Area of Operation **II** - Task **D**

Principles of Flight

Content

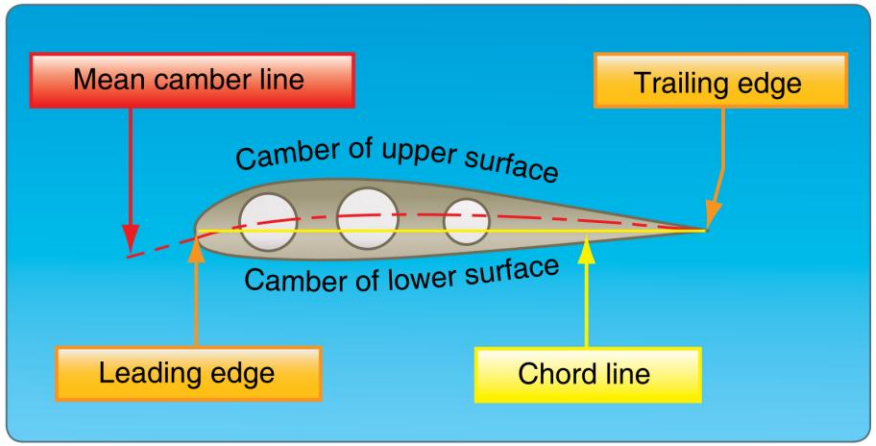
Key References:

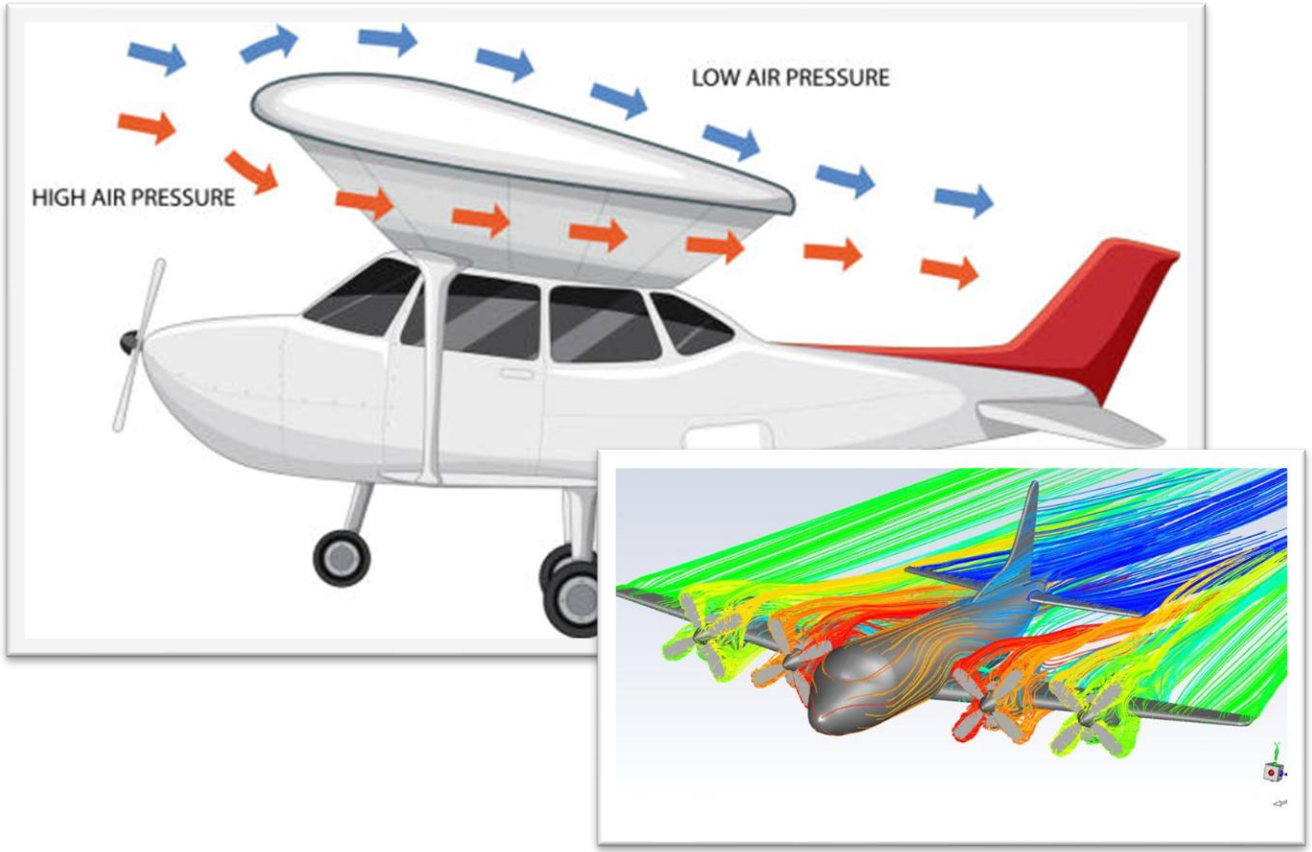
- Airplane Flying Handbook
- Pilot's Handbook of Aeronautical Knowledge

1. Introduction

- **What**: Understand how do airplanes fly and why they perform/behave in the way they do
- **Why**: The pilot must have a well-founded concept of the forces which act on the airplane, the advantageous use of these forces, as well as the limitations that can impact a particular airplane

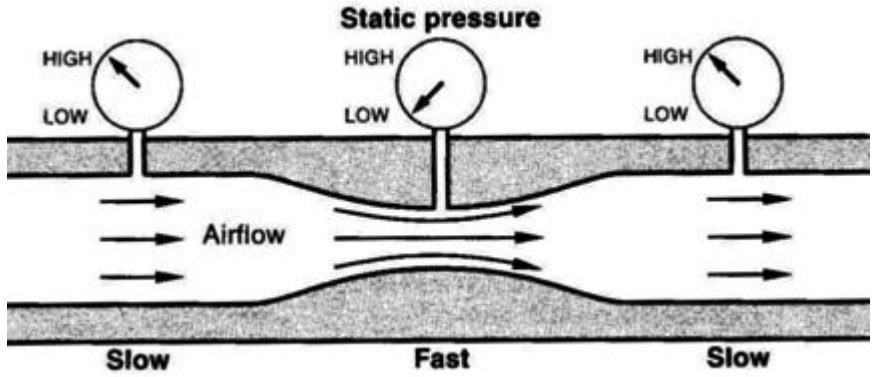
1. **Airplanes creates Lift in the wings**
   - Bernoulli's Principle
   - Newton's 3rd law of Motion
2. **Wings uses Airfoils**



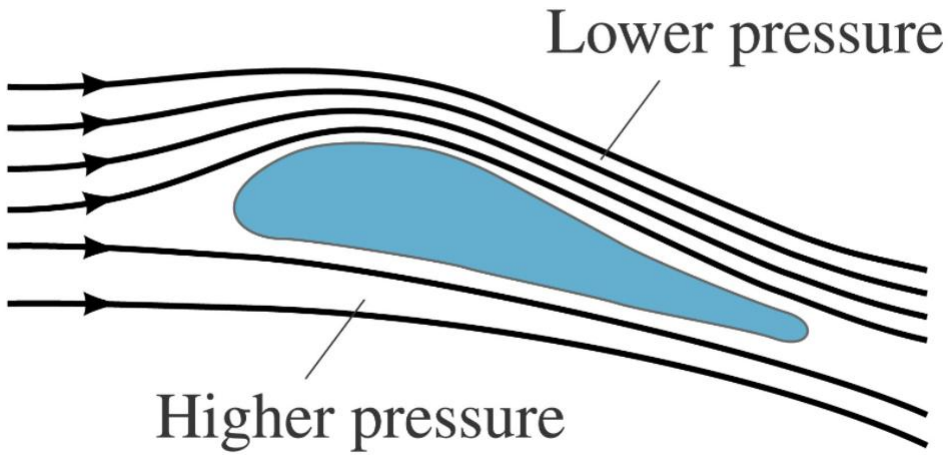


2. Basic Aerodynamics

- **Bernoulli's Principle**: Static Pressure decreases as fluid's flow speeds parallel to the surface
- **Newton's 3rd Law of Motion**: "Action and Reaction"



Venturi Effect



2. Basic Aerodynamics

- **Forces**
  - **Lift**: Perpendicular to the relative wind
  - **Drag** (induced): Parallel to the relative wind
- **Aerodynamic Stalls**
  - Happens when the critical AoA is reached and lift is lost
  - Any speed, any phase of flight

