



Commercial Pilot Ground School

Day 12
Stability & Aerodynamics in Maneuvers

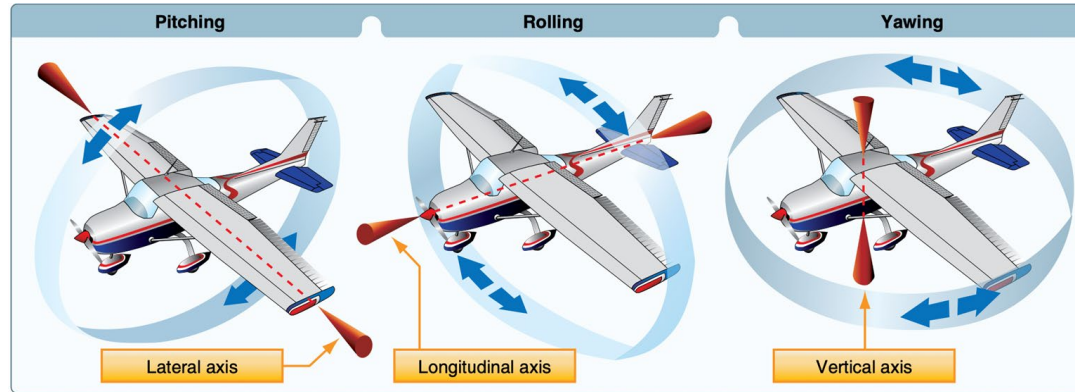


Agenda

- Stability
 - Static
 - Dynamic
 - Longitudinal
 - Lateral
 - Directional
- Aerodynamics in Flight Maneuvers
- Stalls & Spins

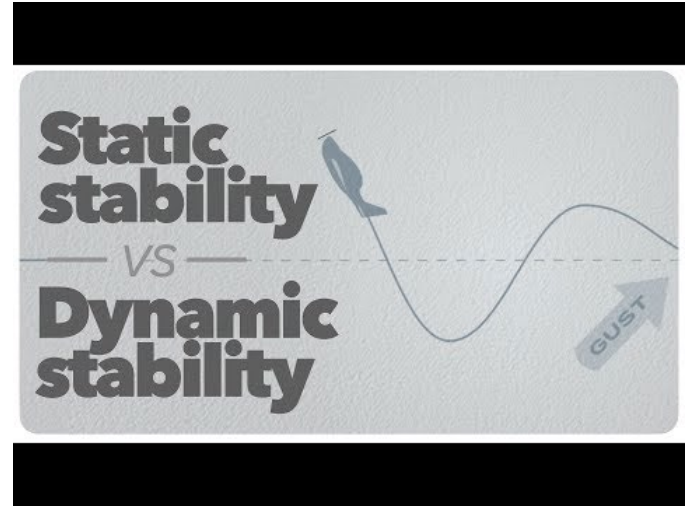
Aircraft Stability - Axes

The axes of an aircraft are three imaginary lines that pass through an aircraft's CG. The axis that passes through the CG and parallel to a line from nose to tail is the longitudinal axis, the axis that passes parallel to a line from wingtip to wingtip is the lateral axis, and the axis that passes through the CG at right angles to the other two axes is the vertical axis.



Aircraft Stability

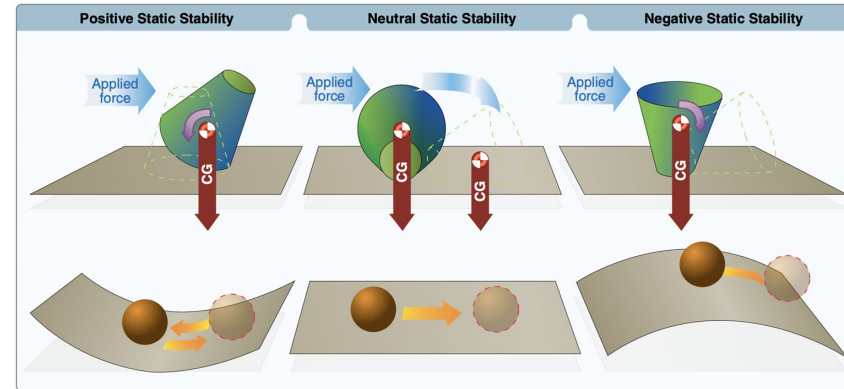
Stability is the inherent quality of an aircraft to correct for conditions that may disturb its equilibrium and to return to or to continue on the original flight path. It is an aircraft design characteristic. The flight paths and attitudes an aircraft flies are limited by the aerodynamic characteristics of the aircraft. This limit indicate the maximum performance and maneuverability of the aircraft. If an aircraft is to fly straight and steady along any arbitrary flight path, the forces acting on it must be in static equilibrium. The reaction of any body when its equilibrium is disturbed is referred to as stability. The two types of stability are static and dynamic.



Static Stability

Static stability is the initial tendency, or direction of movement, back to equilibrium. In aviation, it refers to the aircraft's initial response when disturbed from a given pitch, yaw, or bank.

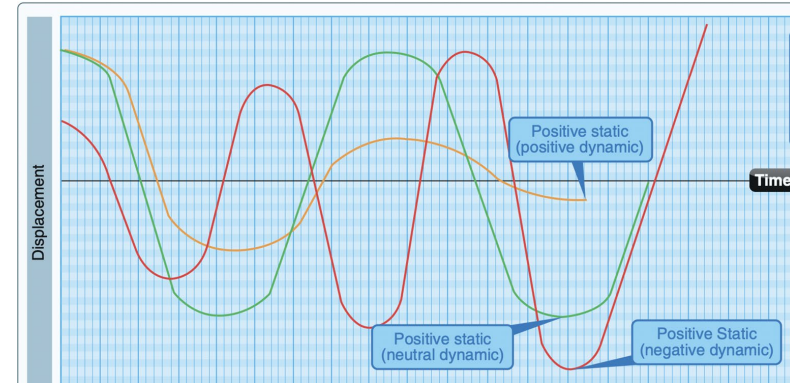
- Positive static stability—the initial tendency of the aircraft to return to the original state of equilibrium after being disturbed.
- Neutral static stability—the initial tendency of the aircraft to remain in a new condition after its equilibrium has been disturbed.
- Negative static stability—the initial tendency of the aircraft to continue away from the original state of equilibrium after being disturbed.



