **dynamic stability** is the response over time (damped, neutral, divergent).
- **Directional (weathercock)** stability from the fin; **lateral (dihedral)** stability from dihedral, sweep and wing position.
- **Dutch roll**: a yaw/roll oscillation when lateral stability is strong relative to directional (damped by a yaw damper). **Spiral instability**: a slow diverging bank when directional stability is strong relative to lateral.
- **Adverse yaw**: the down-going aileron makes more induced drag, yawing toward the outside of the turn.
- Primary controls (ailerons, elevator, rudder) act about the three axes; secondary/high-lift devices are flaps, slats, trim tabs, spoilers and speed brakes.
- **Mass balance** puts weight ahead of the hinge to prevent **flutter**; **aerodynamic balance** reduces pilot control forces (a different purpose).
- **Mach number** = TAS / local speed of sound; a **shockwave** decelerates flow from supersonic to subsonic with a sudden pressure rise and **wave drag**.
- **Buffet** is airframe vibration from separated or shock-disturbed flow, at low speed (stall) or high speed (Mach).
- **Feathering** aligns the propeller blades with the airflow to stop windmilling; a constant-speed prop varies blade angle to hold RPM.

KEY NUMBERS, LIMITS AND VALUES

- Critical (stalling) AoA about **15 to 16 degrees** for a typical subsonic aerofoil VERIFY.
- CLmax occurs **at** the critical AoA; the critical AoA is constant regardless of weight, altitude, bank or airspeed, only the IAS at which it is reached changes.
- CS-25 large-aeroplane limit load factors: **+2.5 g to -1.0 g**.
- CS-23 utility about **+4.4 g / -1.76 g**; aerobatic about **+6 g / -3 g** VERIFY.
- **Va** (manoeuvring) is the max speed for a single full control input without exceeding the limit load factor; Va **decreases** as weight decreases.
- **Vne** never-exceed (red line); **Vno** max structural cruising (top of the green arc); **Vfe** max flap extended (top of the white arc).
- **Mcrit** is the free-stream Mach at which airflow first becomes locally sonic somewhere on the airframe.
- **Coffin corner** is where the low-speed stall buffet and high-speed Mach buffet boundaries converge at altitude.
- Trailing-edge flaps mainly increase CLmax and drag with little change in critical AoA; **slats and slots** increase both CLmax and the critical AoA.
- Gust loads add to manoeuvre loads and increase with airspeed, hence rough-air penetration speeds.

FORMULAS AND RELATIONSHIPS

- Lift L = CL x 1/2 x rho x V^2 x S; Drag D = CD x 1/2 x rho x V^2 x S.
- Aspect ratio = span^2 / S.
- Load factor in a level turn n = L/W = 1/cos(bank angle).
- Stall speed Vs is proportional to sqrt(weight / CLmax).
- Stall speed in a turn Vs(turn) = Vs(1g) x sqrt(n); a 60 degree bank gives n = 2, so Vs rises about 1.41 times.
- Induced drag is proportional to 1/V^2 (dominates at low speed) and to weight^2 at a given speed.
- Parasite drag is proportional to V^2 (dominates at high speed); minimum total drag is at Vmd where induced = parasite.
- L/Dmax is at Vmd: best glide angle for any aircraft, and the maximum-range speed for a propeller aircraft. A jet at Vmd is at maximum endurance; jet maximum range is faster, about 1.3 x Vmd VERIFY.