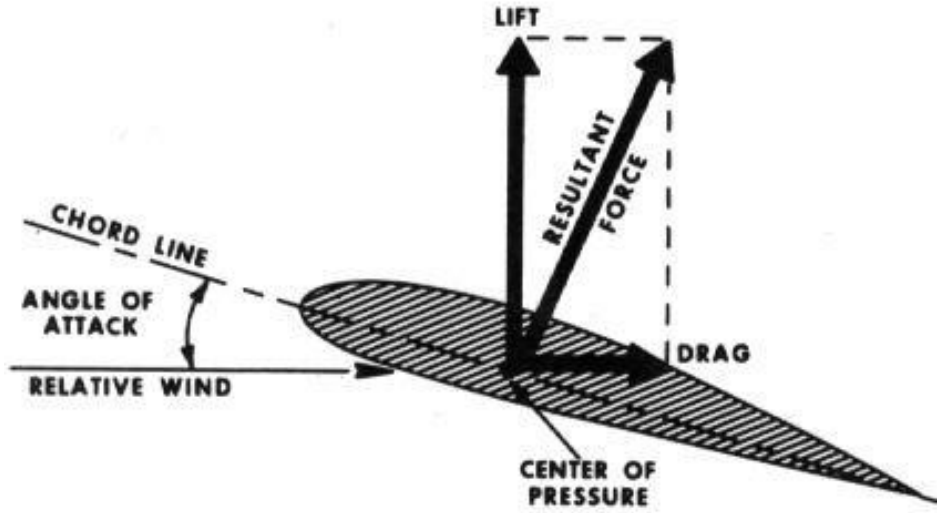
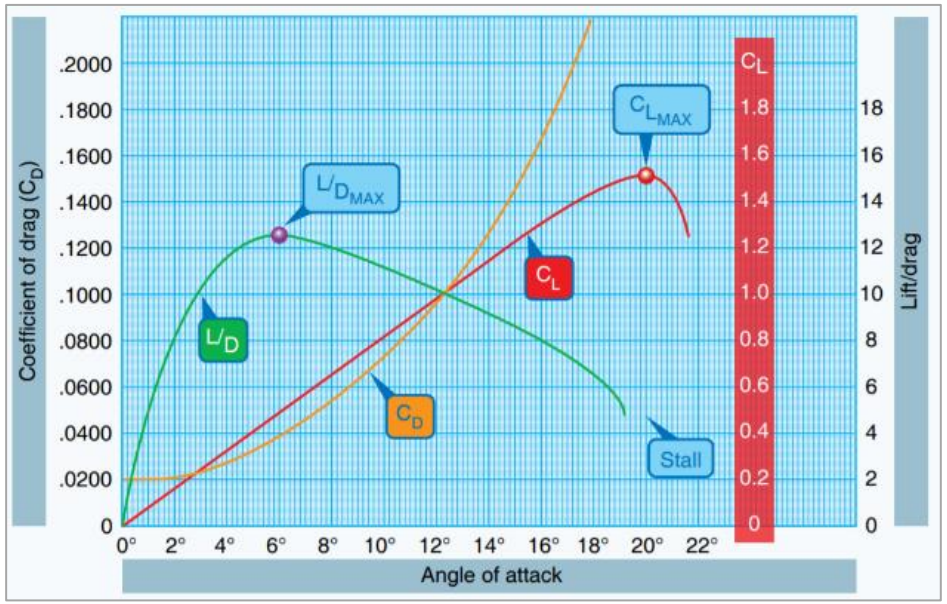
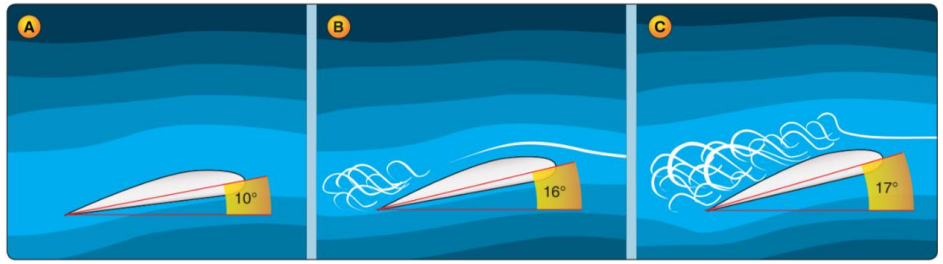


Figure 17–8 Force Vectors on an Airfoil

$$\text{Lift} = \frac{1}{2} p C_L V^2 S$$

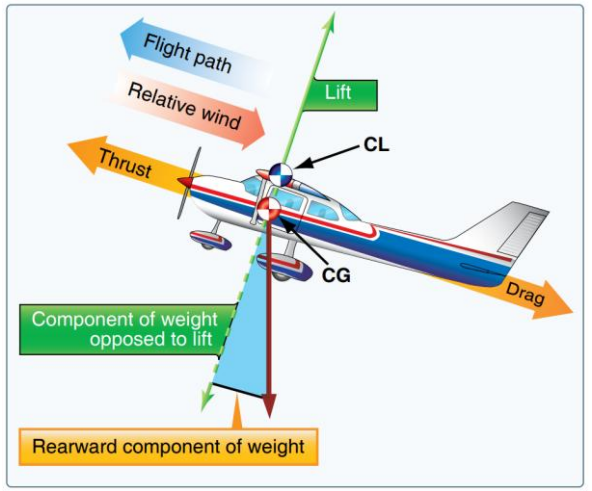
- Angle of Attack (C_L) – Changing pitch changes AOA and therefore lift
- Airspeed (V^2) – Lift is proportional to the square of airspeed
- Surface Area (S) – Flaps and slats can increase surface area

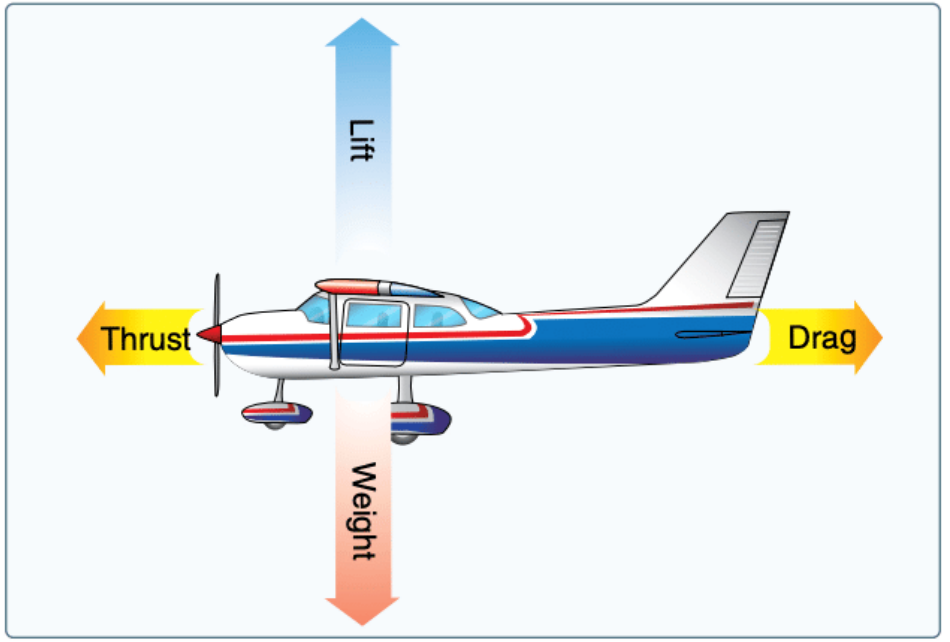


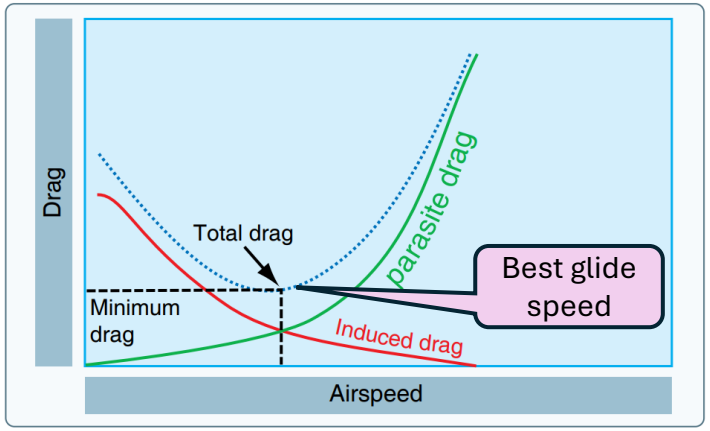


3. Forces of Flight

- **Lift** - Upward force created by the effect of airflow over/under the wing
- **Weight** - Caused by the downward pull of gravity
- **Thrust** - Forward force propelling the aircraft through the air
- **Drag** - Backward force limiting the speed of the airplane
  - Parasite Drag
    - *Form – Size and shape of the aircraft*
    - *Interference – e.g. wing root*
    - *Skin Friction – Roughness of the airplane's surface*
  - Induced Drag – Byproduct of lift



