Aerodynamics

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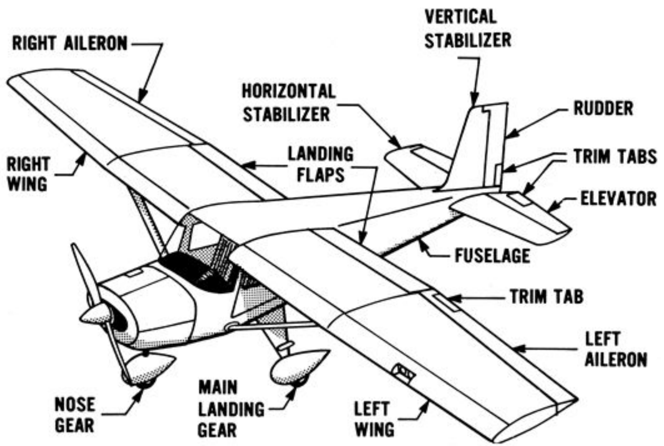
Airplane Construction

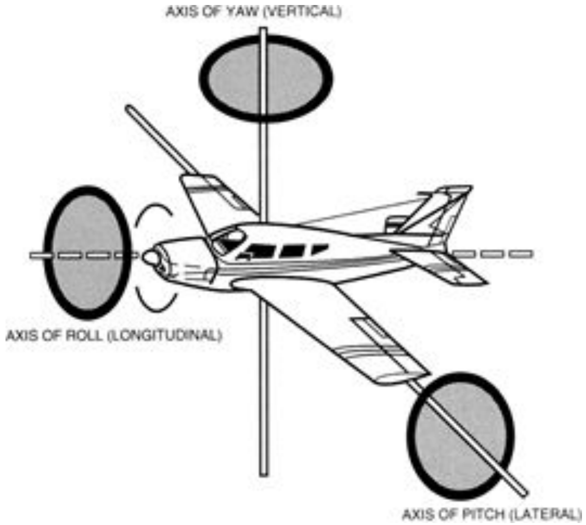
1. Fuselage
   a. Main body of the airplane

2. Wings
   a. Provide lift that supports the aircraft in flight
   b. Ailerons control the Bank (Roll) around the longitudinal axis

3. Empennage (Tail Group)
   a. Vertical Stabilizer – Provides directional balance
   b. Rudder – Controls direction of yaw
   c. Horizontal Stabilizer – Longitudinal balance
   d. Elevator (or Stabilator) – Controls the pitch

4. Three Axes of Flight
   a. Lateral Axis – Wingtip to Wingtip
   b. Longitudinal Axis – Nose to Tail
   c. Vertical Axis – Straight up through the body at the junction of Lateral & Longitudinal





Airfoil Design Characteristics

1. The camber of the upper surface is more pronounced that the camber of the lower surface. You can see this by looking at the cross section of the wing.

2. Air must travel faster across the top of the wing. With this increase in speed, due to **Bernoulli's principle**
    a. An increase in the speed of a fluid occurs simultaneously with a decrease in static pressure

3. **Planform:** the shape of the wing from above
    a. Our airplanes have rectangular wings
    b. Wings provide the lift that supports the aircraft in flight

4. **Aspect ratio:** wing span over avg chord length.
    a. The greater the aspect ratio, the less induced drag (more lift)

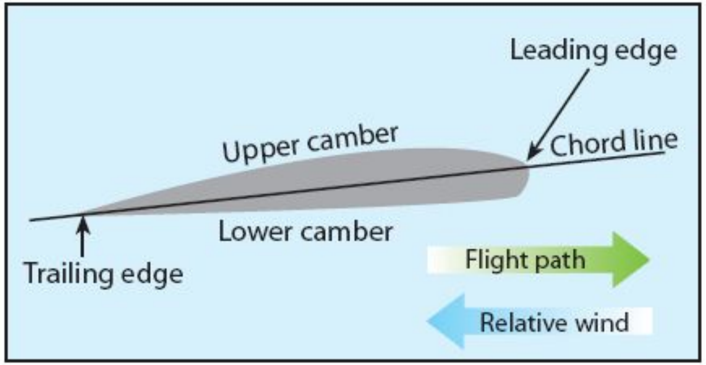
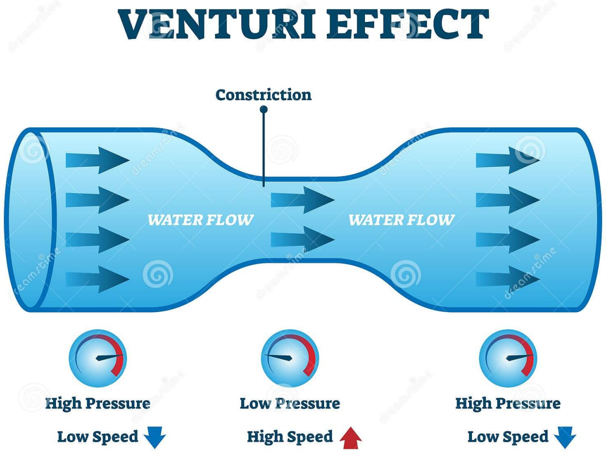
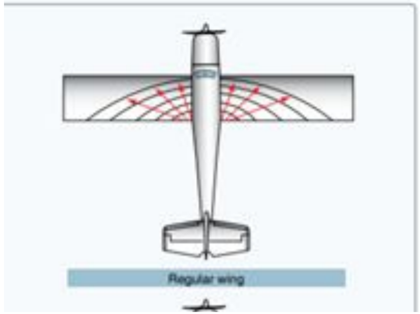
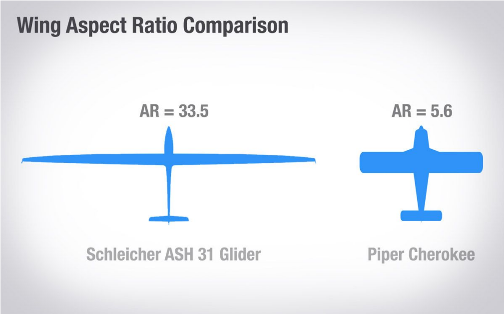


Figure 2-1. Aerodynamic terms of an airfoil.