MNEMONICS AND MEMORY ITEMS

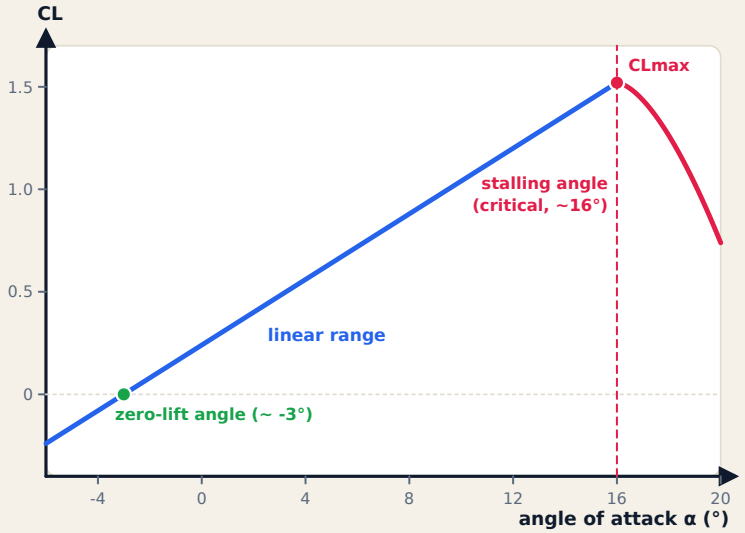
- **Camber curves, chord is straight.**
- AoA moves with the flight path; incidence is bolted to the airframe.
- **Coffin corner squeezes from both ends**: stall buffet speed rises with altitude, Mach buffet speed falls.
- **Adverse yaw: down aileron drags** the nose to the outside of the turn.
- **Static asks IF it returns to trim; dynamic asks HOW** (damped, neutral, divergent).
- **Dutch roll = too much dihedral for the fin; spiral = too much fin for the dihedral.**
- Forward CG: more stable, higher stick forces, higher stall speed, more trim drag. Aft CG: less stable, lighter controls, less trim drag, less stall margin.
- **Mass balance stops flutter; aerodynamic balance lightens the controls.**

COMMON EXAM TRAPS

- Do not confuse **AoA** (to the relative airflow) with pitch attitude (to the horizon).
- Stalling **IAS** is essentially constant with altitude for a given weight; **TAS** at the stall rises with altitude, but the critical AoA and CLmax are unchanged.
- The critical AoA does **not** change in a turn; only the IAS to reach it rises with load factor.
- **Va decreases** as weight decreases; do not assume it is fixed or rises when lighter.
- Induced drag **falls** with speed, parasite drag **rises**; the U-shaped total drag curve has its minimum at Vmd.
- **Slats/slots** increase both CLmax and the critical AoA; plain flaps mainly increase CLmax.
- **Mach tuck** (nose-down from the CP moving aft) is distinct from high-speed **Mach buffet** (vibration).
- Wing **sweep** delays compressibility by reducing the streamwise flow component; it does not change the aerofoil shape.
- Swept wings tend to **tip-stall** first, countered by fences, vortex generators, saw-tooth edges or washout.
- **Mass balance** (flutter) and **aerodynamic balance** (control forces) solve different problems.
- The **area rule** (coke-bottle waist) is a transonic wave-drag principle, not a general subsonic rule.
- **Feathering** (blades aligned with the airflow) is not the same as fine/flat pitch (small angle for takeoff RPM).
- The **+2.5 g / −1.0 g** figure is the CS-25 limit; CS-23 utility and aerobatic categories differ.

The lift curve: CL against angle of attack

081 · PRINCIPLES OF FLIGHT



Low angle of attack
α = 3°
attached flow, small CL

High angle of attack
α = 12°
attached flow, large CL

Beyond the stall
α = 19°
flow separates, CL drops

1 Linear range

Below the stall CL rises in almost a straight line with angle of attack; the slope is the lift-curve slope.

2 Zero-lift angle

A cambered aerofoil still makes zero lift at a small NEGATIVE angle of attack, near -3 to -4 degrees.