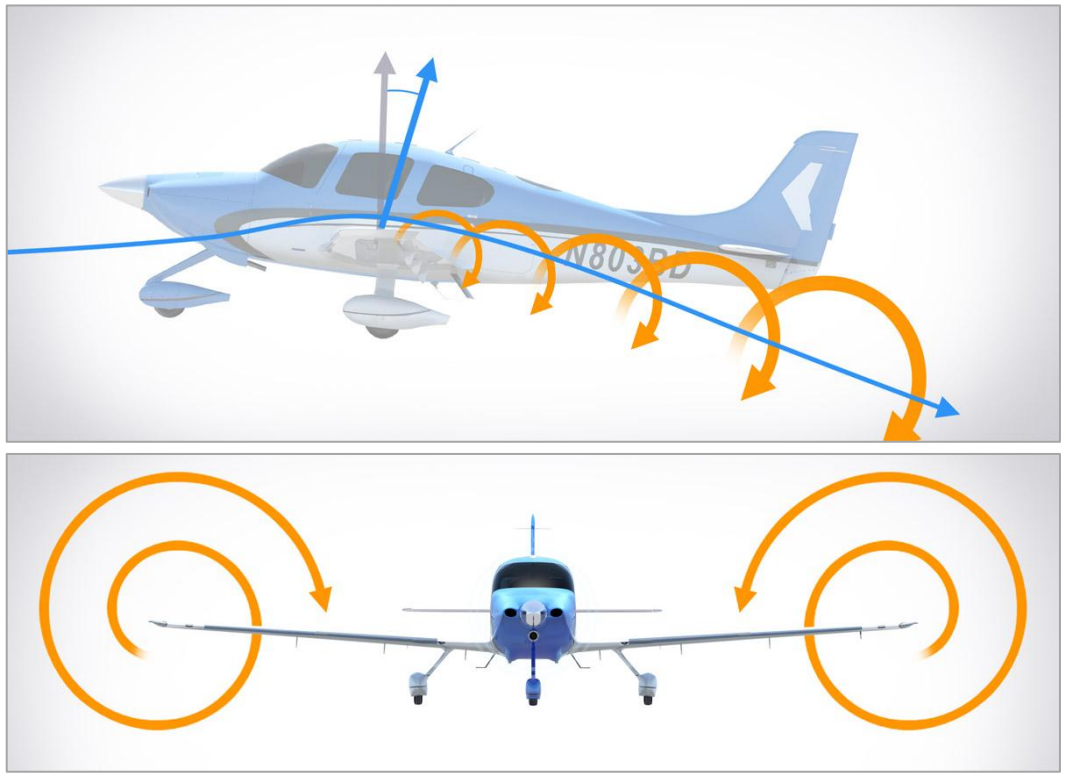




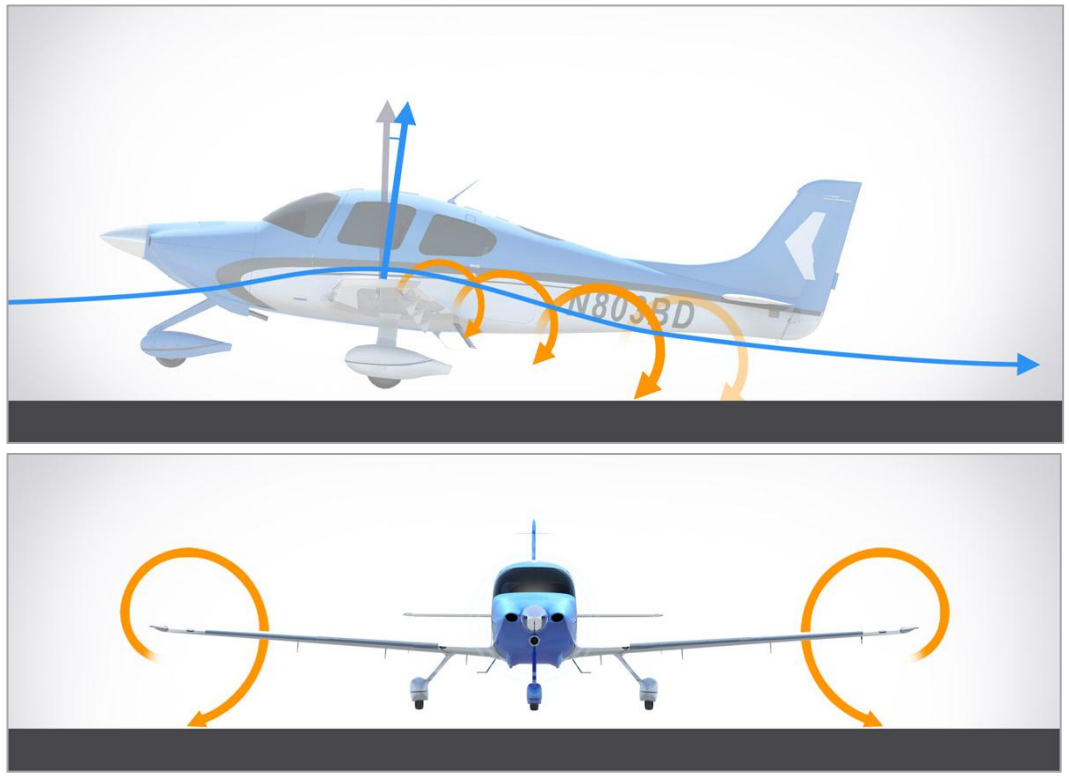
Physics of **Turns**, **Climbs** and **Descent** are covered in a sections VIII (C, D and E)

3. Forces of Flight

- **Ground Effect** *(Altitude less than half of the wingspan)*
  - Interference w/ the ground increases Lift and reduces induced Drag
  - May cause float on landing and premature lift-off on takeoff



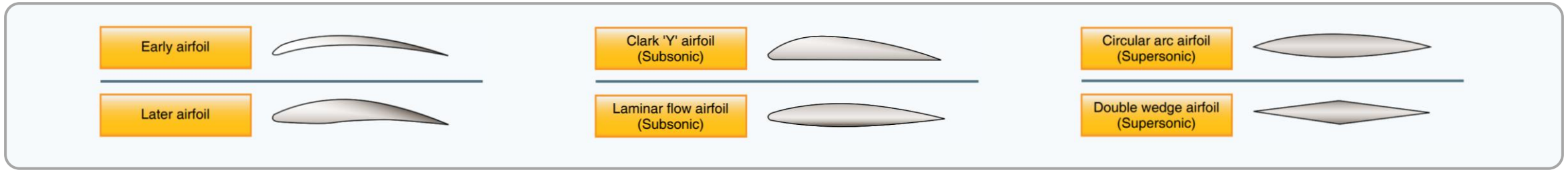
High Altitude

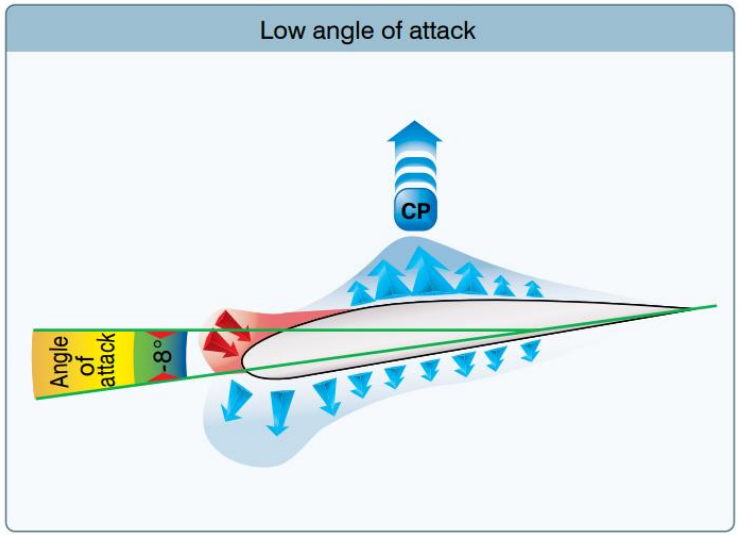


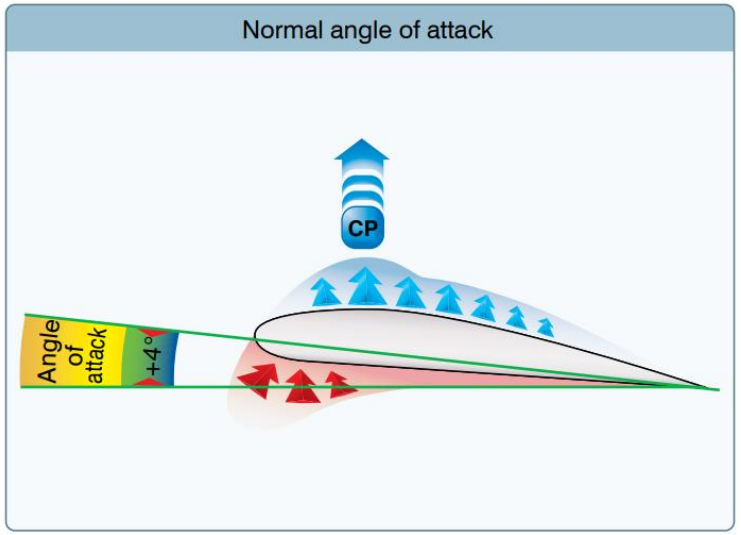
Near the Ground

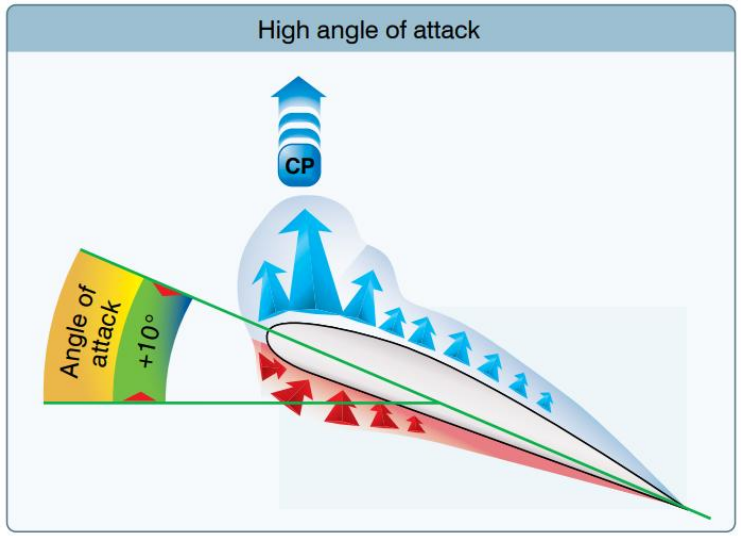
4. Airfoil Design Characteristics

- **An airfoil is a structure designed to obtain reaction upon its surface from the air through**
  - Lift and Drag comes from the pressure distribution on the airfoil's surface
  - Center of Pressure: moves forward as AoA increases