Dynamic Stability

Dynamic stability refers to the aircraft response over time when disturbed from a given pitch, yaw, or bank. This type of stability also has three subtypes:

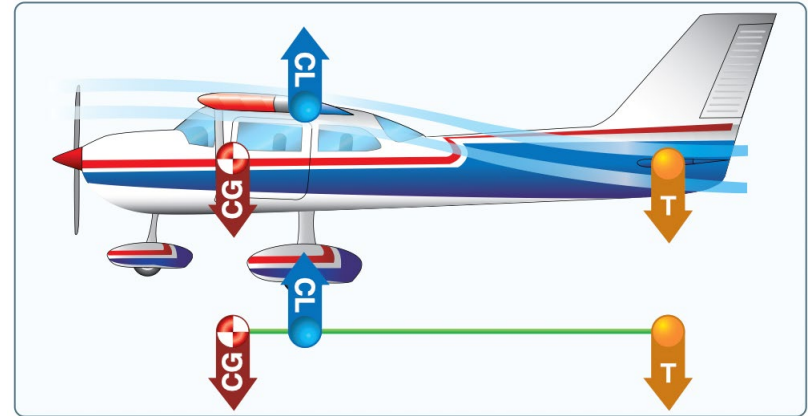
- Positive dynamic stability—over time, the motion of the displaced object decreases in amplitude and, because it is positive, the object displaced returns toward the equilibrium state.
- Neutral dynamic stability—once displaced, the displaced object neither decreases nor increases in amplitude. A worn automobile shock absorber exhibits this tendency.
- Negative dynamic stability—over time, the motion of the displaced object increases and becomes more divergent.



Longitudinal Stability (Pitching)

Longitudinal stability about the lateral axis is considered to be the most affected by certain variables in various flight conditions.

Longitudinal stability is the quality that makes an aircraft stable about its lateral axis. It involves the pitching motion as the aircraft's nose moves up and down in flight. A longitudinally unstable aircraft has a tendency to dive or climb progressively into a very steep dive or climb, or even a stall. Thus, an aircraft with longitudinal instability becomes difficult and sometimes dangerous to fly.

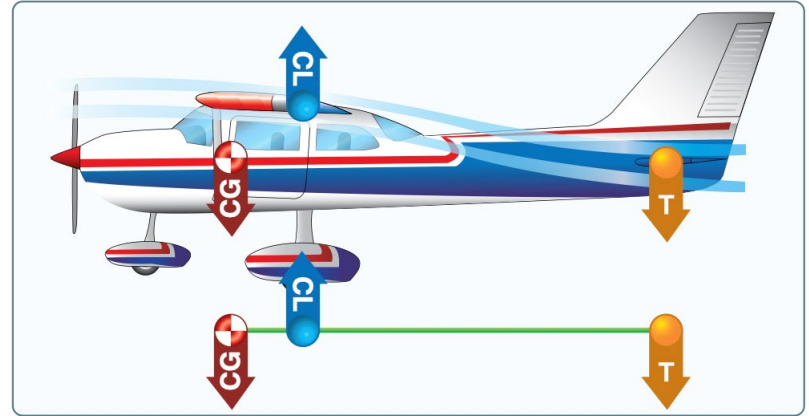


Longitudinal Stability (Pitching)

Static longitudinal stability in an aircraft is dependent upon three factors:

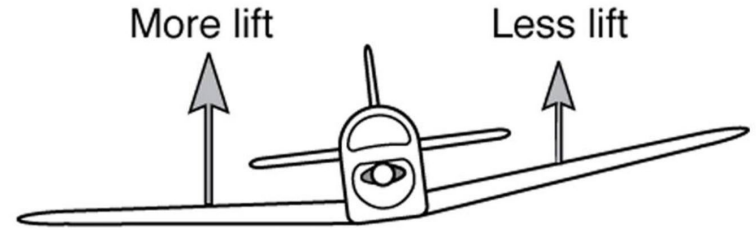
1. Location of the wing with respect to the CG
2. Location of the horizontal tail surfaces with respect to the CG
3. Area or size of the tail surfaces

To obtain static longitudinal stability, the relation of the wing and tail moments must be such that, if the moments are initially balanced and the aircraft is suddenly nose up, the wing moments and tail moments change so that the sum of their forces provides an unbalanced but restoring moment which, in turn, brings the nose down again. Similarly, if the aircraft is nose down, the resulting change in moments brings the nose back up.