4 Forces of Flight

1. **Lift**
   a. Supporting force for flight, generated through Bernoulli's Principle
   b. Acts perpendicular to the relative wind

2. **Thrust**
   a. Considered to act parallel to the Longitudinal axis
   b. Produced by movement of the air by propeller

3. **Weight**
   a. Always acts towards the center of the Earth
   b. Considered to act from the Center of Gravity
   c. CG is the point on the aircraft, that if suspended, it would balance

4. **Drag**
   a. Retarding force that acts parallel to the relative wind
   b. Two types:
      i. Parasite: drag from the form of the airplane and the friction of it moving through the air
      ii. Induced: By product of Lift

5. **Bonus: During Straight & Level and constant airspeed**
   a. Lift = Weight (and tail down force)
   b. Thrust = Drag

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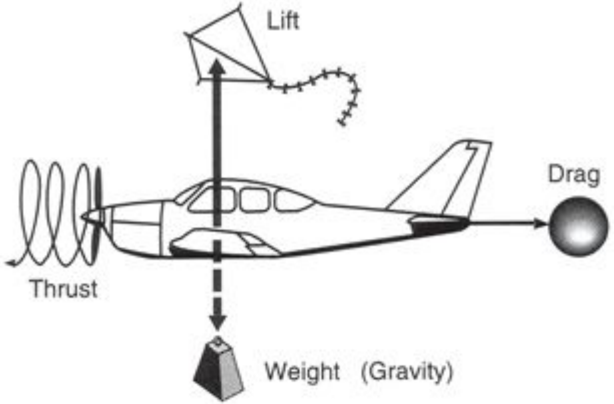
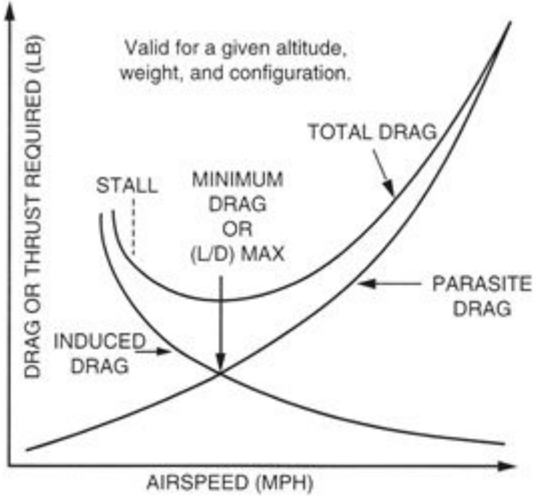
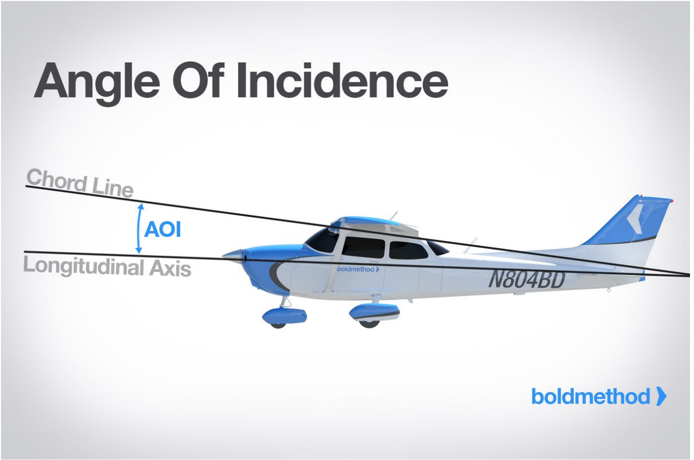




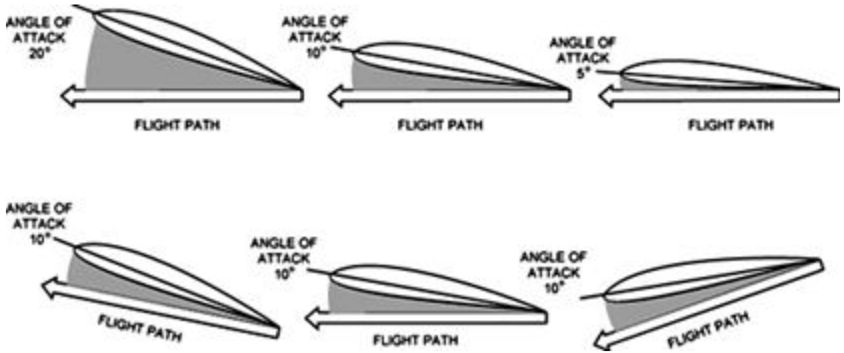
Angle of Incidence/ Angle of Attack

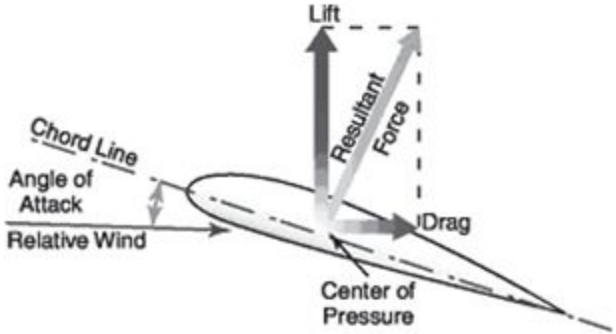


Angle of incidence: is the angle between the **longitudinal axis of the aircraft** (draw a line from the spinner to the tail) and the **chord line** of the wing (draw a line from the leading edge to the trailing edge).