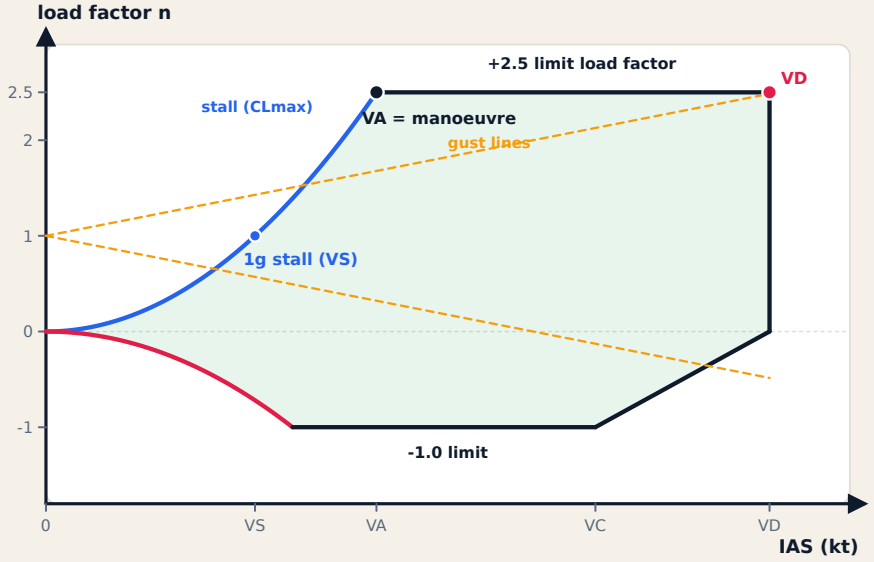
3 CLmax and the stall

CL peaks at the critical angle (about 16 degrees), then falls as the flow separates. The angle is fixed, the speed is not.

Stall is reaching the critical ANGLE of attack, not a particular speed. CLmax sets the lowest flying speed. Drawn in code.

The manoeuvring envelope (Vn diagram)

081 · PRINCIPLES OF FLIGHT



1 Load factor n
Lift divided by weight. The diagram bounds the load factors the airframe is certified to carry.

2 Stall boundaries
The curved limits are CLmax: below them the wing stalls before it can be overstressed. They rise with V squared.

3 Limit load factor
The horizontal limits (about +2.5 / -1.0 for transports) must be carried without permanent deformation.

4 VA manoeuvre speed
Where the stall line meets the limit load. At or below VA, full control deflection stalls the wing before it breaks.

5 VC and VD
Design cruise and design dive speeds set the right edge; VD is the highest speed the structure is tested to.

6 Gust lines / ultimate
Gusts add load along the dashed lines. Ultimate load is 1.5 times limit; structure must not fail below it.

The Vn diagram bounds load factor against speed: CLmax stall lines, the limit load factors, and VA, VC, VD. Drawn to scale in code.

Two of the 369 code-drawn study figures inside the SkyStudy question bank. Try them with the free demo at skystudyatpl.com/demo.

091 VFR Communications

Phonetic alphabet, standard phraseology, readback, light signals, squawks.

PHONETIC ALPHABET, KEY NUMBERS AND SQUAWKS

A Alfa	**B** Bravo	**C** Charlie	**D** Delta	**E** Echo	**F** Foxtrot
G Golf	**H** Hotel	**I** India	**J** Juliett	**K** Kilo	**L** Lima
M Mike	**N** November	**O** Oscar	**P** Papa	**Q** Quebec	**R** Romeo
S Sierra	**T** Tango	**U** Uniform	**V** Victor	**W** Whiskey	**X** X-ray
Y Yankee	**Z** Zulu	**3** Tree	**4** Fower	**5** Fife	**9** Niner

7500 Hijack	**7600** Radio failure	**7700** Emergency

Numbers are spoken digit by digit (nine is "niner", five is "fife"); a decimal is spoken "decimal". **MAYDAY** and **PAN PAN** are each said three times. The three squawks: **7500** hijack, **7600** radio failure, **7700** general emergency.

MUST-KNOW DEFINITIONS AND CONCEPTS

- **Readability scale 1 to 5**: 1 unreadable, 2 readable now and then, 3 readable with difficulty, 4 readable, 5 perfectly readable.
- **ROGER** = I have received all of your transmission (not agreement or compliance). **WILCO** = received, understood, will comply.
- **AFFIRM** = yes; **NEGATIVE** = no / not correct / permission not granted.
- **STANDBY** = wait, I will call you. **SAY AGAIN** = repeat all or the specified part.
- **READ BACK** = repeat back exactly as received. **CORRECTION** = an error was made, the correct version follows. **DISREGARD** = ignore that transmission.
- Mandatory readback items: ATC clearances, level instructions, heading and speed instructions, altimeter settings, runway-in-use, SSR codes, and any instruction to enter, hold short of, cross or backtrack a runway.
- Callsign abbreviation: only the aircraft callsign may be abbreviated, and only after the station abbreviates it first; never abbreviate the first call to a new station.
- Station types: **TWR** (Aerodrome), **APP** (Approach), **ACC/Control** (Area), **Information** (FIS), **Radar**, **Delivery**, **Ground**, **Radio** (AFIS).
- Report levels as **FLIGHT LEVEL (number)** above the transition altitude, and as **(number) FEET** below it.
- **ATIS** is a continuous broadcast of routine aerodrome/met information, coded by a phonetic letter that increments; state the code you received on first contact.
- **VOLMET** is a continuous broadcast of meteorological reports for en-route aircraft.
- **Distress** traffic has absolute priority and imposes silence on the frequency; **urgency** traffic has priority over all but distress.