Lateral Stability (Rolling)

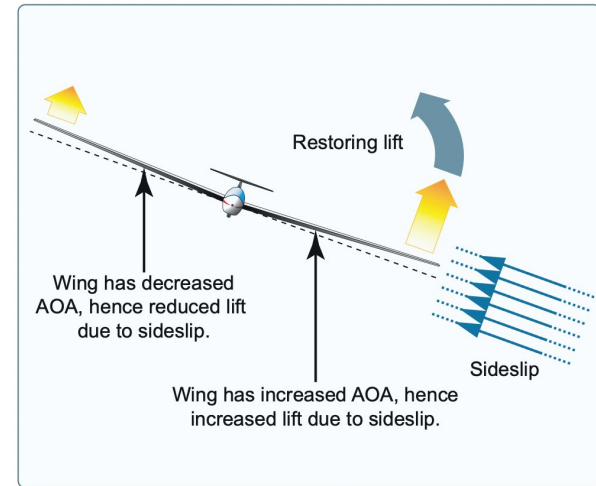
Stability about the aircraft's longitudinal axis, from the nose of the aircraft to its tail, is called lateral stability. Positive lateral stability helps to stabilize the lateral or "rolling effect" when one wing gets lower than the wing on the opposite side of the aircraft. There are four main design factors that make an aircraft laterally stable: dihedral, sweepback, keel effect, and weight distribution.



lateral stability

Lateral Stability - Dihedral

Some aircraft are designed so that the outer tips of the wings are higher than the wing roots. This is called dihedral. When a gust causes a roll, a sideslip will result. This causes the relative wind affecting the entire airplane to be from the direction of the slip. When the relative wind comes from the side, the wing slipping into the wind has an increased AOA and develops an increase in lift. When the relative wind comes from the side, the wing slipping out of the wind has a decreased AOA and develops a decrease in lift.



Lateral Stability - Dihedral

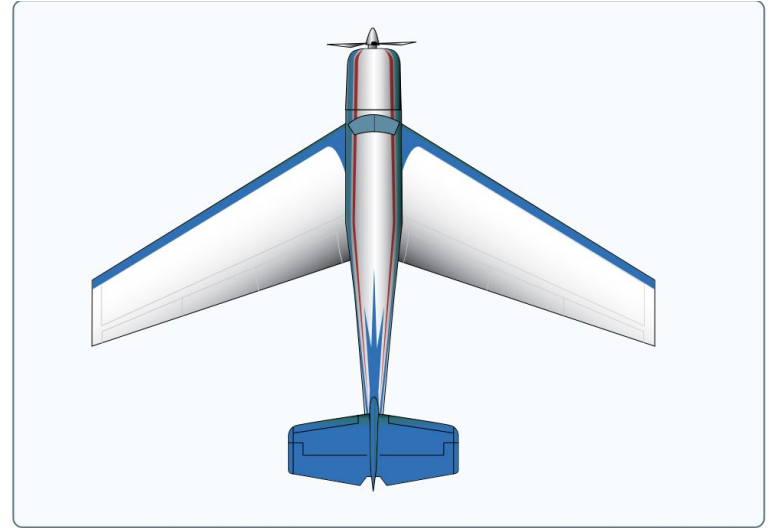
The wing away from the wind has a decreased angle of attack, and develops a decrease in lift. The changes in lift effect a rolling moment tending to raise the windward wing, and contributes to a stable roll due to sideslip.



Lateral Stability- Sweepback and Wing Location

As a rough estimation, 10° of sweepback on a wing provides about 1° of effective dihedral, while a high wing configuration can provide about 5° of effective dihedral over a low wing configuration.

A sweptback wing is one in which the leading edge slopes backward. When a disturbance causes an aircraft with sweepback to slip or drop a wing, the low wing presents its leading edge at an angle that is more perpendicular to the relative airflow. As a result, the low wing acquires more lift, rises, and the aircraft is restored to its original flight attitude.



Lateral Stability - Keel Effect

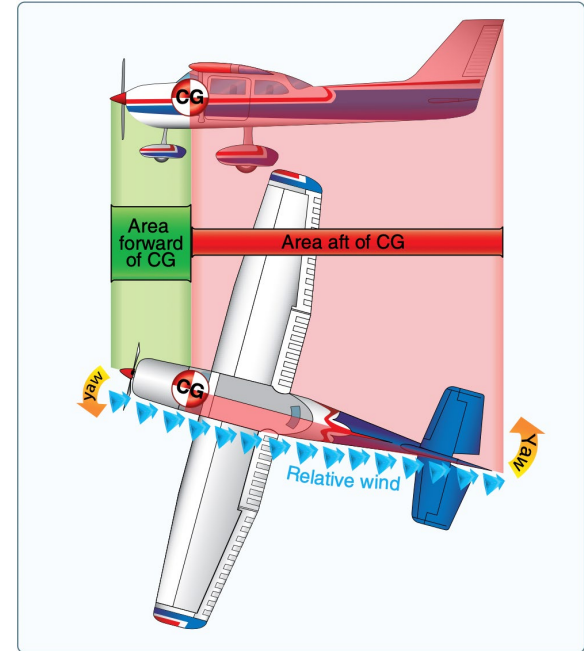
A high wing aircraft always has the tendency to turn the longitudinal axis of the aircraft into the relative wind, which is often referred to as the keel effect. These aircraft are laterally stable simply because the wings are attached in a high position on the fuselage, making the fuselage behave like a pendulum.



Directional Stability (Yawing)

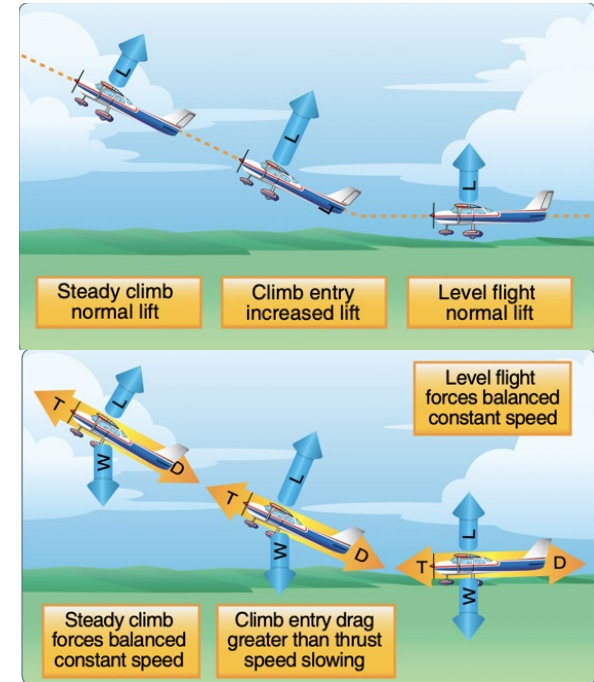
Stability around the aircraft's vertical axis is called yawing or directional stability. Directional stability is the most easily achieved stability in aircraft design. The area of the vertical fin and the sides of the fuselage aft of the CG are the prime contributors that make the aircraft act like the well known weather vane or arrow, pointing its nose into the relative wind.