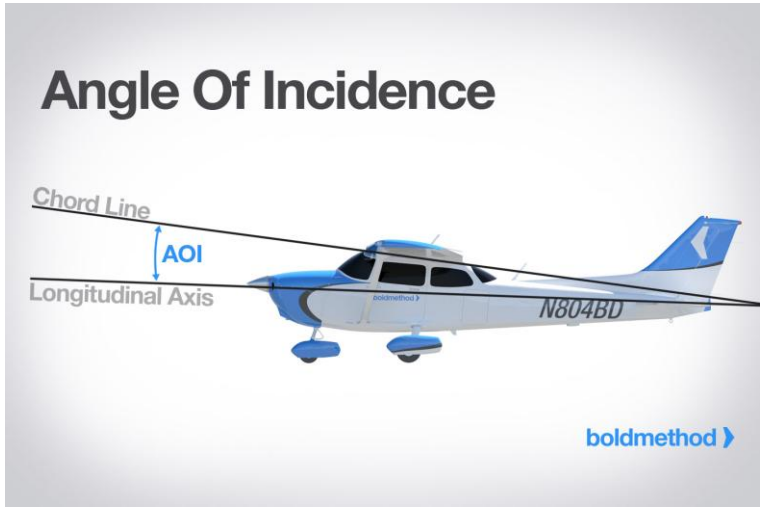


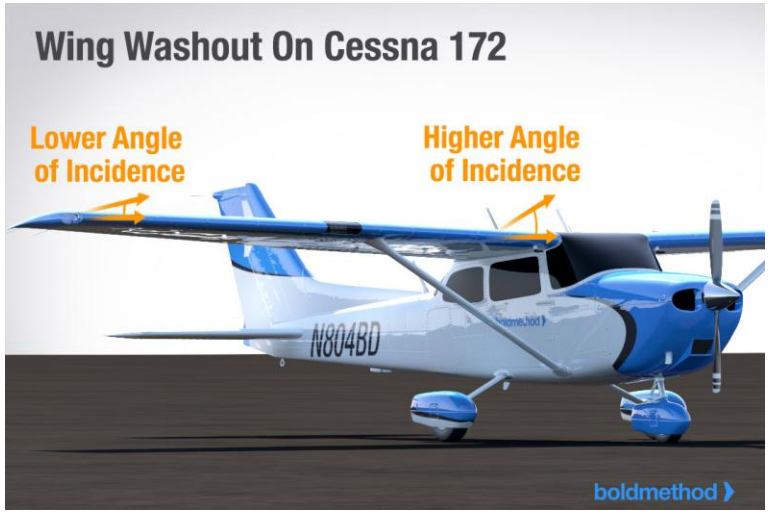


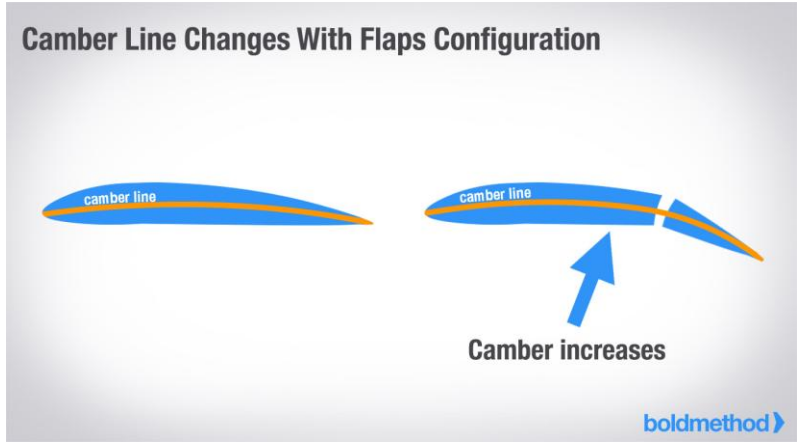
4. Airfoil Design Characteristics

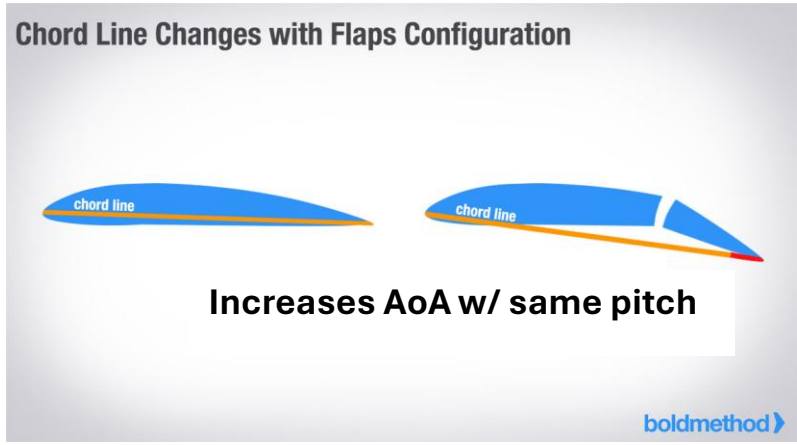
- **The airfoil in the wing have different angle of incidences across the wing's length**
  - Lower AoA at the tips (to not stall the ailerons)

- **Flaps changes the wing (airfoil)**
  - Increases the area of the wing (more lift and more drag)
  - Angles the chord line (increasing AoA without changing pitch)





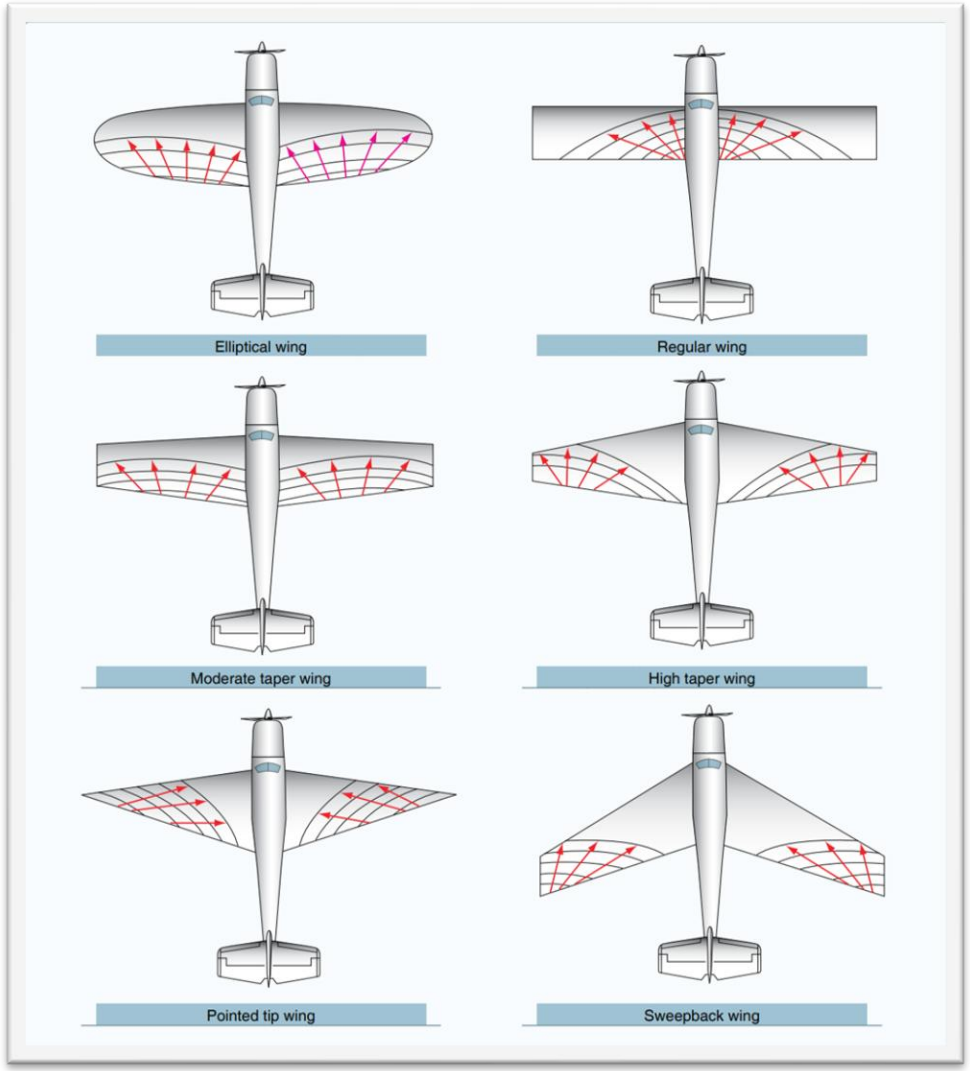




5. Wing Planform

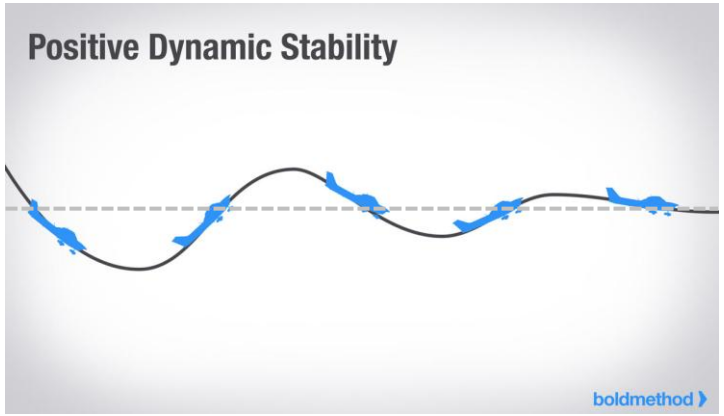
- **Planform: Outline of the wing from above**
  - Varies with desired aerodynamic characteristics
  - Stalls, stability, weight, strength
  - Taper, Aspect Ratio & Sweepback affect planform

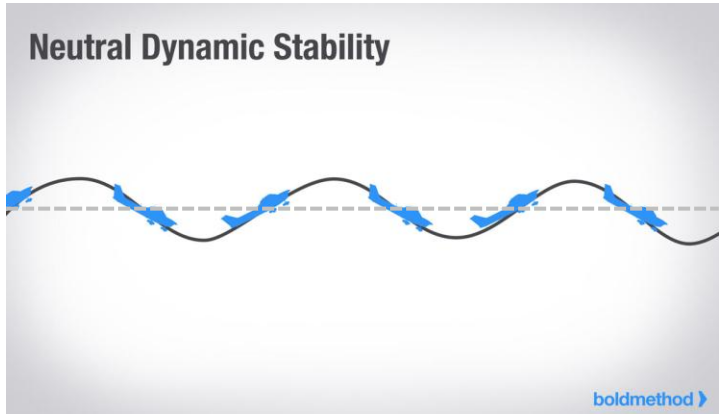
- **Aspect Ratio (AR) – Ratio of wingspan to chord**
  - Primary factor in determining lift / drag ratio
  - Increased AR decreases drag, and vice versa
- **Taper - Decrease of chord from root to tip**
  - Structurally and aerodynamically more efficient
- **Sweepback – Rearward slant of the wing**
  - Reduces shockwaves (drag) and enable high airspeeds

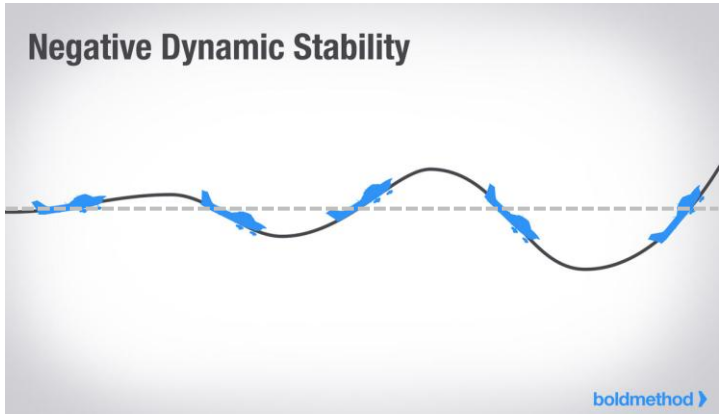


6. Stability & Controllability

- **Stability ➔** *Inherent quality to correct for disturbances and return to the original flight path*
  - Static Stability – Aircraft's initial tendency when disturbed
    - *Positive (returns to original state), Neutral (remains in new condition), Negative (trends away from original state)*
  - Dynamic Stability – Aircraft's response over time when disturbed