KEY NUMBERS, LIMITS AND VALUES

- VHF communication band **118.000 to 136.975 MHz**; emergency **121.5 MHz**.
- **8.33 kHz** channel spacing is standard in most EASA airspace; the older 25 kHz is being phased out VERIFY.
- **MAYDAY** and **PAN PAN** are each spoken **three times** at the start of the call.
- Transponder codes: **7500** hijack, **7600** radio failure, **7700** general emergency; **7000** is the common VFR conspicuity squawk VERIFY.
- Numbers are spoken digit by digit, except whole hundreds and thousands use HUNDRED and THOUSAND (4500 = four thousand five hundred).
- A frequency decimal is spoken as **DECIMAL** (118.275 = one one eight decimal two seven five).
- Time is UTC, normally passed as minutes only (two figures); the full four-figure group (hours and minutes) is used only when confusion is possible.
- Digit **9 is NINER** and **5 is FIFE**.
- Radio failure VFR: squawk **7600**, continue in VMC, land at the nearest suitable aerodrome.

MNEMONICS AND MEMORY ITEMS

- **ROGER = Received, WILCO = Will Comply**: ROGER never acknowledges an instruction needing compliance.
- **MAYDAY = grave danger now; PAN PAN = a problem, not yet grave.**
- Squawk ladder: **7500 hijack, 7600 comms, 7700 emergency.**
- Light gun logic: **green = go, red = stop**; flashing usually means return or reposition.
- Phonetic alphabet: Alfa, Bravo, Charlie, Delta, Echo, Foxtrot, Golf, Hotel, India, Juliett, Kilo, Lima, Mike, November, Oscar, Papa, Quebec, Romeo, Sierra, Tango, Uniform, Victor, Whiskey, X-ray, Yankee, Zulu.

COMMON EXAM TRAPS

- Do not confuse **ROGER** (received) with **WILCO** (will comply).
- Light signals differ **in flight** versus **on the ground**. In flight: steady green = cleared to land, flashing green = return to land, steady red = give way and circle, flashing red = do not land. On the ground: steady green = cleared for takeoff, flashing green = cleared to taxi, steady red = stop, flashing red = taxi clear of the runway, flashing white = return to starting point.
- **7600** is radio failure, not the general emergency code (**7700**).
- **NEGATIVE** answers a yes/no question; it is not a general unable/refuse statement.
- Do not abbreviate your own callsign before ATC does.
- **QNH** gives altitude AMSL, **QFE** gives height above the reference; do not swap them.
- **READ BACK** confirms content received; **SAY AGAIN** requests a retransmission.
- State the current **ATIS** letter on first contact.
- Only the station controlling the distress (or the aircraft in distress) may lift the imposed silence.
- **STANDBY** means wait, not understood-and-will-comply.

Standard words and phrases

090 · COMMUNICATIONS

Each standard word carries ONE defined meaning

AFFIRM	Yes	**ACKNOWLEDGE**	Let me know you have received and understood
NEGATIVE	No, that is not correct, or permission not granted	**CORRECTION**	An error was made; the correct version follows
ROGER	I have received all of your last transmission	**DISREGARD**	Consider that transmission as not sent
WILCO	I have received your message, understand it and will comply	**I SAY AGAIN**	I am repeating my own transmission
UNABLE	I cannot comply with the instruction	**SAY AGAIN**	Repeat all of your last transmission
STAND BY	Wait and I will call you	**OUT**	This exchange is ended, no reply is expected

1 ROGER is not WILCO

ROGER only confirms that the transmission was received; WILCO promises compliance. Never transmit 'roger wilco': WILCO already acknowledges receipt.

2 MONITOR is not CONTACT

MONITOR means listen out on the frequency without transmitting, so no initial call is made. CONTACT means tune the frequency and make an initial call.

3 NEGATIVE is not UNABLE

NEGATIVE means no, that is not correct, or permission is not granted. UNABLE means the station cannot comply with the instruction it was given.