When turbulence or rudder application causes the aircraft to yaw to one side, the opposite wing presents a longer leading edge perpendicular to the relative airflow. The airspeed of the forward wing increases and it acquires more drag than the back wing. The additional drag on the forward wing pulls the wing back, turning the aircraft back to its original path.



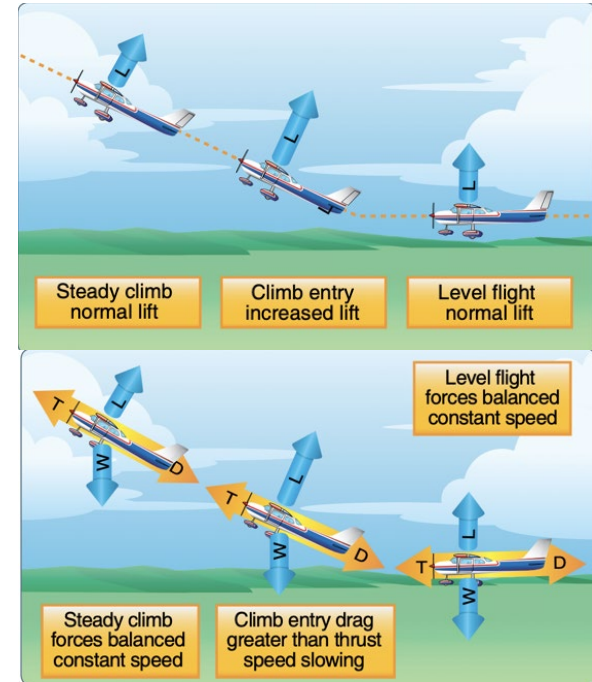
Aerodynamics and Flight Maneuvers - Forces in a Climb

The wing's lift in a steady state normal climb is the same as it is in a steady level flight at the same airspeed. During the transition from straight-and-level flight to a climb, a change in lift occurs when back elevator pressure is first applied. Raising the aircraft's nose increases the AOA and increases the lift. Lift at this moment is now greater than weight and starts the aircraft climbing. After the flight path is stabilized on the upward incline, the AOA and lift again revert to about the level flight values.



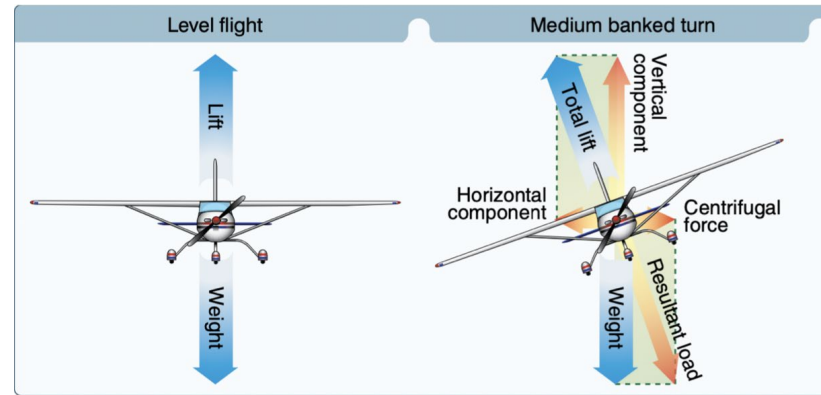
Aerodynamics and Flight Maneuvers - Forces in a Climb

If the climb is entered with no change in power setting, the airspeed gradually decreases because the thrust required to maintain a given airspeed in level flight is insufficient to maintain the same airspeed in a climb. When the flight path is inclined upward, a component of the aircraft's weight acts in the same direction as, and parallel to, the total drag of the aircraft, and increasing the total effective drag. The total effective drag is greater than the power, and the airspeed decreases. The reduction in airspeed gradually results in a corresponding decrease in drag until the total drag equals the thrust.



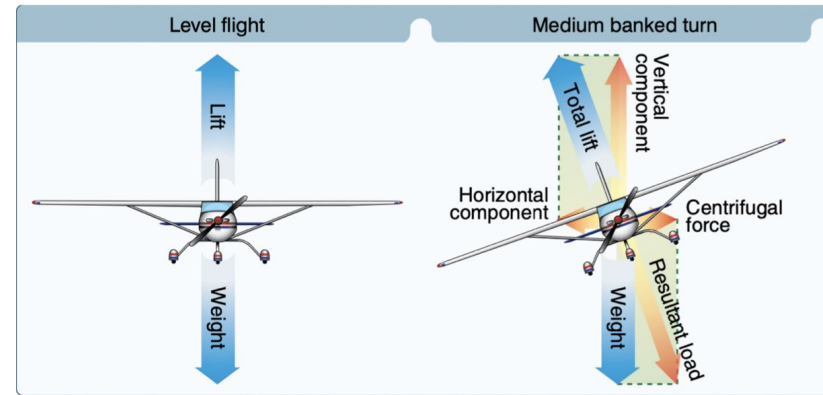
Aerodynamics and Flight Maneuvers - Forces in Turns

If an aircraft were viewed in straight-and-level flight from the front, and if the forces acting on the aircraft could be seen, lift and weight would be clear: two forces. If the aircraft were banking it would be clear that lift did not act directly opposite to the weight, rather it now acts in the direction of the bank. A truth about turns is that when the aircraft banks, lift acts inward toward the center of the turn, perpendicular to the lateral axis as well as upward.