Angle of attack: Is the acute angle between the **chord line** of the airfoil and the direction of the **relative wind**

- At angles less than the critical angle of attack, an increase in angle of attack will increase lift





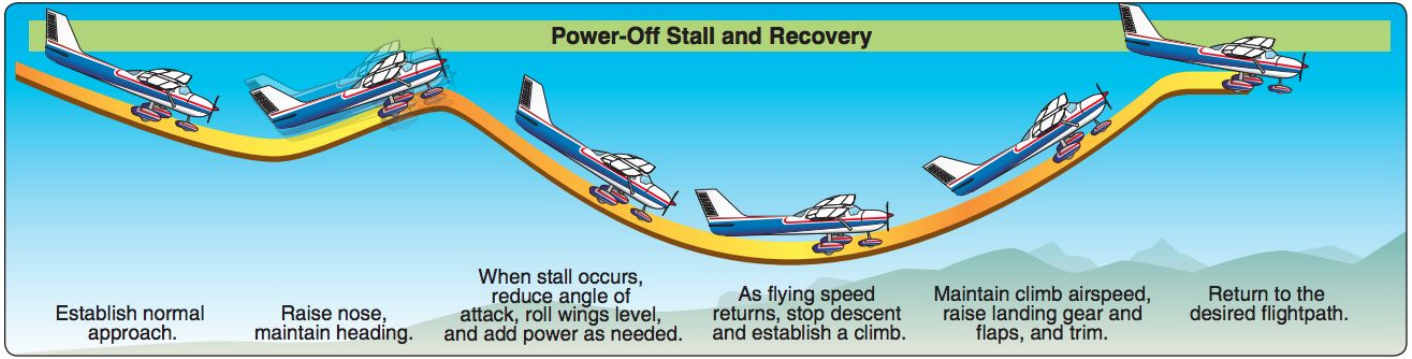
Critical Angle of Attack / Stalls

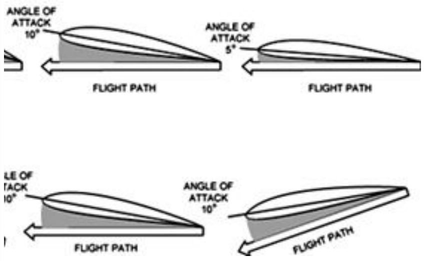
1. An airplane will fly as long as the wing is creating sufficient lift to counteract the load imposed on it

2. The angle of attack at which a wing stalls **regardless of airspeed**, flight attitude, or weight is known as the critical angle of attack
   - a. **The direct cause of every stall is an excessive angle of attack**
   - b. The smooth flow of air over the top of the wing is disturbed at this critical angle of attack
   - c. The stalling speed of a particular airplane is **not a fixed value** for all flight situations
   - d. A given airplane will always stall at the same angle of attack **regardless of airspeed, weight, load factor, or density altitude**
   - e. The angle is typically from 16° to 20°, depending on the airplane's design

3. The critical angle of attack can be exceeded **at any attitude or airspeed**

4. Recovery from a stall requires the pilot to **reduce the angle of attack** to allow a smooth flow of air over the wing to begin again





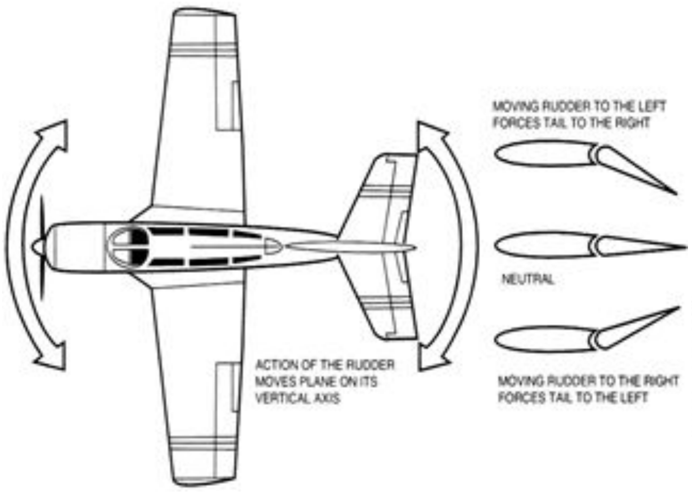
Flight Controls

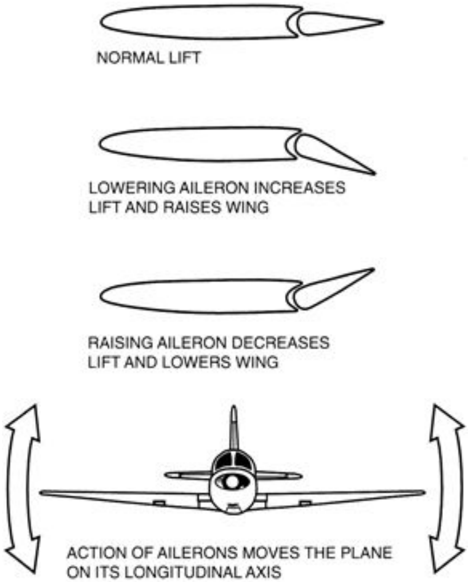
Primary Flight Controls

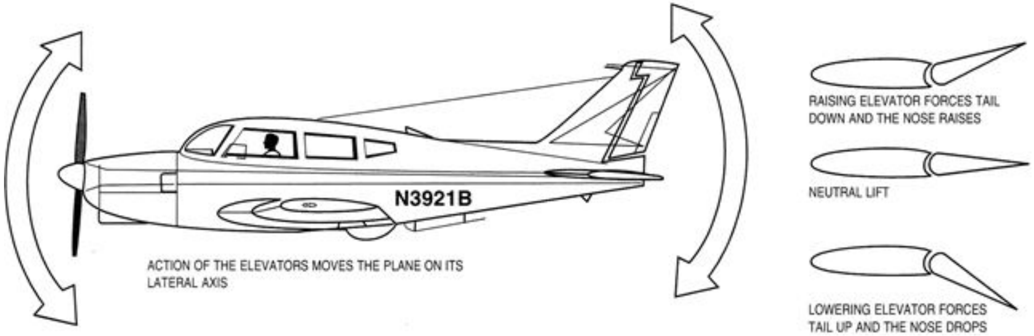
1. Rudder – Yaw about the vertical axis
2. Elevator – Pitch about the lateral axis
3. Ailerons – Bank (Roll) around the the longitudinal axis

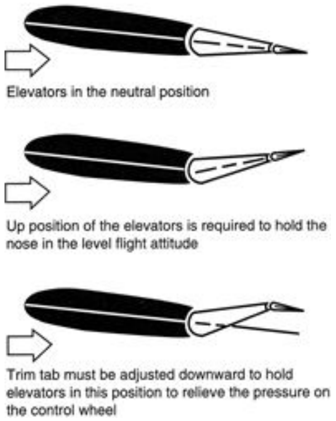
Secondary Flight Controls

4. Trim Tabs – Used in trimming & balancing the aircraft
5. Wing Flaps- increase lift and drag
6. Spoilers– Increase descent without an increase in speed (Not installed on our airplanes)