4 SAY AGAIN, never REPEAT

SAY AGAIN asks the other station to repeat; I SAY AGAIN precedes a repeat of your own message. The word REPEAT is never used in civil radiotelephony.

Every standard word has one defined meaning: ROGER is receipt only, WILCO is receipt plus compliance, NEGATIVE is no or not granted, and UNABLE is inability to comply.

Transmission of numbers

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Pronunciation

0	ZE-RO	7	SEV-en
1	WUN	8	AIT
2	TOO	9	**NIN-er**
3	**TREE**	.	DAY-SEE-MAL
4	**FOW-er**	100	HUN-dred
5	**FIFE**	1000	**TOU-SAND**
6	SIX		

How numbers are grouped

Single digits
heading 080 → HEADING ZE-RO AIT ZE-RO

SSR code
squawk 4216 → FOW-er TOO WUN SIX

Whole thousands
5 000 ft → FIFE TOU-SAND

Thousands + hundreds
2 500 ft → TOO TOU-SAND FIFE HUN-dred

Frequency decimal
121.5 → WUN TOO WUN DAY-SEE-MAL FIFE

1 Trap words

The deliberate spellings survive a noisy radio: 3 = TREE, 4 = FOW-er, 5 = FIFE, 9 = NIN-er, and 1000 = TOU-SAND.

2 Single digits

Call signs, headings, flight levels and SSR codes are spoken digit by digit, for example 'squawk four two one six'.

3 Hundreds and thousands

Round altitudes, heights and cloud use HUNDRED and TOU-SAND, so 5000 ft is 'fife tousand' and 2500 ft is 'too tousand fife hundred'.

4 Decimal point

A frequency decimal point is spoken 'DAY-SEE-MAL', so 121.5 is 'wun too wun DAY-SEE-MAL fife'.

Numbers are spoken digit by digit (3 tree, 4 fower, 5 fife, 9 niner); round altitudes use HUNDRED and TOU-SAND; a frequency decimal point is spoken 'DAY-SEE-MAL'.

Two of the 369 code-drawn study figures inside the SkyStudy question bank. Try them with the free demo at skystudyatpl.com/demo.

092 IFR Communications

IFR clearances, mandatory readback, holding, radio failure, emergencies.

TRANSITION ALTITUDE/LEVEL AND THE HOLD

FLIGHT LEVELS set 1013 hPa (QNE)

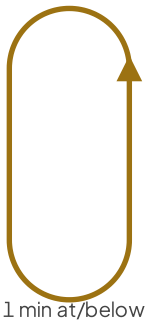
Transition Level (ATC assigned, floats)

layer: do not level off here

Transition Altitude (fixed, published)

ALTITUDES set QNH

HOLDING PATTERN



inbound leg: 1 min at/below 14,000 ft,
1.5 min above. Standard turns are right.

Below the transition altitude fly altitudes on QNH; **above the transition level** fly flight levels on 1013. The transition altitude is fixed and published; the transition level is assigned by ATC and moves with pressure. Never level off inside the layer between them.

MUST-KNOW DEFINITIONS AND CONCEPTS

- An IFR **clearance** authorises proceeding under specified traffic conditions; it is not an instruction to fly a specific track unless a route is stated.
- Items read back verbatim: route clearances, any runway entry/land/takeoff/hold-short/cross/backtrack instruction, runway-in-use, altimeter settings, SSR codes, level, heading and speed instructions, frequency changes, and VDF information.
- A **conditional clearance** is issued and read back as: identification, then the condition, then the clearance.
- **Transition altitude** is fixed and published (QNH); **transition level** is the lowest usable FL above it on 1013.2 and is assigned by ATC; do not level in the layer between.
- **RVSM** applies FL290 to FL410 inclusive and needs specific approval.
- **MAYDAY** = distress (grave, imminent danger); **PAN PAN** = urgency (a concern, no immediate danger). PAN can be upgraded to MAYDAY; it is a distinct category, not an automatic step.
- **SELCAL** lets a station call a specific aircraft by a unique tone code, relieving a continuous listening watch.
- **CPDLC** is text-based data link for clearances, complementing voice, especially oceanic/en-route.
- **MONITOR** = listen out on a frequency (no two-way needed); **CONTACT** = establish two-way communication.
- Radio failure IFR, in order of priority: fly the last acknowledged clearance, then the notified or expected further clearance, then the filed flight plan route.
- Holding uses standard **right** turns unless the chart or ATC specifies left; fly the published or amended missed approach if a landing is not completed.