Aerodynamics and Flight Maneuvers - Forces in Turns

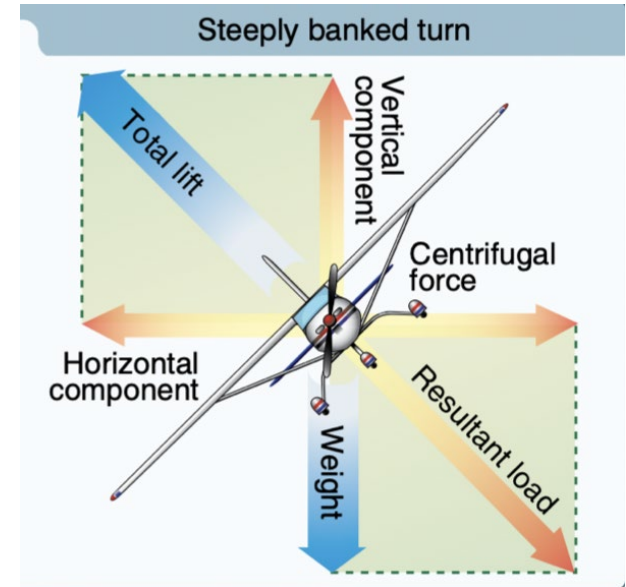
An aircraft, like any moving object, requires a sideward force to make it turn. In a normal turn, this force is supplied by banking the aircraft so that lift is exerted inward, as well as upward. The force of lift during a turn is separated into two components at right angles to each other. One component, which acts vertically and opposite to the weight, is the “vertical component of lift.” The other, which acts horizontally toward the center of the turn, is the “horizontal component of lift” or centripetal force. The horizontal component of lift is the force that pulls the aircraft from a straight flight path to make it turn.



Aerodynamics and Flight Maneuvers - Forces in Turns

The rudder is used to correct any deviation between the track of the nose and tail of the aircraft into the relative wind. A good turn is one in which the nose and tail of the aircraft track along the same path of to the turn. If no rudder is used in a turn, the nose of the aircraft yaws to the outside of the turn.

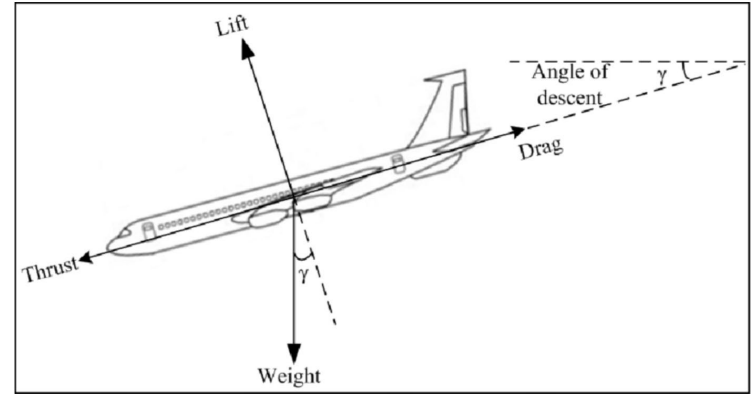
An aircraft is not steered like a boat or an automobile. In order for an aircraft to turn, it must be banked. Good directional control is based on the fact that the aircraft attempts to turn whenever it is banked. Pilots should keep this fact in mind when attempting to hold the aircraft in straight-and-level flight.



Aerodynamics and Flight Maneuvers - Forces in Descent

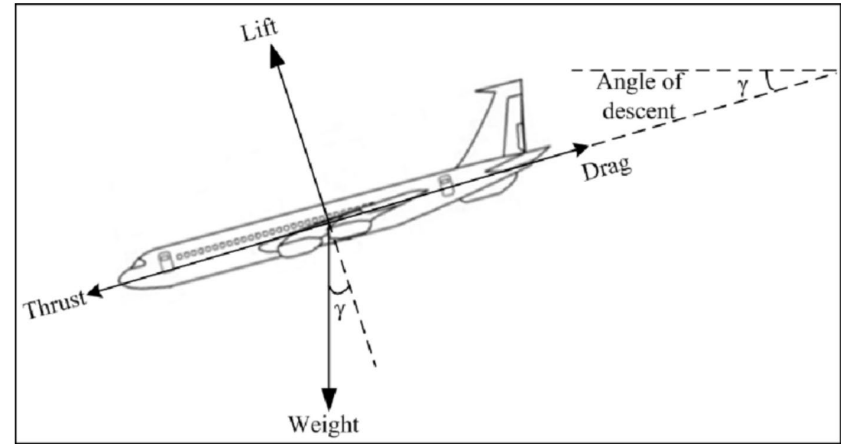
As in climbs, the forces that act on the aircraft go through definite changes when a descent is entered from straight-and-level flight. For the following example, the aircraft is descending at the same power as used in straight-and-level flight.

As forward pressure is applied to the control yoke to initiate the descent, the AOA is decreased. First, the momentum of the aircraft causes the aircraft to briefly continue along the same flight path. For this instant, the AOA decreases causing the total lift to decrease. With weight now being greater than lift, the aircraft begins to descend. At the same time, the flight path goes from level to a descending flight path.