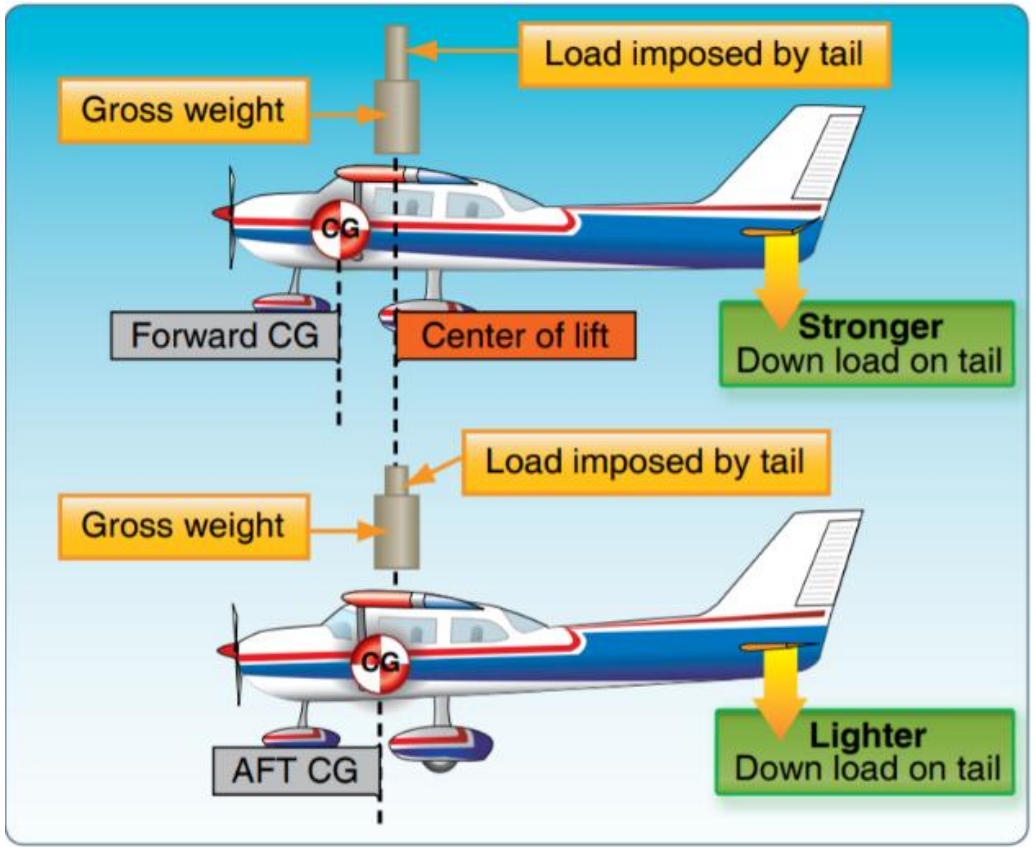


- **Stability affects the capacity to Control and Maneuver the airplane**
  - Controllability: quality of the aircraft to respond to inputs and follow paths
  - Maneuverability: performance in changing attitude/direction while withstanding stress
    - ✓ *More stable → Less maneuverable*

6. Stability & Controllability

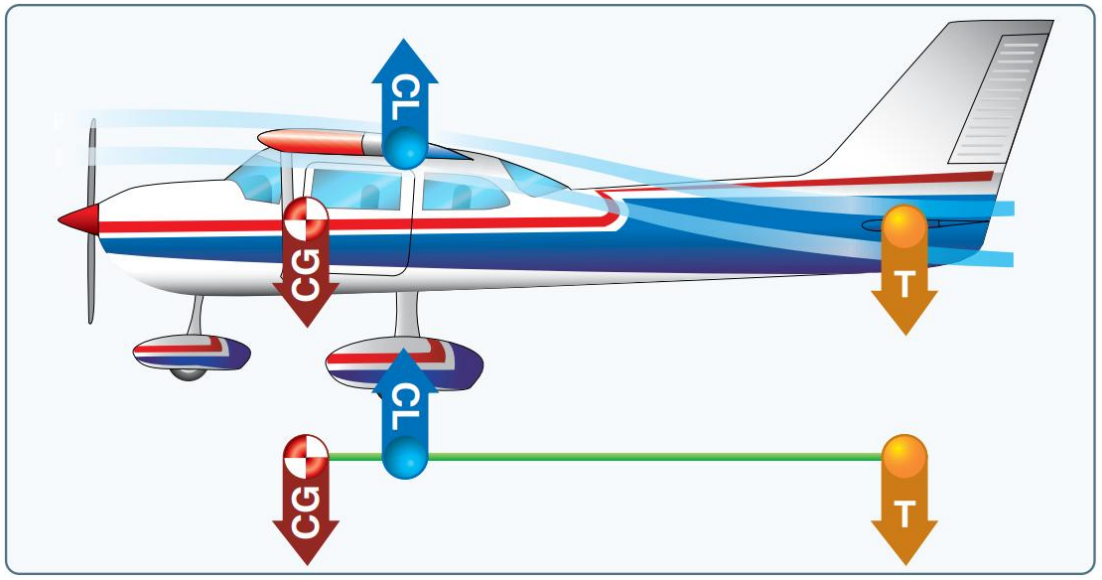
- **Forward CG**
  - Needs higher elevator down forces (higher load in the wings)
  - Higher load required higher AoA ➔ more induced drag, slower cruise speed, and a higher stall speed
  - Stall and Spin recovery becomes easier as the CG moves fwd (longer arm from the CG to the elevator and rudder)
  - More stable (nose drop faster), less maneuverable
- **Aft CG**
  - Needs less elevator down forces (lower load in the wings)
  - Lower load required lower AoA ➔ less induced drag, faster cruise speed, and a lower stall speed
  - Stall recovery becomes more difficult as the CG moves aft (shorter arm from the CG to the elevator)
  - Less stable, more maneuverable
- **Weight: A heavier aircraft is more stable (higher inertia)**

Center of Gravity

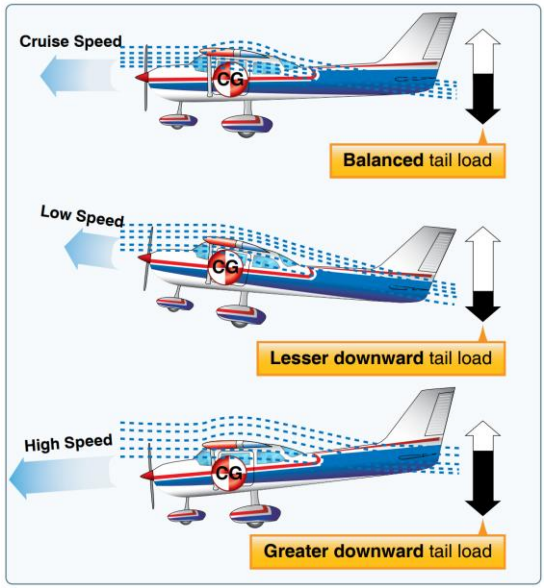


6. Stability & Controllability

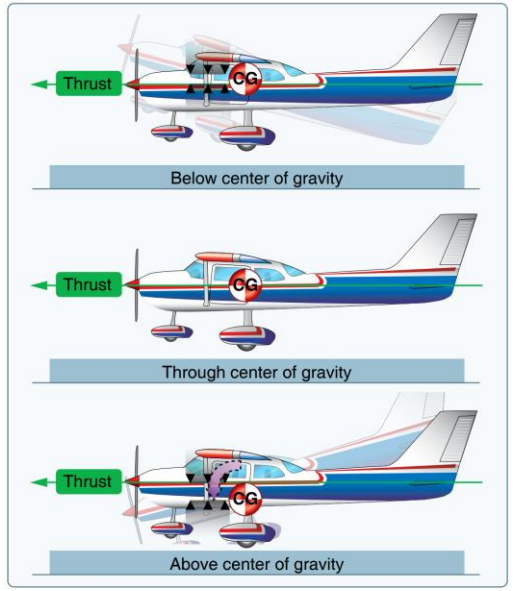
- **Longitudinal Stability**
  - About the lateral axis (pitch)
    - *In a stable aircraft, if the plane is nosed down, the wing / tail moments will bring it back up, and vice versa*
  - Dependent on 3 factors
    - *Location of the wing relative to the CG*
    - *Location of the horizontal tail relative to the CG*
    - *Size of the tail surfaces*