KEY NUMBERS, LIMITS AND VALUES

- **CLEARED** = authorised to proceed; **CLIMB/DESCEND** = commence to the level; **MAINTAIN** = continue at the stated level/speed/heading.
- **EXPECT** = planning information only, not an authorisation to act.
- Transponder codes: **7500** hijack, **7600** radio failure, **7700** general emergency.
- Distress/emergency frequencies: **121.5 MHz VHF** (civil), **243.0 MHz UHF** (military); HF for long-range relay VERIFY.
- Standard pressure setting **1013.2 hPa** (29.92 inHg).
- RVSM vertical separation **1000 ft** FL290 to FL410 inclusive; **2000 ft** above FL410.
- Holding timing: **1 minute** inbound at or below 14,000 ft, **1.5 minutes** above 14,000 ft VERIFY.
- **MAYDAY** and **PAN PAN** are each spoken three times.
- SSR phraseology: SQUAWK (code), SQUAWK IDENT, SQUAWK STANDBY, SQUAWK CHARLIE (altitude reporting on).

MNEMONICS AND MEMORY ITEMS

- **CRAFT** to copy an IFR clearance: Clearance limit, Route, Altitude, Frequency, Transponder code.
- Codes by loss of normal operation: **7500** someone else has control, **7600** you cannot talk, **7700** something is critically wrong.
- **EXPECT is for your ears, not your hands**: it feeds the plan, it never authorises action.
- **Transition altitude is fixed like the ground; transition level floats with the weather.**
- Each distress/urgency call is said **three times** so it cannot be mistaken for routine chatter.

COMMON EXAM TRAPS

- Do not act on **EXPECT** before the actual clearance is issued.
- Not every transmission needs a full readback; only the specific safety-critical items do, others may be acknowledged with the callsign.
- Do not confuse **MONITOR** (listen only) with **CONTACT** (call in).
- **Transition level** varies with QNH and is assigned by ATC; it is not fixed like the transition altitude.
- ATC will not openly acknowledge a **7500** squawk by name; controllers use indirect phraseology.
- **PAN PAN** does not automatically escalate to MAYDAY; the crew must declare it.
- Holding turns default to **right** unless stated otherwise.
- VMC radio failure (continue in VMC, land nearest suitable) differs from the IMC rule (follow the last clearance / flight plan).
- **CPDLC** does not replace voice for distress and urgency.
- A conditional clearance is invalid if the **condition** is not stated before the clearance, or omitted in the readback.
- **121.5 MHz is VHF** (civil), **243.0 MHz is UHF** (military); do not reverse them.

Mandatory read-back items

090 · COMMUNICATIONS

Safety-related items you must read back to ATC

- ATC route clearances
- Runway: enter, land, take off
- Runway: cross, hold short, backtrack
- Runway in use
- Altimeter settings (QNH / QFE)
- SSR (transponder) codes
- Newly assigned communication frequencies
- Level instructions
- Heading and speed instructions
- Transition levels

1 Why read back

A full read-back lets the controller confirm the clearance was received correctly. Only the safety-related items above are read back, ended with your call sign.

2 Roger and Wilco are not enough

ROGER only means the transmission was received and WILCO means it will be complied with; neither replaces a required read-back of a safety-related item.

3 End with your call sign

Every read-back or acknowledgement is terminated by the aircraft call sign, so the controller knows which station answered.