Aerodynamics and Flight Maneuvers - Forces in Descent

To descend at the same airspeed as used in straight-and-level flight, the power must be reduced as the descent is entered. Entering the descent, the component of weight acting forward along the flight path increases as the angle of descent increases and, conversely, when leveling off, the component of weight acting along the flight path decreases as the angle of descent decreases.



Stall

An aircraft stall results from a rapid decrease in lift caused by the separation of airflow from the wing's surface brought on by exceeding the critical AOA. A stall can occur at any pitch attitude or airspeed. Stalls are one of the most misunderstood areas of aerodynamics because pilots often believe an airfoil stops producing lift when it stalls. In a stall, the wing does not totally stop producing lift. Rather, it cannot generate adequate lift to sustain level flight.



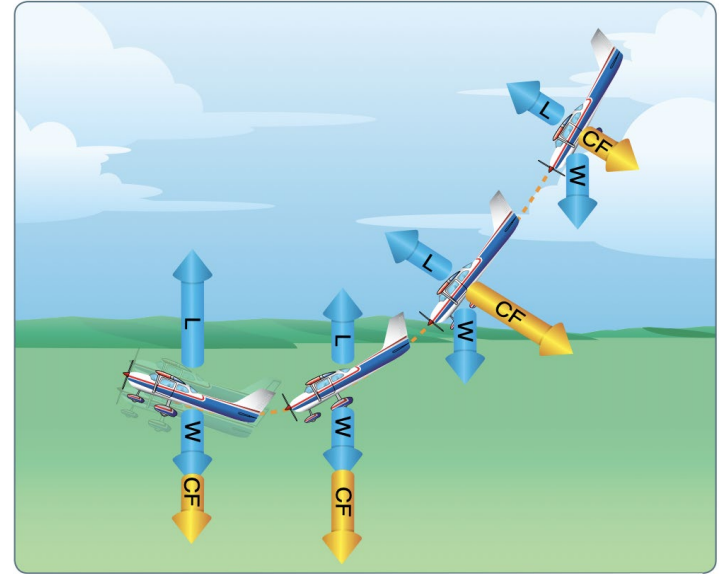
Stall

In most straight-wing aircraft, the wing is designed to stall the wing root first. The wing root reaches its critical AOA first making the stall progress outward toward the wingtip. By having the wing root stall first, aileron effectiveness is maintained at the wingtips, maintaining controllability of the aircraft. Various design methods are used to achieve the stalling of the wing root first. In one design, the wing is “twisted” to a higher AOA at the wing root. Installing stall strips on the first 20–25 percent of the wing’s leading edge is another method to introduce a stall prematurely.



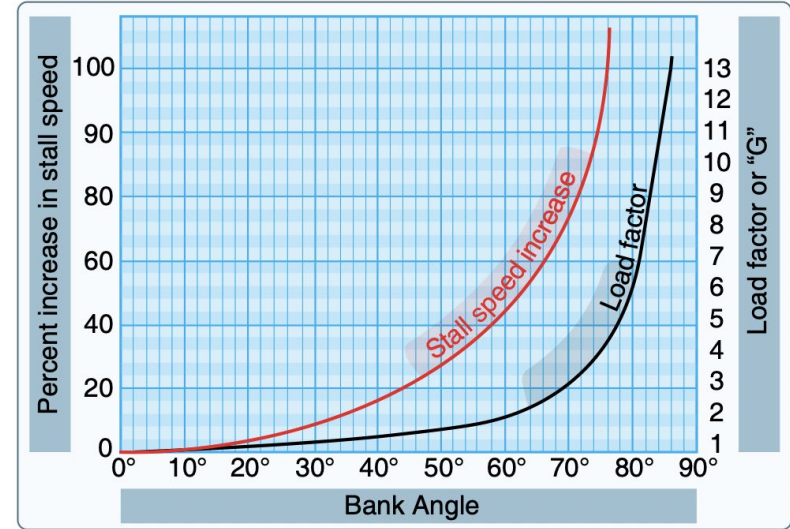
Stall

Low speed is not necessary to produce a stall. The wing can be brought into an excessive AOA at any speed. For example, an aircraft is in a dive with an airspeed of 100 knots when the pilot pulls back sharply on the elevator control. Gravity and centrifugal force prevent an immediate alteration of the flight path, but the aircraft's AOA changes abruptly from quite low to very high. Since the flight path of the aircraft in relation to the oncoming air determines the direction of the relative wind, the AOA is suddenly increased, and the aircraft would reach the stalling angle at a speed much greater than the normal stall speed.



Stall

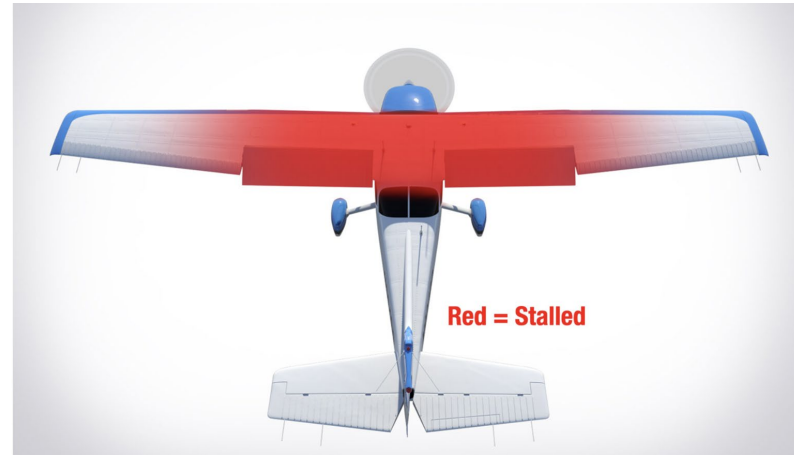
The stalling speed of an aircraft is also higher in a level turn than in straight-and-level flight. Centrifugal force is added to the aircraft's weight and the wing must produce sufficient additional lift to counterbalance the load imposed by the combination of centrifugal force and weight. In a turn, the necessary additional lift is acquired by applying back pressure to the elevator control. This increases the wing's AOA and results in increased lift. The AOA must increase as the bank angle increases to counteract the increasing load caused by centrifugal force. If at any time during a turn the AOA becomes excessive, the aircraft stalls.