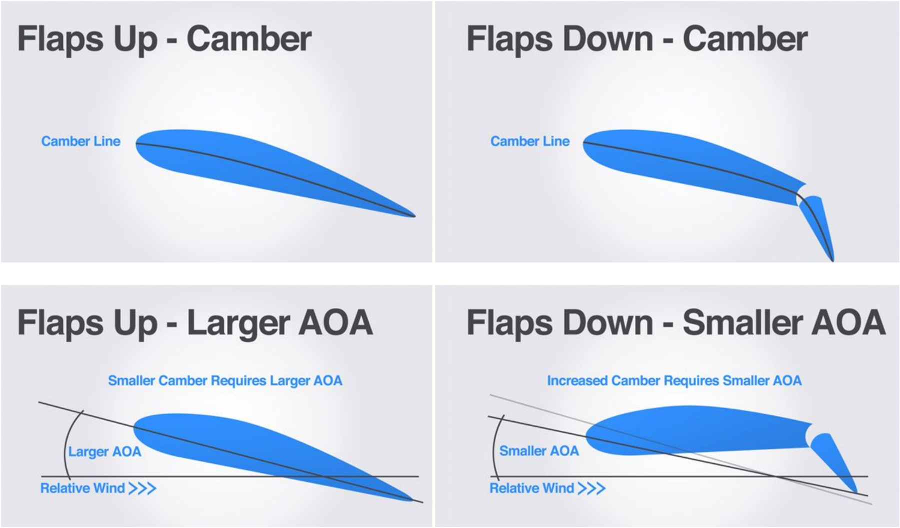
Effects of Flaps

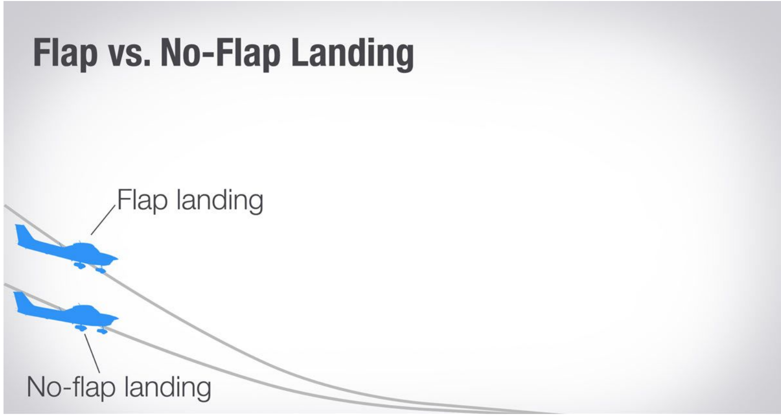
1. Extending flaps **increases the camber**, or curvature, of your wing. When your wing has a higher camber, it also has a higher lift coefficient, meaning **it can produce more lift (and drag) at a given angle-of-attack**.

2. Extending flaps **reduces your aircraft's stall speed**. Because your wing creates **more lift with the flaps down**, you don't need to as much angle-of-attack to balance the four forces of flight.

3. **Allows pilot to make a steeper approach without increasing airspeed**

4. May provide increased lift required for certain maneuvers (short field takeoff)





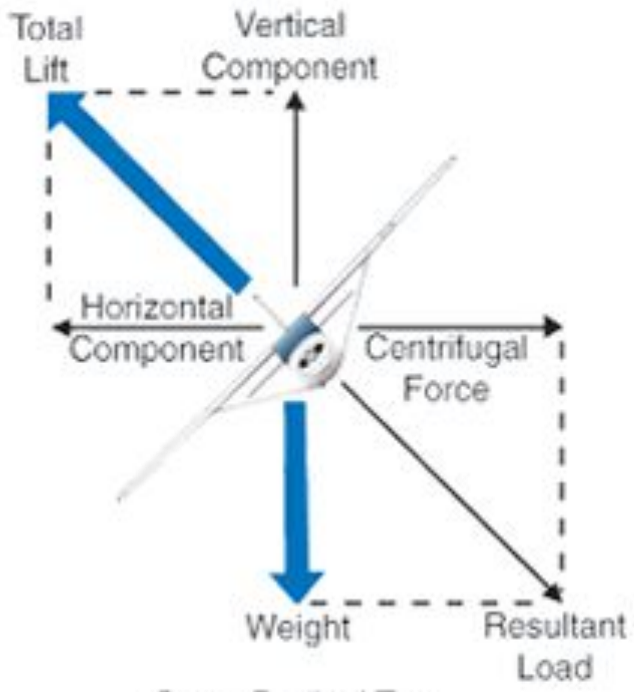
Forces Acting on a Turning Airplane

1. Bank the aircraft in order to change the direction of flight
   a. The rudder yaws the airplane but does not create the unbalance of forces needed to change direction

2. Lift vector is tilted and is broken out between vertical and horizontal lift
   a. Back pressure must be applied to increase vertical component of lift in order to maintain level flight.

3. Level Turns
   a. Vertical = Weight
   b. Horizontal opposition force is called centrifugal force
   c. The resultant load of total lift are the G's or acceleration

4. Types of Turns
   a. Shallow Bank – 0° to 20°
   b. Medium Bank – 20° to 45°
   c. Steep Bank – More than 45°



Forces Acting on a Climbing Airplane

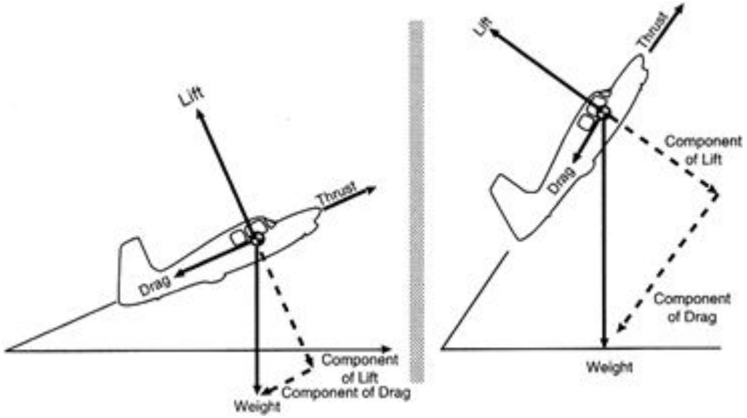
1. Steady State Climb (Constant Rate & Airspeed Climb)
   a. Lift is greater for the entry

