EASA ATPL(A) · THEORY REVISION

The ATPL Cheat Sheet
081 Principles of Flight

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.

081 Principles of Flight | **59** memory items

One of 14 subjects; the full set is free at skystudyatpl.com/atpl-cheat-sheet

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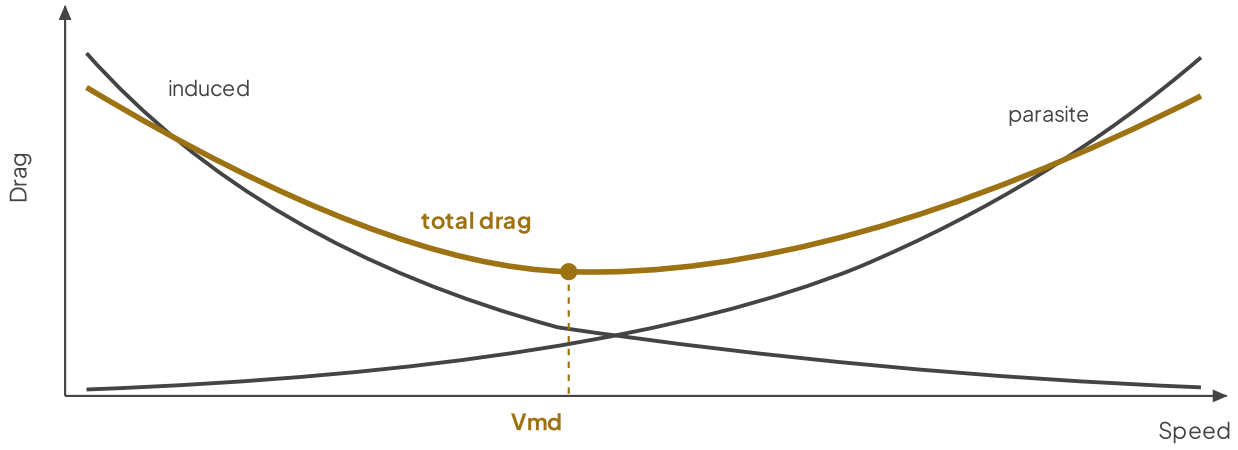
081 Principles of Flight

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

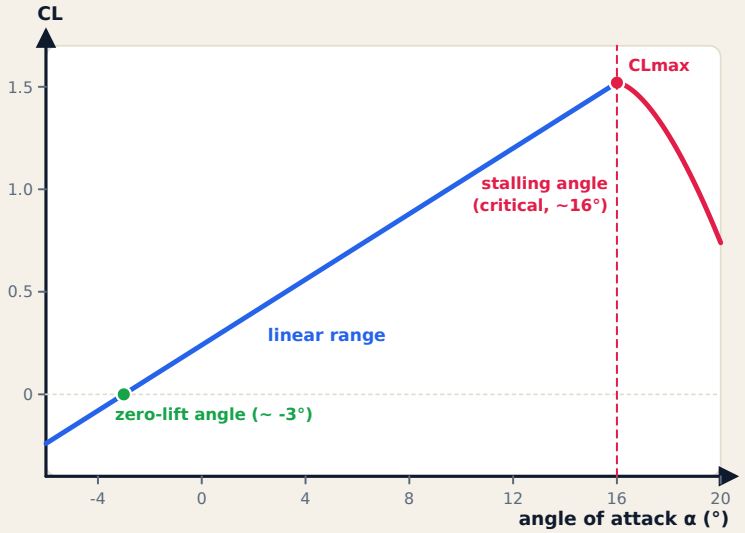
- **Camber curves, chord is straight.**
- AoA moves with the flight path; incidence is bolted to the airframe.
- **Coffin corner squeezes from both ends**: stall buffet speed rises with altitude, Mach buffet speed falls.
- **Adverse yaw: down aileron drags** the nose to the outside of the turn.
- **Static 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

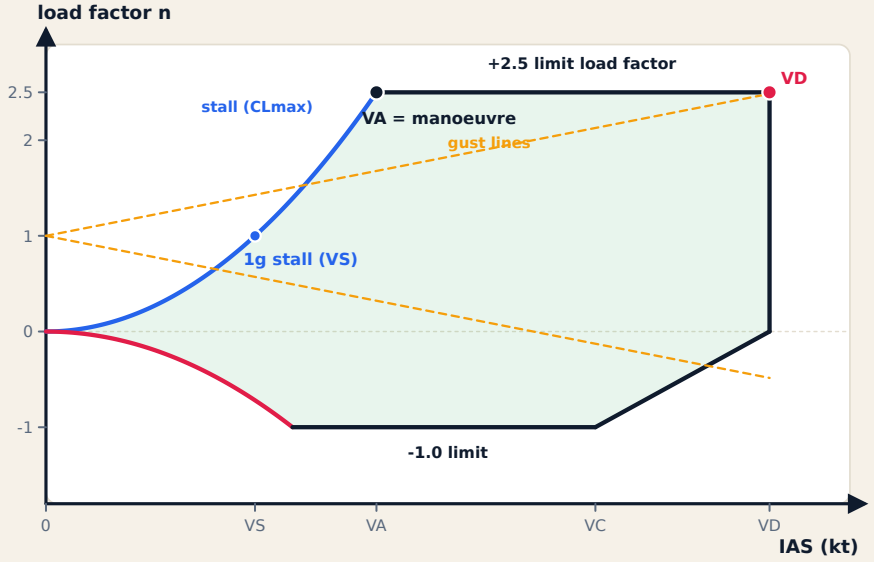
A cambered aerofoil still makes zero lift at a small NEGATIVE angle of attack, near -3 to -4 degrees.

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)



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.

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