Objectives	▪ The student will understand the theory behind weight and balance and will obtain the skills needed to calculate an aircraft's weight and balance
Motivation	▪ ***F-27 Guernsey*** ▪ ***Atlas Air 747***
Elements	▪ Terms ▪ Weight & Flight Characteristics ▪ Center of Gravity & Flight Characteristics ▪ W&B Control ▪ Ways to Calculate W&B ▪ Weight Shift
Schedule	▪ Overview ▪ Terms ▪ Content ▪ Conclusion & Review
Equipment	▪ White Board & Marker ▪ Miniature Aircraft ▪ Ruler ▪ Pen ▪ Quarters or Small Weights
CFI Actions	▪ Present lesson ▪ Use teaching aids ▪ Provide sample problems ▪ Ask/ answer questions
Student Actions	▪ Participate in discussion ▪ Take notes ▪ Ask / answer questions ▪ Review printout and sample problems as homework
Completion Standards	▪ The Student Understands the Factors Relating to Weight and Balance and How It Effects Airplane Control, Stability and Performance. The Student Also Can Calculate the Weight and Balance for A Given Situation and Adjust as Necessary.

Introduction

Overview

Review Objectives / Elements

What

Airplane weight and balance is basically, balancing the airplane within approved limits

Why

Pilots need to keep the aircraft within safe limits and balance the loads carried to maintain control of the airplane

How

Terms

- **Reference Datum (RD)** - An imaginary vertical plane from which all horizontal distances are measured for balance purposes
  - The datum may be located anywhere the manufacturer chooses
  - Common locations are the nose, the engine firewall, the wing's leading edge, or ahead of the nose
- **Station** - A location on the airplane fuselage usually given in terms of distance from the reference datum
- **Arm** – The horizontal distance, usually in inches, from the RD to the Center of Gravity of an item
  - Arms ahead of the reference datum are negative and those behind the reference datum are positive
    - If the reference datum is ahead of the nose, all the arms are positive
- **Moment** – A force that causes or tries to cause an object to rotate
  - It is the product of the weight of an item multiplied by its arm and expressed in pound-inches
- **Moment Index** – The moment divided by a reduction number (100/1000) to get it smaller/reduce errors
- **Center of Gravity (CG)** – the point at which an airplane would balance if it were suspended at that point
  - The distance of the CG from the RD is found by dividing the total moment by total weight
- **CG Limits** – The extreme (forward/aft) CG locations within which the plane must be operated at a weight
- **Usable Fuel** – the fuel available for flight planning
- **Unusable Fuel** – the fuel in the tanks that cannot be safely used in flight or drained on the ground
- **Basic Empty Weight** – the weight of the standard airplane, optional equipment, unusable fuel, and full operating fluids (including oil)

- **Payload** – the weight of the occupants, cargo and baggage
- **Useful Load** –difference between takeoff weight (or ramp weight if applicable) and basic empty weight
- **Max Ramp Weight** – the max weight approved for ground maneuvers (includes start, taxi, run-up fuel)
- **Max Takeoff Weight** – the max weight approved for the start of the takeoff run
- **Max LDG Weight** – The max weight approved for landing touchdown
- **Max Zero Fuel Weight** – the max weight exclusive of usable fuel
- **Standard Weights** – Established for numerous items in weight and balance computations
    - **100LL**: 6lbs , **Jet Fuel:** 7lbs, **Oil:** 7.5lbs, **Water:** 8.35lbs (all per gallon)

Weight & Flight Performance

Weight & Flight Performance

- Operating above the max gross weight will result in:
    - Higher takeoff speeds, longer takeoff roll, reduce rate of climb, lower maximum altitude, reduced cruise speed, shorter range, reduced maneuverability, higher stall speed, longer landing roll, excessive weight on nose wheel
    - The decreased climb and cruise performance can lead to excessive wear on the engine and increased fuel burn

Weight and structure

- Structural failures from overloading may be catastrophic, but often they affect the aircraft structure progressively making it difficult to detect or repair
- An airplane is designed to withstand the loads presented in section 2 of the POH/AFM

Weight and stability

- Weight distribution has a great effect on how the aircraft acts

Airplane with forward loading

- Slower compared to a forward cg
    - More downforce is required to keep nose up which results in higher AOA in cruise flight thus, more drag and higher stall speeds
    - "Already closer to critical angle of attack"
    - The airplane is more controllable due to the leverage on control surfaces
    - Demonstrate with plane
    - Stalls are easier to recover from due to the "heavy nose"