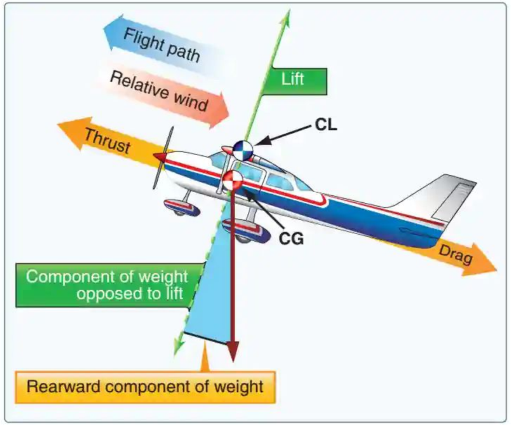
2. Weight is the same
   a. Portion is acting in the same direction as drag

3. Drag may be about the same
   a. Remember it is acting parallel to the relative wind

4. Thrust
   a. Must increase to counteract increased drag and thus loss of airspeed

5. Different types
   a. VY – Best Rate
      i. Most altitude per unit of time
   b. VX – Best Angle
      i. Most altitude per unit of distance
   c. Cruise Climb
      i. Used for improved cooling & visibility



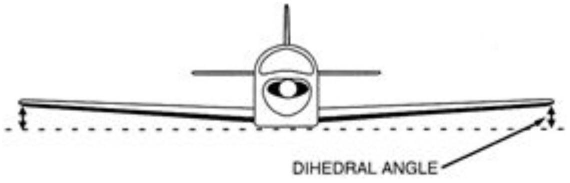


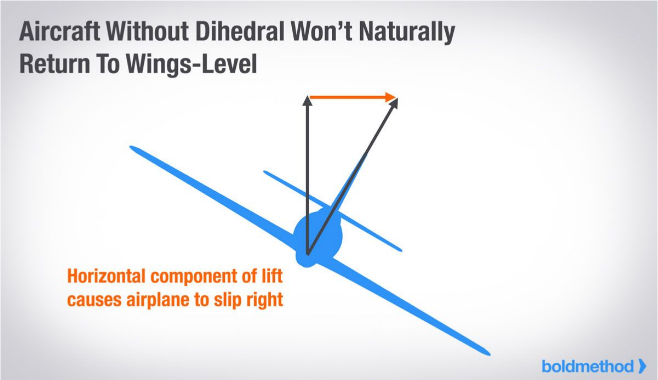
Dihedral Effect

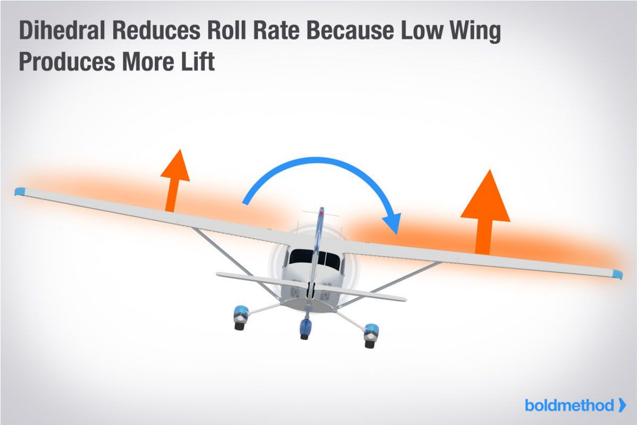
1. Upward angle of an aircraft's wings

2. When you bank an airplane, the lift vector tilts with it. And when that happens, your airplane starts slipping in the same direction, in this case, to the right.
   a. The problem is, if you have a completely straight winged aircraft, there's no force that will bring the airplane back to wings-level flight without you intervening.

3. Wings with dihedral don't produce lift vertically. Instead, **there's a vertical component, and a horizontal component.** So when you're flying straight and level, your lift is not 100% vertical.
   a. When you put an aircraft into a bank, **the dihedral effect constantly tries to return your wings to level.**





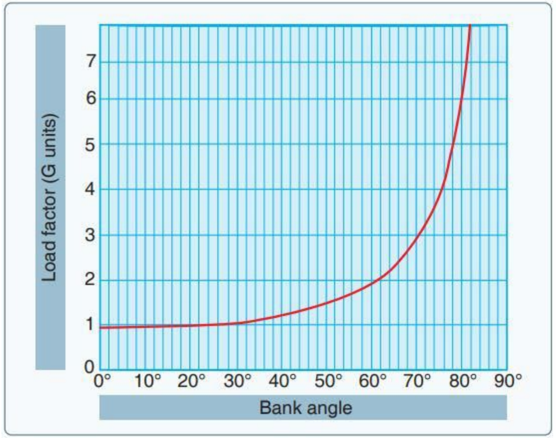


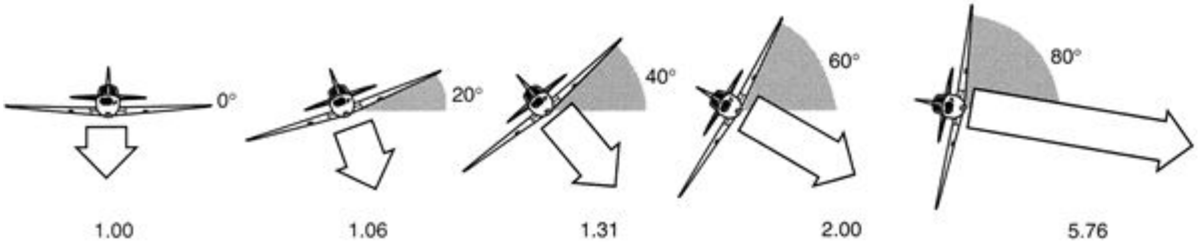
Load factors in airplane design

1. Load factor is the ratio of the total air load acting on the airplane to the gross weight of the airplane measured in G's

2. A load factor of 3 means that the total load supported by the airplane is three times its weight

3. Airplanes are designed in accordance with the category system:
   a. Normal Category limit load factors are **-1.52 G's to 3.8 G's**
   b. Utility Category limit load factors are **-1.76 G's to 4.4 G's**
      i. Mild acrobatics, including spins
   c. Acrobatic Category limit load factors are **-3.0 G's to 6.0 G's**