Elevator authority and CG



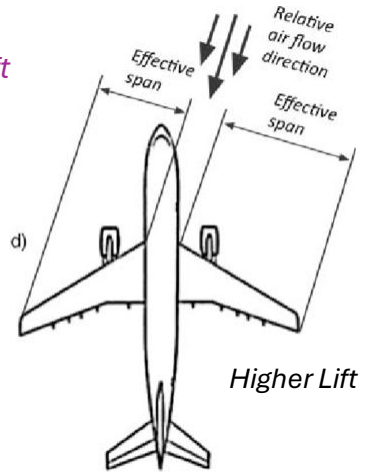
Effect of Thrust on pitch



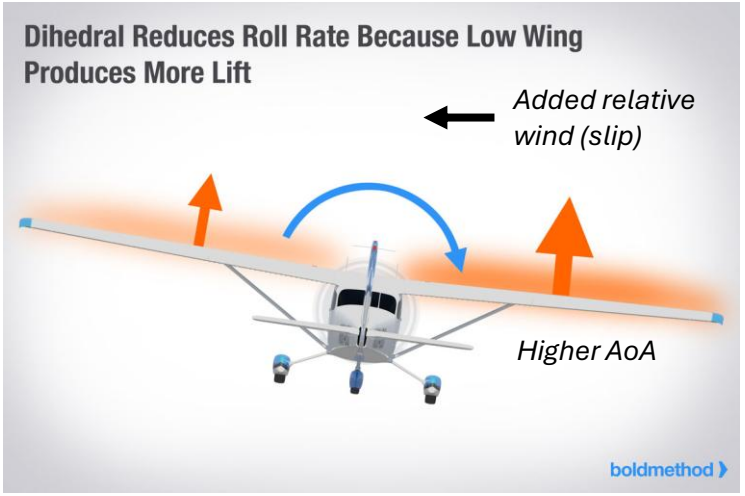
6. Stability & Controllability

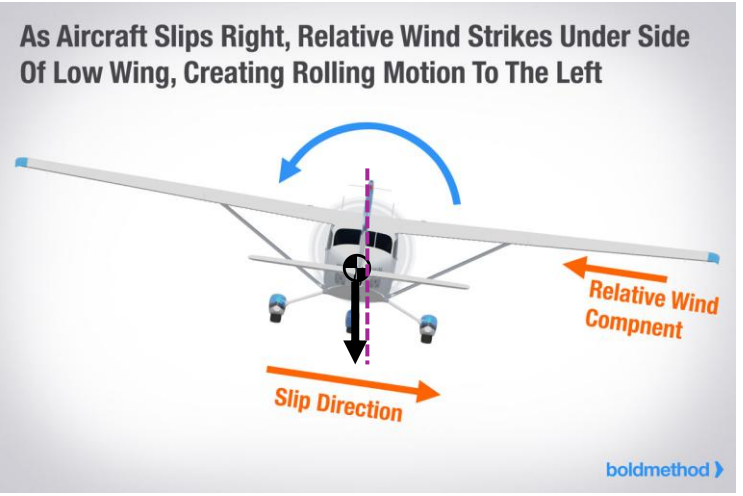
- **Lateral Stability**
  - About the longitudinal axis (bank)
- **3 Factors**
  - Dihedral: Upward angle of the wings from root to tip
  - Sweepback: Increases effects of dihedral (10º sweepback = 1º dihedral)
  - Keel Effect & Weight: "Pendulum" effect in high-wing aircraft

Sweepback increases Lateral stability:
- *Wing drop → side slip → increase lift*



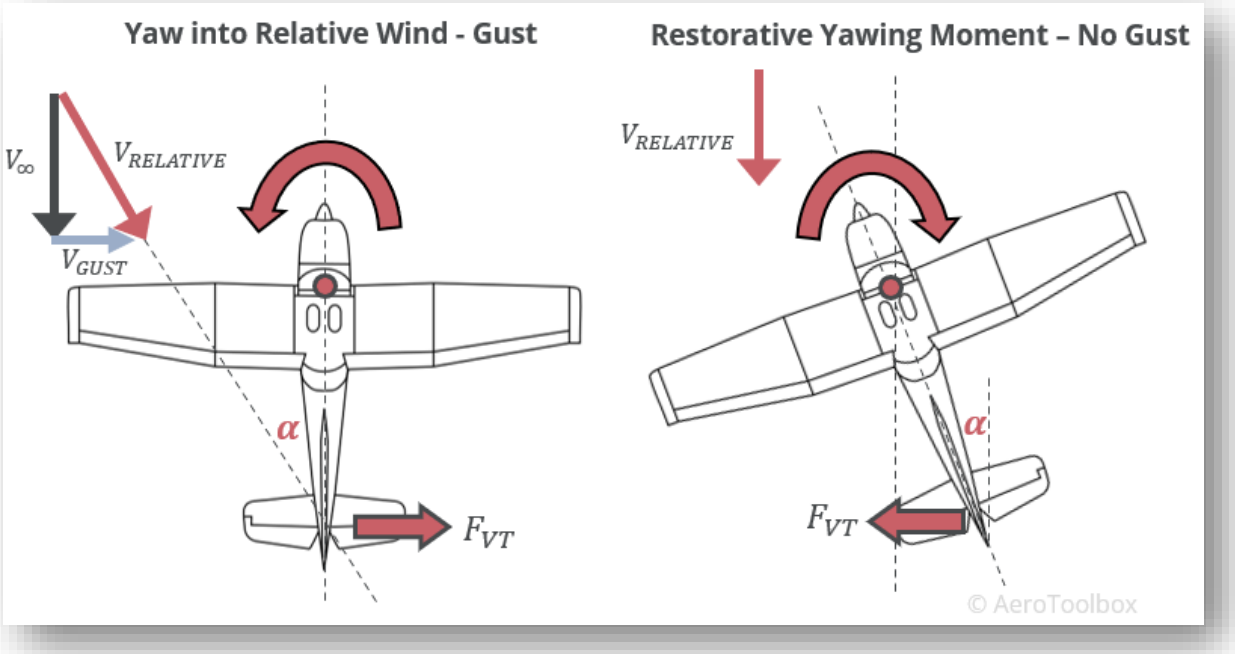
Keel Effect & Weight

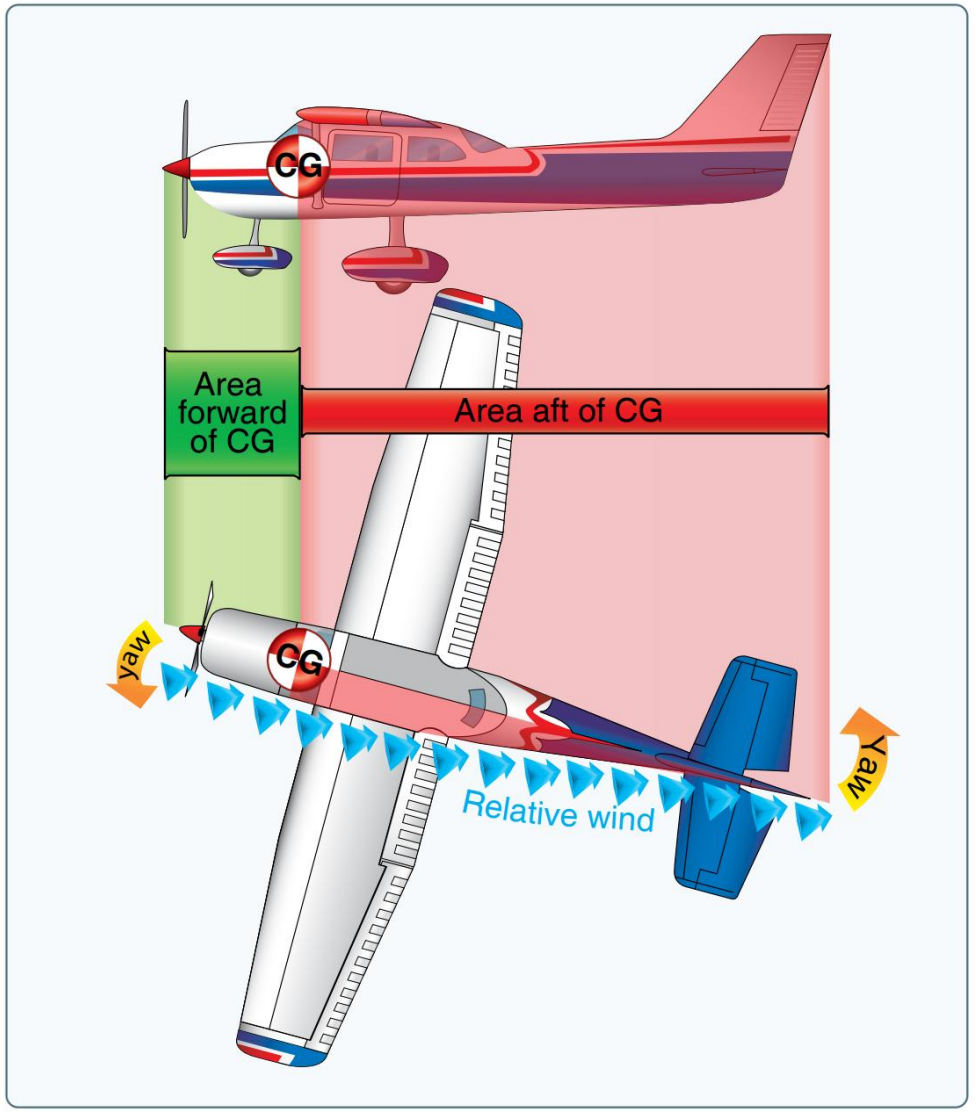




6. Stability & Controllability

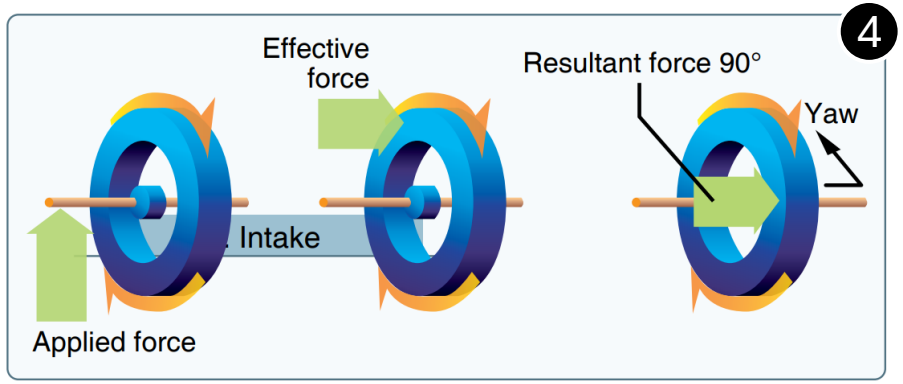
- **Directional Stability**
  - About the vertical axis (yaw)
- **Factors**
  - Area of the fuselage aft of the CG
  - Vertical fin (vertical stabilizer)