Stall Recognition

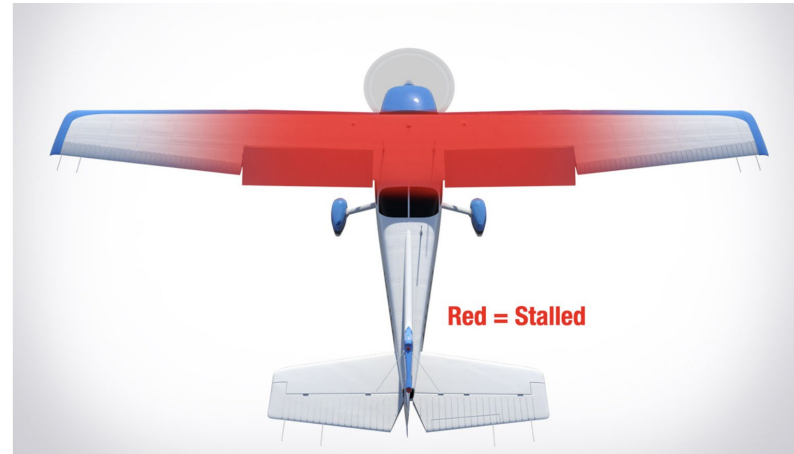
There are several ways to recognize that a stall is impending before it actually occurs. When one or more of these indicators is noted, initiation of a recovery should be instinctive. One indication of a stall is a mushy feeling in the flight controls and less control effect as the aircraft's speed is reduced. This reduction in control effectiveness is attributed in part to reduced airflow over the flight control surfaces.

Just before the stall occurs, buffeting, uncontrollable pitching, or vibrations may begin. Many aircraft are equipped with stall warning devices that will alert the pilot 4 to 8 knots prior to the onset of a stall.



Stall Recognition

Finally, kinesthesia (the sensing of changes in direction or speed of motion), when properly learned and developed, will warn the pilot of a decrease in speed or the beginning of a mushing of the aircraft. These preliminary indications serve as a warning to the pilot to increase airspeed by adding power, lowering the nose, and/or decreasing the angle of bank.



Types of Stalls

Power-off stalls are practiced to simulate normal approach-to-landing conditions and configuration. Many stall/spin accidents have occurred in these power-off situations, such as crossed control turns from base leg to final approach; attempting to recover from a high sink rate on final approach by using only an increased pitch attitude.



Types of Stalls

Power-on stalls are practiced to simulate takeoff and climbout conditions and configuration. Many stall/spin accidents have occurred during these phases of flight, particularly during go-arounds. A causal factor in such accidents has been the pilot's failure to maintain positive control due to a nose-high trim setting or premature flap retraction, and during short field takeoffs has also been a causal accident factor.



Types of Stalls

Accelerated stalls can occur at higher-than-normal airspeeds due to abrupt and/or excessive control applications. These stalls may occur in steep turns, pullups, or other abrupt changes in flightpath. Accelerated stalls usually are more severe than unaccelerated stalls and are often unexpected because they occur at higher-than-normal airspeeds.



Types of Stalls

A **cross-controlled stall** simulates a base to final skidding turn, where pilots may apply aileron in one direction and rudder in the other direction. This can happen when pilots overshoot final and attempt to correct improperly. There is little warning once a stall does occur before loss of control effectiveness.



Types of Stalls

When a pilot adds too much nose up pitch trim during approach, they're setting themselves up for an elevator trim stall. If the airplane is trimmed to fly itself all the way to the runway and maximum power is suddenly added during a go-around, the nose can pitch up rapidly. You'll need to use substantial forward pressure on the yoke as you retrim to prevent the stall.



Stall Recovery

The key factor in recovering from a stall is regaining positive control of the aircraft by reducing the AOA.

At the first indication of a stall, the aircraft AOA must be decreased to allow the wings to regain lift. It should be noted that too much forward pressure can hinder recovery by imposing a negative load on the wing.



Stall Recovery

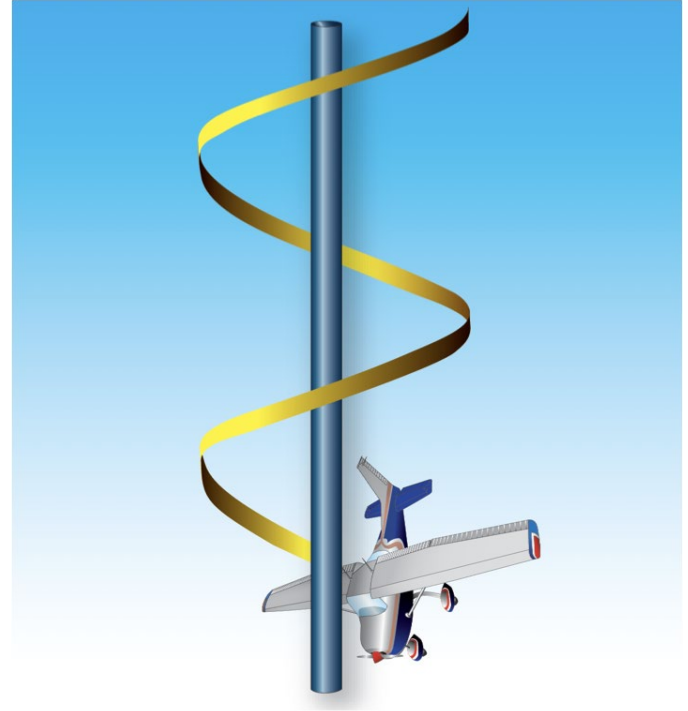
The next step in recovering from a stall is to smoothly apply maximum allowable power (if applicable) to increase the airspeed and to minimize the loss of altitude. Certain high performance airplanes may require only an increase in thrust and relaxation of the back pressure on the yoke to effect recovery.