Load factors in airplane design

The Vg diagram shows the flight operating strength of a plane based on:

1. Load factor (vertical scale)
2. Indicated airspeed (horizontal scale)

3. Describes the allowable airspeed/LF combinations for safe flight

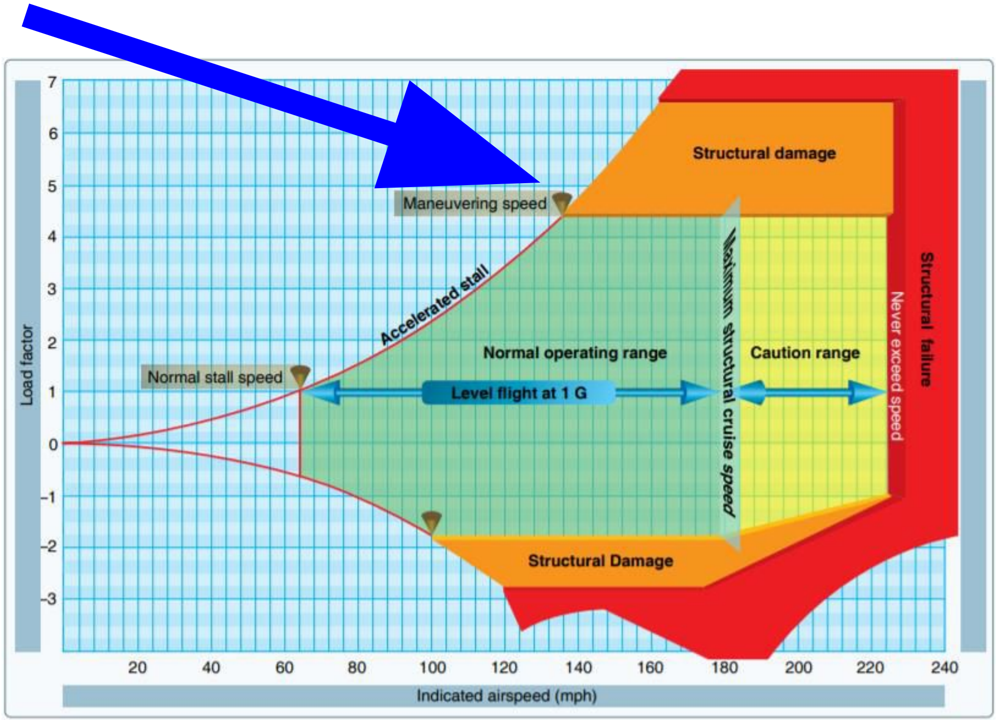
Maneuvering Speed

4. The intersection of the **positive limit load factor** (4.4 Gs) and the line of **maximum positive lift capability**

5. Speeds less than this do not provide the lift capability to cause damage from excessive load
   a. Any speed greater than this provides the capability to damage the aircraft in rough/ turbulent air

6. Maximum speed at which the aircraft will stall before a damaging load factor results

7. The maximum speed at which full or abrupt control movements may be used without overstressing the airframe

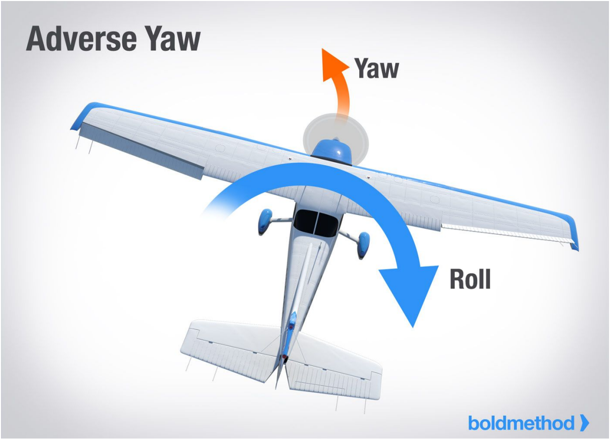


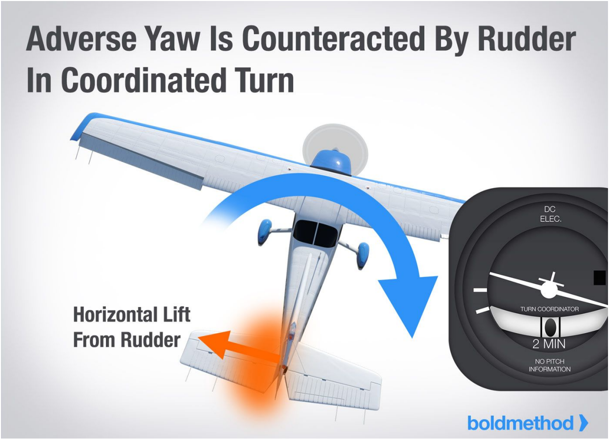
Adverse Yaw (Turns)

Adverse yaw is the **tendency of an airplane to yaw in the opposite direction of the turn**. For example, as you roll to the right, your airplane may initially yaw to the left.

When you roll your airplane to the right, your right aileron goes up, and your left aileron goes down. The aileron in the upward position (the right aileron in this example) creates less lift and less drag than the aileron that is lowered. The aileron angled downward (the left aileron in this example) produces more drag and more lift, initially yawing the airplane in the opposite direction of your roll.

In a coordinated turn, **adverse yaw is countered by using the rudder (in almost all cases, stepping on the rudder *into* the turn).** When you add rudder input, you're creating a side force on the vertical tail that opposes adverse yaw. By adding rudder, you create a yawing moment that helps turn the airplane in the correct direction and stay coordinated.