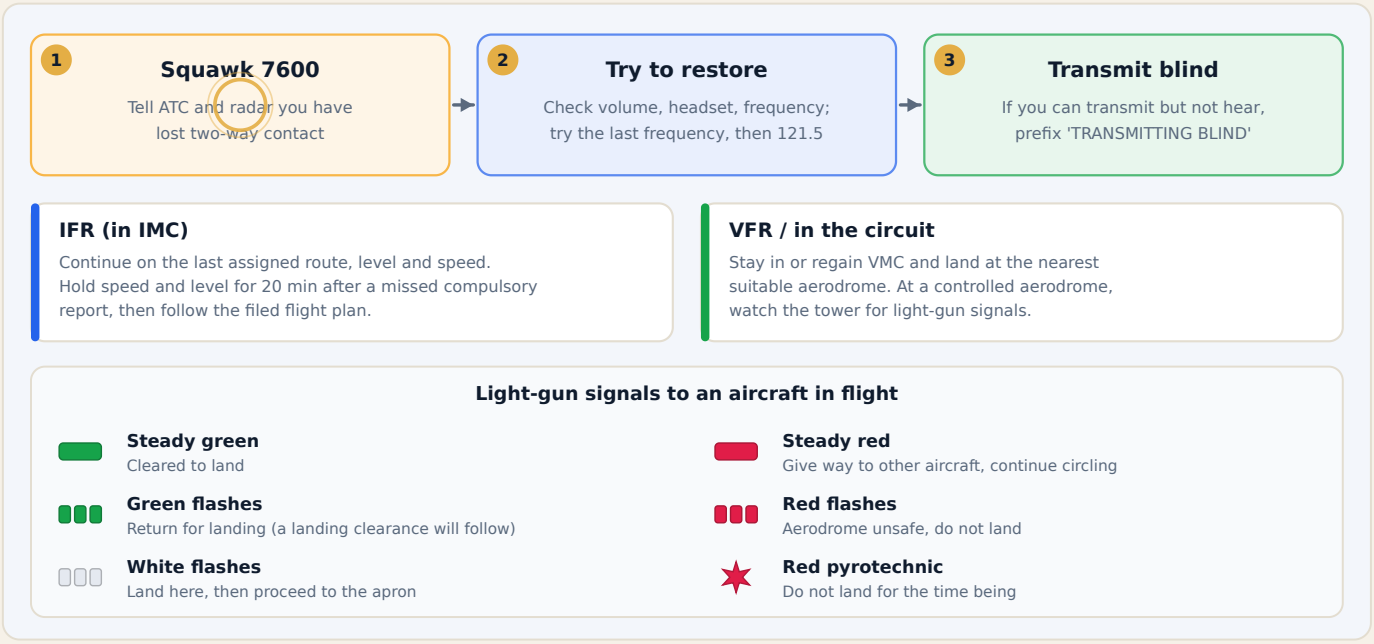
4 Say 'flight level'

Levels flown on the standard setting are preceded by 'flight level', so read 'flight level eight zero', never the bare number.

Route clearances, runway clearances, runway-in-use, SSR codes, altimeter settings, frequency changes, level, heading and speed instructions and transition levels are read back, ended with your call sign.

Radio communication failure

090 · COMMUNICATIONS



1 Squawk 7600
Select 7600 so ATC and radar recognise a two-way communication failure and can route other traffic clear of you.

2 Restore, then 121.5
Check volume, headset and the selected frequency; try the previous frequency, then 121.5 MHz, before assuming full failure.

3 Transmit blind
If you can transmit but not receive, make blind transmissions prefixed 'TRANSMITTING BLIND', at reporting points and before manoeuvres.

4 IFR route and timing
In IMC hold the last assigned speed and level for 20 minutes after a missed compulsory report, then continue on the filed flight-plan route and levels.

On radio failure squawk 7600, try to restore then 121.5, and transmit blind if you can only transmit; IFR hold level and speed then fly the flight plan, VFR obey the light-gun signals.

Two of the 369 code-drawn study figures inside the SkyStudy question bank. Try them with the free demo at **skystudyatpl.com/demo**.

Exam technique in 60 seconds

1. Answer everything

EASA ATPL exams have **no negative marking** VERIFY, so never leave a blank. A guess after eliminating two options is a coin flip you paid for.

2. Budget the clock

Divide the minutes by the questions before you start. Anything eating more than about **90 seconds**, flag it and move on; unanswered easy questions at the end cost the most.

3. Read the stem twice

Watch for **NOT** and **except**, for "most correct", and for unit switches: kg vs lb, nm vs km, hPa vs inHg, ft vs m. Half the classic traps are in the wording, not the theory.

4. Eliminate first

Cross out the two clearly wrong options before comparing the last two. Most distractors are built from the **right numbers in the wrong place**.

5. The night before

Sleep beats cramming. Skim only the Traps boxes and your flagged weak areas, then stop. Fatigue loses more marks than any single forgotten number.

6. Check the flags

Leave the last minutes to revisit flagged questions and to confirm you answered **every** question. Change an answer only when you can say why the first one is wrong.

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