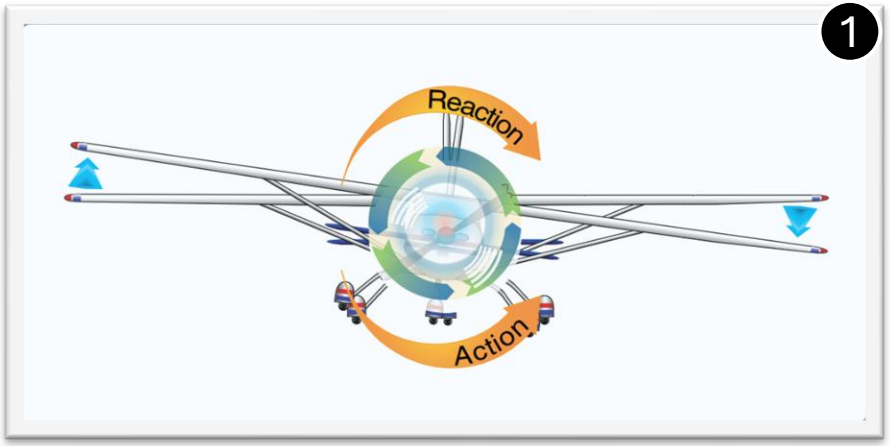


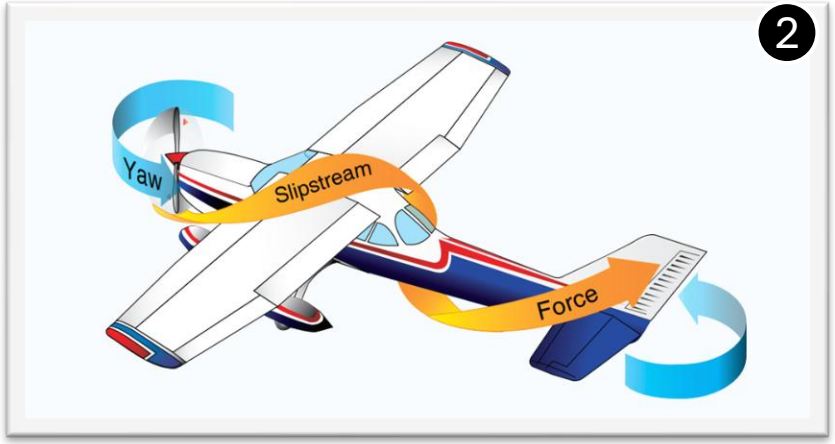


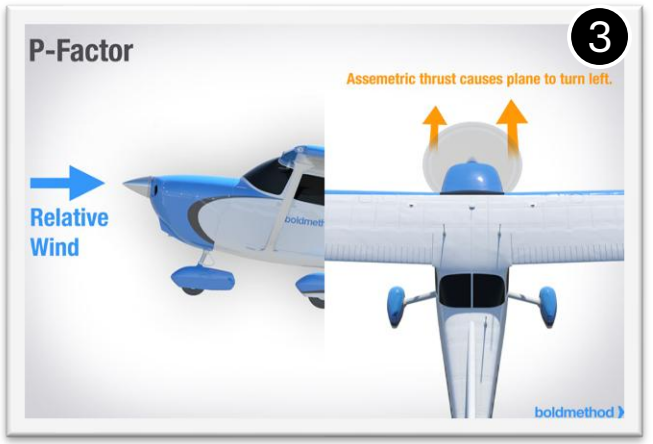
7. Turning Tendencies

1. **Torque Effect** *(left turning tendency)*
   - Newton's 3rd Law: Engine rotates the Propeller clockwise, who attempts to rotate the airplane counter-clockwise
2. **Corkscrew Effect** *(left turning tendency)*
   - Prop rotation sends air spiraling aft, striking left side of vertical stabilizer
3. **P-Factor** *(left turning tendency)*
   - Descending prop blade takes a bigger bite of air than ascending blade
4. **Gyroscopic Precession**
   - Tailwheel: *left turning tendency when tail goes up on takeoff*
   - Nosewheel: *right turning tendency when pitch-up takeoff*



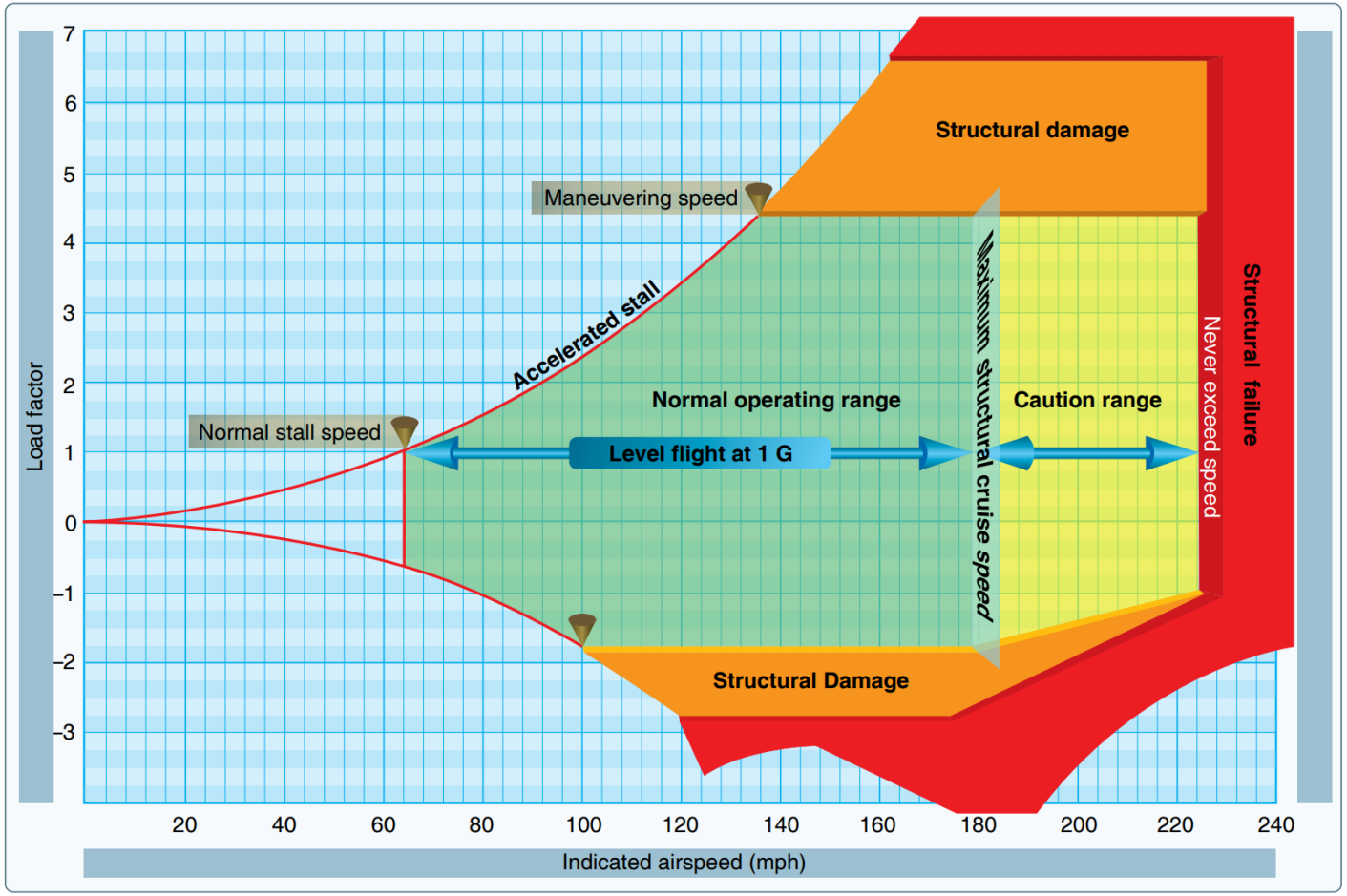






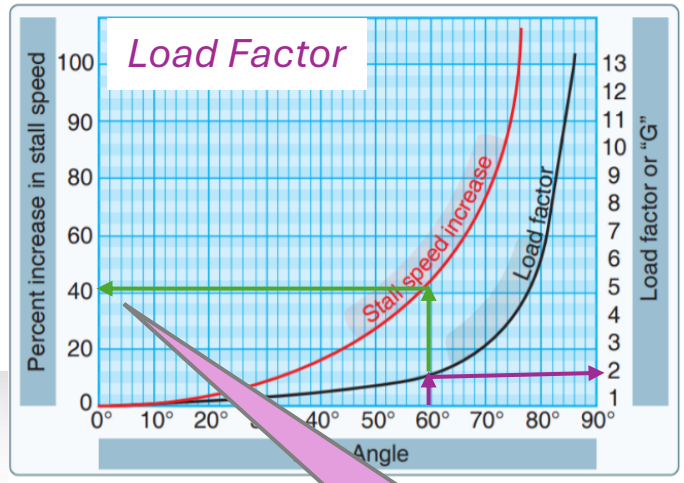
8. Load Factor

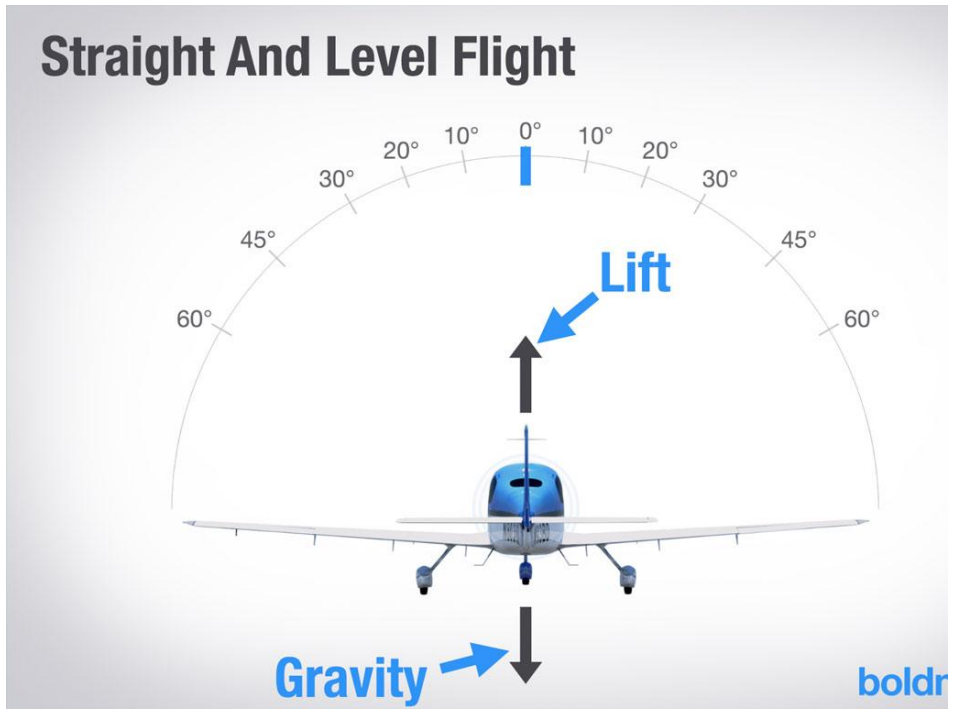
- Definition: Ratio of the total load acting on a plane (measure in Gs) to the load caused by the weight
- **Why it's important**
  - Structural integrity
  - ↑ Load factor = ↑ Stall speed
- **Airplane Design (Categories)**
  - Normal (-1.52 to 3.8G)
  - Utility (-1.76 to 4.4G)
  - Acrobatic (-3 to 6Gs)
- **Vg diagram**
  - Limits Gs
  - Limits Speed
  - Maneuvering Speed