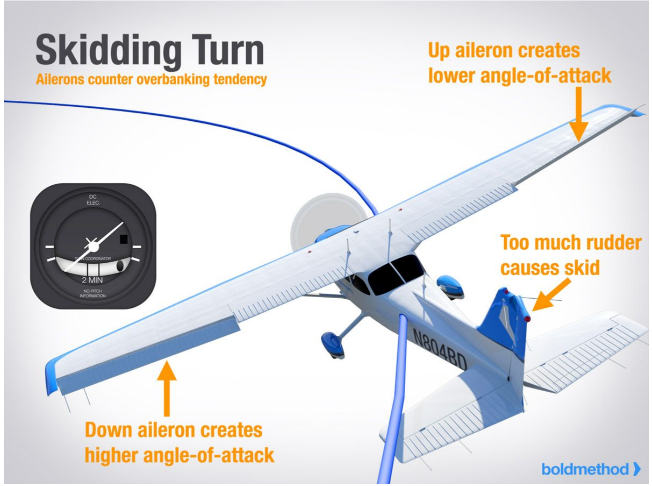


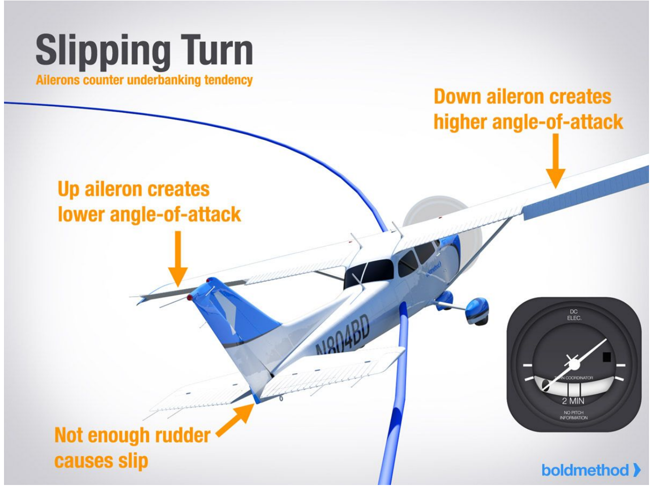


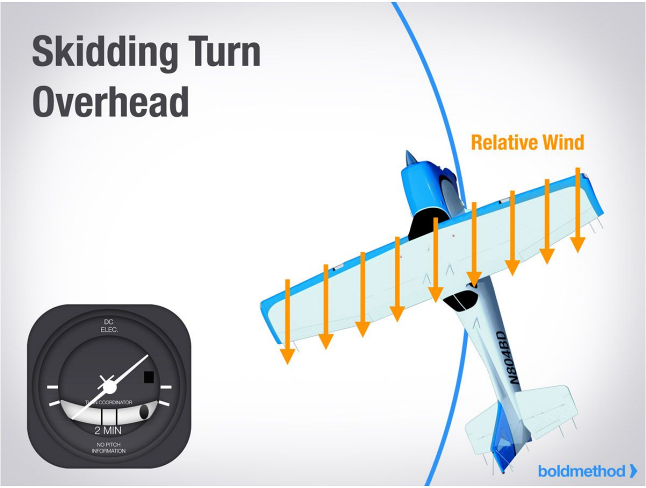
Skids and Slips

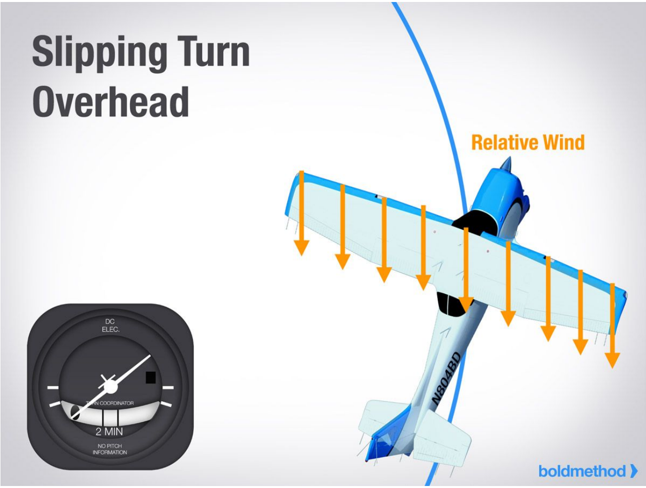
Skidding Turn: The aircraft is turning too fast for the bank angle, and yaws into the turn. (Most likely, you're pushing too much rudder and causing the skid.)

Slipping Turn: the opposite scenario happens. The nose of the aircraft yaws to the outside of the turn, and the aircraft's banked too much for the rate of turn.







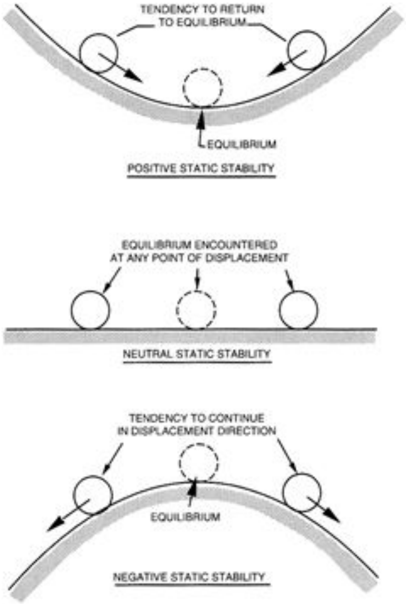


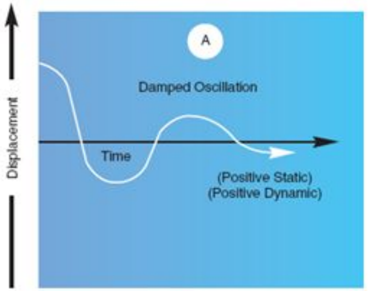
Airplane stability and controllability

1. Stability: The inherent quality of an airplane to correct for conditions that may disturb its equilibrium, and return to or continue on the original flight path.
   a. Static Stability
      i. **Positive SS:** The initial tendency to **return to the original state of equilibrium** after being disturbed
      ii. **Negative SS:** The initial tendency to **continue away from original equilibrium** after being disturbed
      iii. **Neutral SS:** The initial tendency to **remain in a new condition** after equilibrium has been disturbed
   b. Dynamic Stability
      i. Refers to the aircraft **response over time when disturbed** from a given pitch, bank, or yaw
      ii. Does the airplane return to equilibrium over time or not
      iii. Referred to as Positive, Negative, and Neutral – Same as SS, but over time (overall tendency)

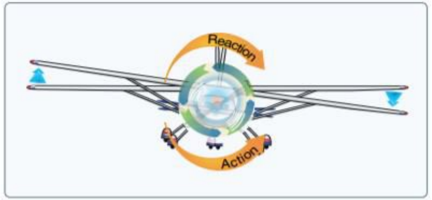
2. **Controllability:** capability to respond to the pilot's control especially in regards to flight path and attitude.