Airplane with Aft Loading

- Requires less downforce to maintain level flight resulting in lower AOA and higher cruise speeds
- Stall speeds are lower due to the lower AOA
  - Although stall speed is lower stall recovery is harder due to the tail-heavy nature
  - If CG goes aft out of the limits, stall and spin recovery may become impossible
- Controls are less effective due to the shorter arm between CG and empennage

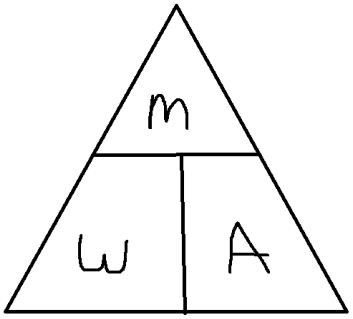
Weight Balance Control

- Use the AFM/POH for aircraft weight and balance
  - Do not exceed the manufacturer's eight and CG limits
- There are various methods to determine weight and balance:
  - Computational
  - Graphical
  - Table

Determining Weight & Balance

Computational Method

- The computational method uses basic math functions to compute W&B
  - Teach how to use the W&B pyramid
- Add up all the weights
- Find the arms from the POH then use the computational method to determine the CG and total weight
  - If weight is too high remove items, fuel or passengers
  - If CG is out of limits, move items to attempt to bring it back into limits



Graphical method

- The computational method uses a variety of charts to determine the moment and CG of an aircraft
- To use it, simply plot the weight on the Y axis and move over until you intercept a line for the given station. Your moment will be directly below this on the X axis

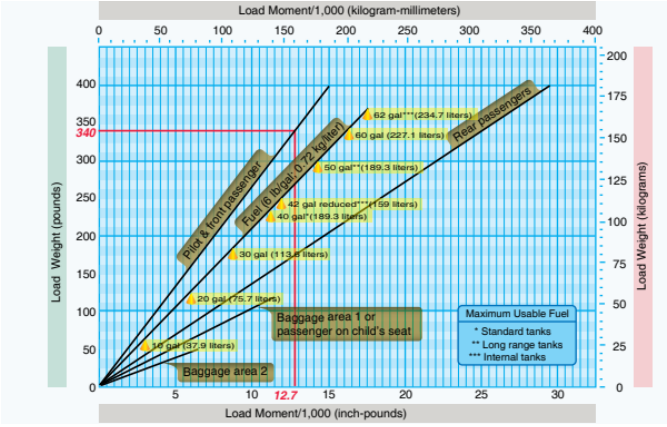
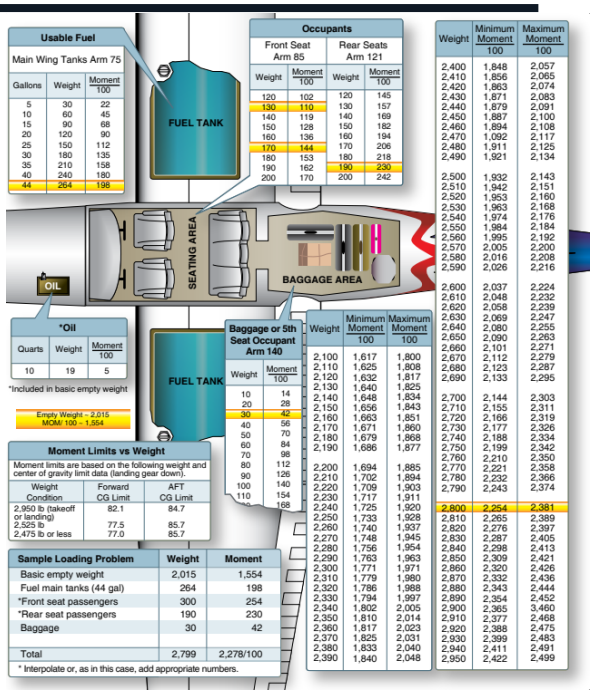


Table Method

- The table method uses a table for each station. The table has a variety of weights that will give you the moment.
- Values may need to be interpolated



Weight Shift

- When items are shifted around the aircraft, the weight shift formula can be used to quickly find the new CG

$$\frac{\text{Weight shifted}}{\text{Total weight}} = \frac{\Delta CG \text{ (change of CG)}}{\text{Distance weight is shifted}}$$

- This gives a Delta CG or Change in CG
- The value will either be positive or negative (added or subtracted from previous CG)

Conclusion & Review

Review the Main Lesson Points

- Weight and balance greatly affect flight and therefore, its very important to the safety of flighty

Review

1. Weight and balance terms
2. Effects on weight balance on performance
3. Methods of weight and balance control
4. Sample problems on printout