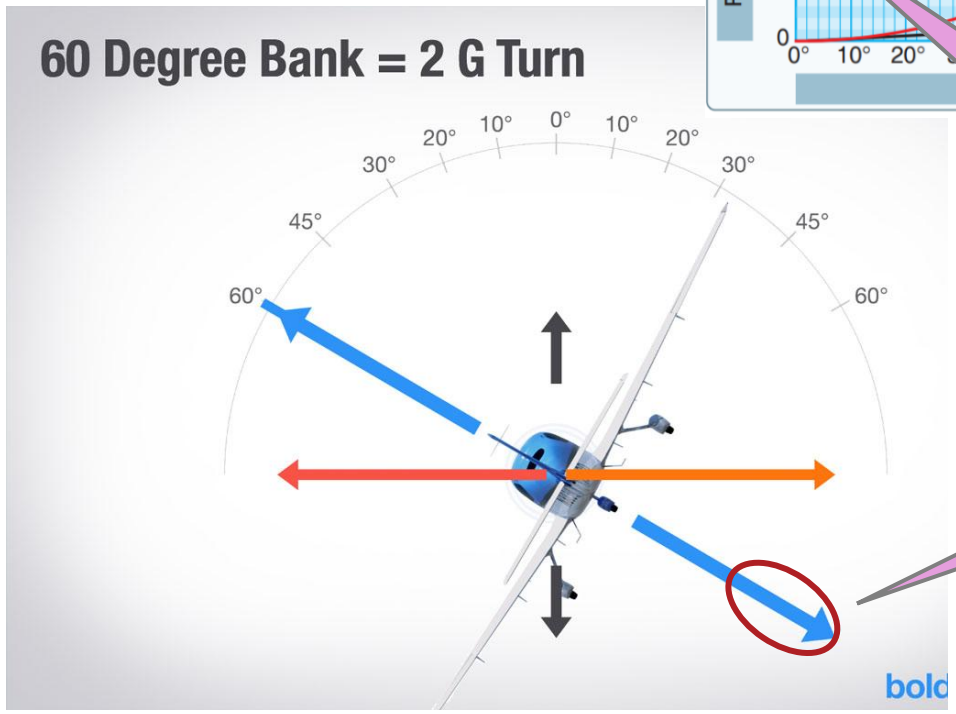


8. Load Factor

- **Turns and Load Factor**
  - A turn splits lift into 2 components: vertical and horizontal
  - More lift is needed so the vertical component offsets the weight
    - ✓ *Total lift increases = Load on the wings increase (as if airplane was heavier)*
  - To generate more lift → higher AoA → increases stall speed



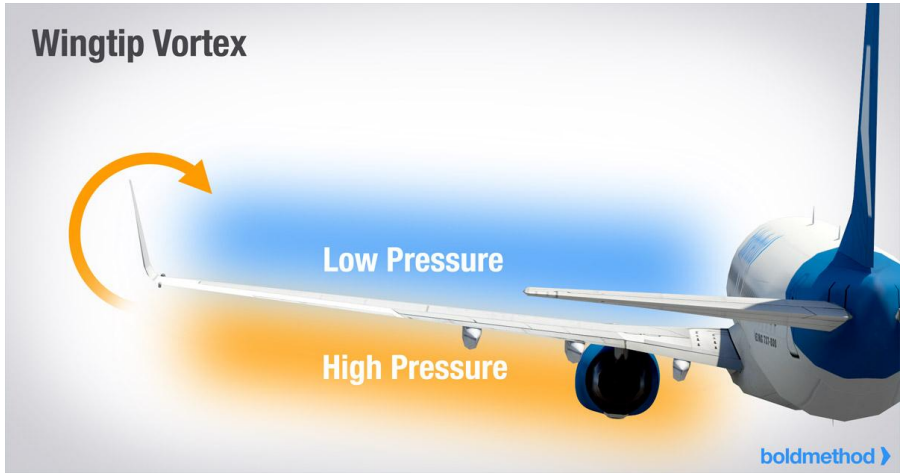




9. Wingtip Vortices and Wake Turbulence Avoidance

- **Wing Vortices**
  - Occur whenever an airfoil is producing lift
  - Difference in pressure above and below the wing results in fast spinning vortices spiraling off each wingtip
  - Increase induced drag (energy wasted producing the turbulence and disturbance on nearby wing flow)

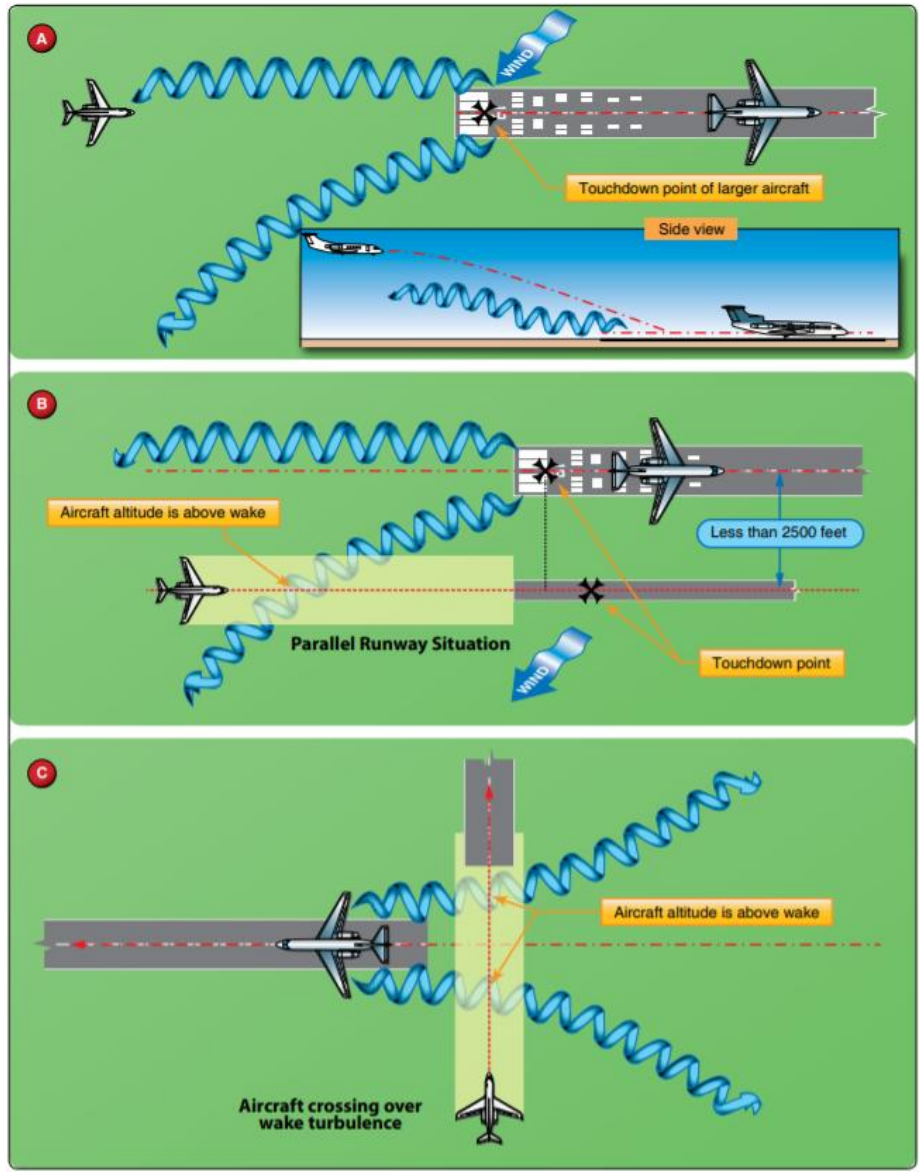
- **Wake Turbulence**
  - Caused by wing vortices (worse in heavy, clean, slow aircraft)
  - Hazards:
    - ✓ *Rolling moments can exceed control authority of the aircraft*
    - ✓ *Possible structural damage*



9. Wingtip Vortices and Wake Turbulence Avoidance

Precautions to avoid Wake Turbulence

- **Approach**
  - Behind aircraft: Stay at/above their flight path
  - On parallel runways: possibility of drift
- **Landing**
  - Behind departing aircraft: Land prior to their rotation point
  - Behind arriving aircraft: Land beyond their touchdown point
  - Behind aircraft on a crossing runway: Cross above their flight path
  - Aircraft executing a missed approach: Wait at least 2 minutes
- **Departing**
  - Behind aircraft: Rotate prior to rotation & climb above their flight path
  - Intersection takeoff : Be alert to larger aircraft operations on runway
  - Wait 2 minutes after a large aircraft executing a missed approach



Questions?