3. **Maneuverability:** ability of airplane to be maneuvered easily and to withstand stresses imposed by maneuvers

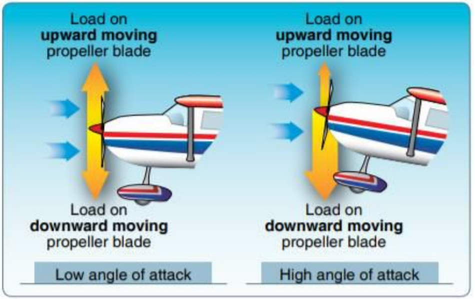


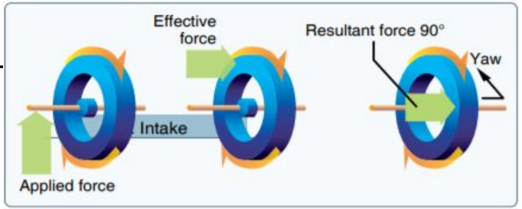


Left Turning tendencies



Torque Reaction: turning force about an axis. This is the equal and opposite reaction physics effect.	**Slipstream:** spirals air contacting L side of rudder thus pushing plane to the R
P-factor: in a climb the descending blade has a higher AoA. This moves the center of thrust to the right of the propeller disc area (causing a yaw to the left) 1. The blade proceeding forward into the flow of air will have a higher airspeed than the blade retreating with the airflow	**Gyroscopic precession:** Most often occurs with tail wheel aircraft when the tail is raised on the takeoff roll. Lifting the tail wheel has the same effect as a forward force to the top of the prop 1. This force is felt 90 degrees in the direction of rotation and will take effect on the right side of the propeller, yawing the nose **left** 2. This works in the opposite direction on a tricycle gear aircraft. when we pull up on takeoff the nose yaws **right**.





Wingtip vortices and precautions to be taken.

When an airfoil is flown at a positive AOA, a pressure differential exists above and below the wing

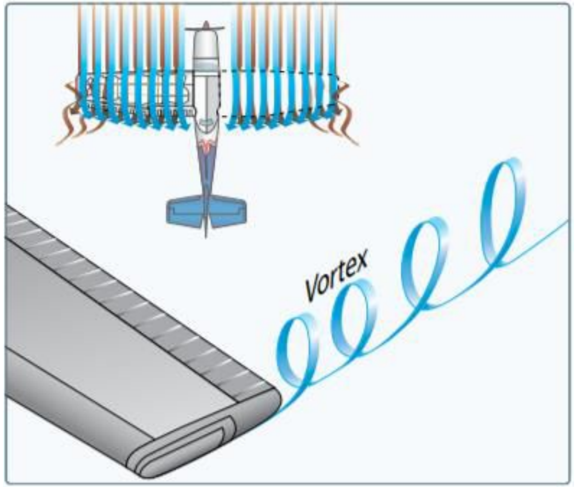
1. The **pressure above the wing is less than atmospheric pressure**

2. The **pressure below the wing is equal to or greater than atmospheric pressure**

3. Since air always move from higher to lower pressure, and the path of least resistance is the tips of the wings, there is a spanwise movement of air from the bottom of the wing outward from the fuselage to the tips

4. These vortices increase drag because of energy spent in producing the turbulence. Thus, whenever an airfoil is producing lift, induced drag occurs and wingtip vortices are created

5. The greater the AOA, the stronger the vortices



Wake Turbulence

Dangers of Vortices

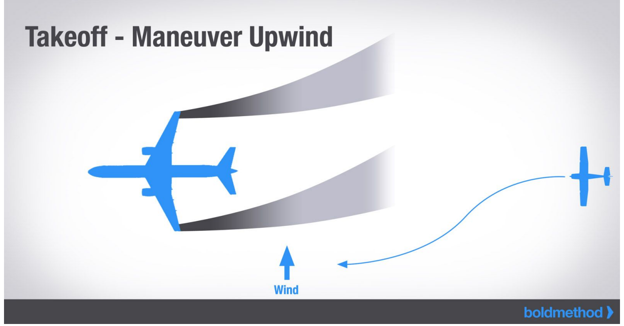
1. Wake turbulence can be a hazard to any aircraft significantly lighter than the generating aircraft
2. Flying through another aircraft's wake can result in major structural damage, or induced rolling making the aircraft uncontrollable

Behavior

1. Greatest Strength is when aircraft is **heavy, clean, and slow**
2. Sink at a rate of several hundred fpm, slowing/diminishing the further they get behind an aircraft
3. When vortices sink to the ground, they tend to move laterally with the wind

Avoidance

4. Takeoff:
   a. Takeoff prior to the point the preceding aircraft rotated, and attempt to climb above or away from their flight path
5. Enroute:
   a. Avoid flying through another aircraft's flight path
6. Landing:
   a. Stay above a preceding aircraft's path, and land past their touch down point
   b. Parallel runways – stay at and above the other jet's flight path for the possibility of drift
   c. Land prior to a departing aircraft's



Ground Effect

1. A condition of improved performance encountered when the aircraft is operated near the ground
   a. Ground effect basically comes down to **how big your wingtip vortices are, and how much downwash they're creating.**
      i. When your wing is **close to the ground, wingtip vortices can't get as big**, because as they spin around your wingtip, they impact the ground and dissipate. The result? A reduction in something called downwash.
      ii. Results in a reduction of induced drag

2. Uses and dangers of ground effect
   a. Good stuff
      i. May be utilized to soften a landing

   b. Bad stuff
      i. May allow the aircraft to takeoff before the aircraft is ready to continue flying which can result in settling
      ii. May cause excessive float on landing

Spins

What is a spin?

1. An aggravated stall that results in an airplane descending in a corkscrew path
2. Both wings are stalled in a spin, but one is more deeply stalled than the other. The "more stalled" wing is on the inside of the spin, it flies at a higher angle-of-attack, and it generates less lift than the outside wing.

What are the recovery steps for a spin?

3. **Power Idle**- reduce tail downforce- airflow from prop
4. **Ailerons neutral**- help wings reach same angle of attack
5. **Rudder Opposite**- stop the roll and yaw
6. **Elevator forward**- get back under critical angle of attack

Why do we nose down at the end of a spin recovery?

7. Reduce angle of attack to break the spin