As airspeed increases and the recovery is completed, power should be adjusted to return the airplane to the desired flight condition. Straight and level flight should be established with full coordinated use of the controls. The airspeed indicator or tachometer, if installed, should never be allowed to reach their high speed red lines at any time during a practice stall.



Spins

A spin may be defined as an aggravated stall that results in what is termed “autorotation” wherein the airplane follows a downward corkscrew path. As the airplane rotates around a vertical axis, the rising wing is less stalled than the descending wing creating a rolling, yawing, and pitching motion. The airplane is basically being forced downward by gravity, rolling, yawing, and pitching in a spiral path.

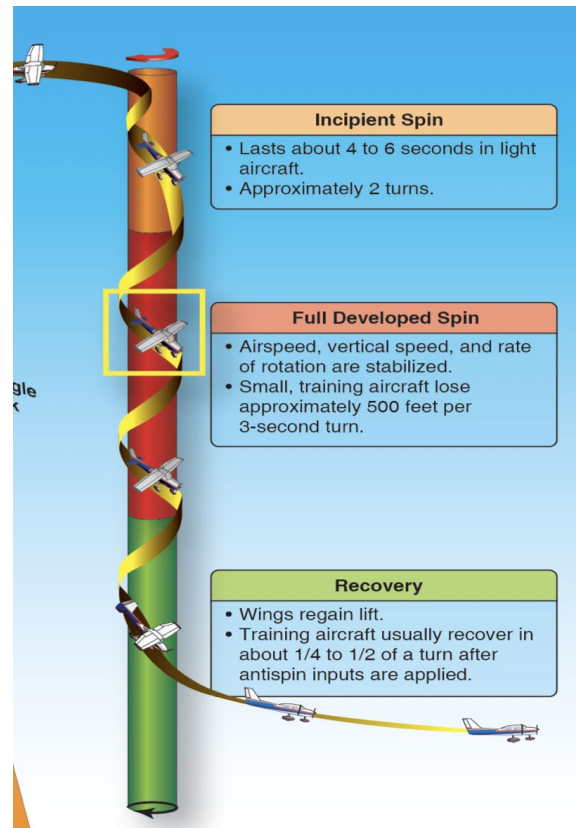


Types of Spins

a. An incipient spin is that portion of a spin from the time the airplane stalls and rotation starts, until the spin becomes fully developed. Incipient spins that are not allowed to develop into a steady state spin are commonly used as an introduction to spin training and recovery techniques.

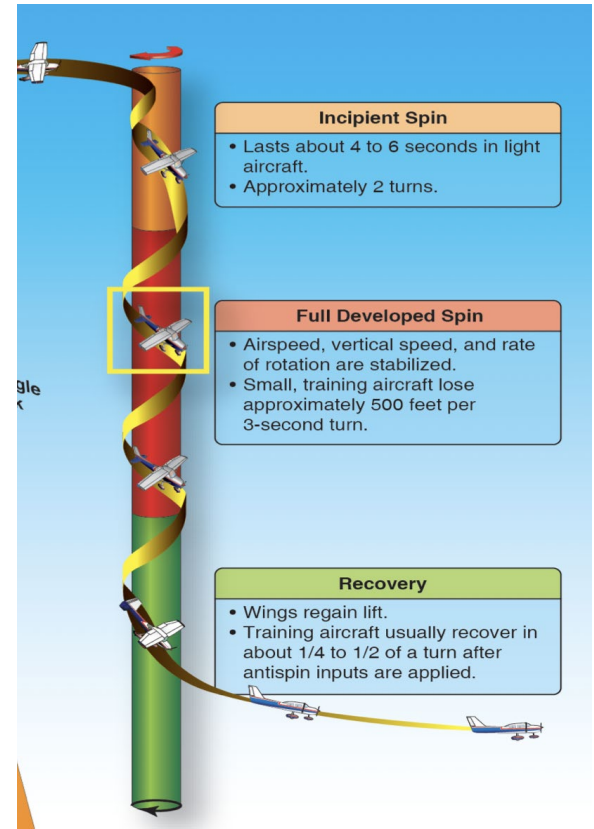
b. A fully developed, steady state spin occurs when the aircraft angular rotation rate, airspeed, and vertical speed are stabilized from turn-to-turn in a flightpath that is close to vertical.

c. A flat spin is characterized by a near level pitch and roll attitude with the spin axis near the CG of the airplane. Recovery from a flat spin may be extremely difficult and, in some cases, impossible.



Spin Recovery

- The pilot should be familiar with the operating characteristics and standard operating procedures, including spin recovery techniques, specified in the approved AFM or POH.
- The first step in recovering from an upright spin is to close the throttle completely to eliminate power and minimize the loss of altitude.
- The next step is to neutralize the ailerons, determine the direction of the turn, and apply full opposite rudder.



Spin Recovery

- When the rotation slows, briskly move the elevator control forward to approximately the neutral position. Forward movement of the elevator control will decrease the AOA.
- Once the stall is broken, the spinning will stop. Neutralize the rudder when the spinning stops to avoid entering a spin in the opposite direction. When the rudder is neutralized, gradually apply enough aft elevator pressure to return to level flight.

