

The ATPL Cheat Sheet

031 Mass and Balance

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.

031 Mass and Balance

50 memory items

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

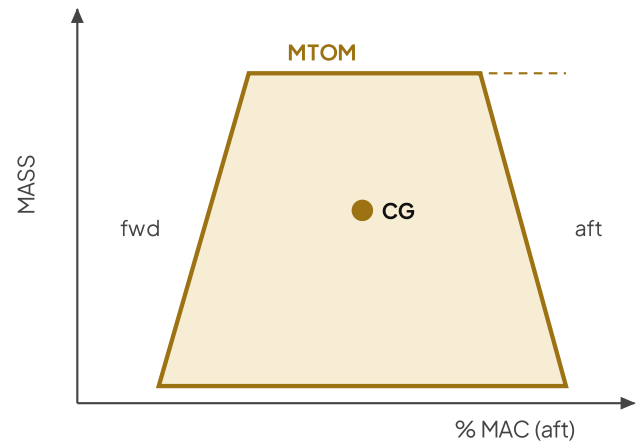
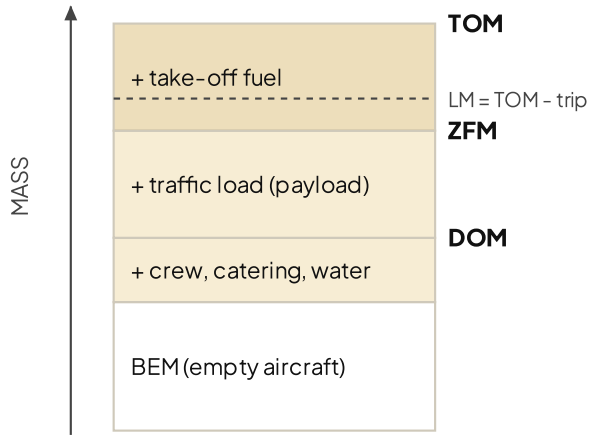
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Mass and Balance

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 = $\frac{\sum(\text{mass}_i \times \text{arm}_i)}{\sum(\text{mass}_i)}$.

- %MAC = $\left(\frac{\text{CG arm} - \text{LEMAC arm}}{\text{MAC length}} \right) \times 100$.

- Adding mass: New CG = $\frac{\text{Old moment} + \text{added mass} \times \text{its arm}}{\text{Old mass} + \text{added mass}}$.

- Removing mass: New CG = $\frac{\text{Old moment} - \text{removed mass} \times \text{its arm}}{\text{Old mass} - \text{removed mass}}$.

- Shifting mass: CG change = $\frac{\text{mass shifted} \times \text{distance shifted}}{\text{Total mass}}$.

- Mass to shift for a required CG change = $\frac{\text{Total mass} \times \text{required CG change}}{\text{distance shifted}}$.

- Index = $\left(\frac{\text{Mass} \times \text{Arm}}{\text{reduction constant}} \right) + \text{reference constant (type-specific)}$.

- 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.

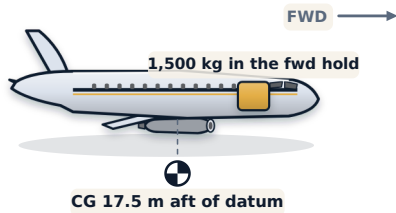
◆ COMMON EXAM TRAPS

- 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 **arms 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

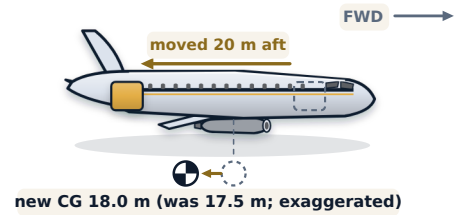
1

BEFORE the move



2

AFTER the move



$$\text{CG shift} = (\text{mass moved} \times \text{distance moved}) / \text{total mass}$$

$$= (1,500 \text{ kg} \times 20 \text{ m}) / 60,000 \text{ kg} = 0.5 \text{ m aft}$$

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: $(1,500 \times 20) / 60,000 = 0.5 \text{ m}$.

4 Light aircraft shift more

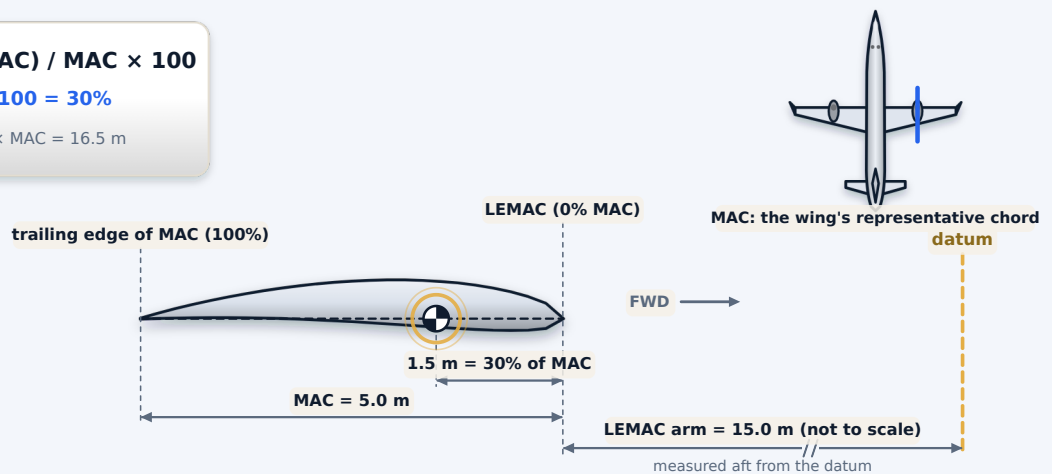
Total mass sits in the denominator, so the identical move on a lighter aircraft produces a larger CG shift; heavy aircraft are less sensitive.

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

$$\% \text{ MAC} = (\text{CG} - \text{LEMAC}) / \text{MAC} \times 100$$

$$= (16.5 - 15.0) / 5.0 \times 100 = 30\%$$

reverse: $\text{CG} = \text{LEMAC} + 0.30 \times \text{MAC} = 16.5 \text{ m}$



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 $\text{CG} = \text{LEMAC} + (\% \text{ MAC} / 100) \times \text{MAC}$: $15.0 + 0.30 \times 5.0 = 16.5 \text{ m}$ 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.

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