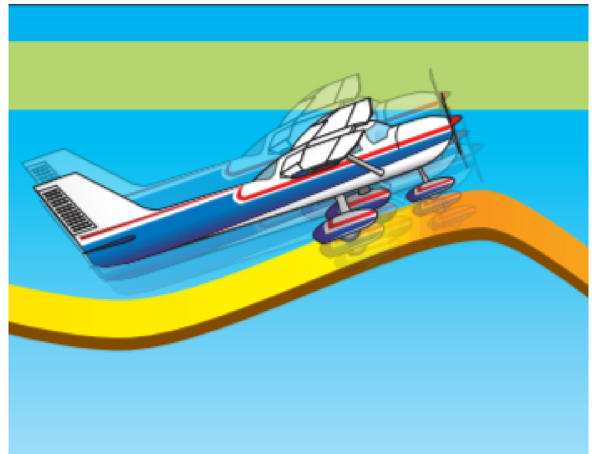
Power-On Stalls

Objective	
To ensure the applicant learns the purpose of and can exhibit a clear understanding of the power-on stall maneuver and how to perform the maneuver properly.	
Purpose	
Stalls are what happens when a wing 'stops flying'. The power-on stall maneuver introduces pilots to a stall that might be encountered just after takeoff. Pilots will develop proficiency in proper stall awareness and recovery, as well as understanding the dangers of uncoordinated stalls.	
Schedule	**Equipment**
● **Ground Lesson**: 15 minutes ● Initial ■ **Flight 1**: 40 minutes - *Introduction to Maneuver* ■ **Flight 2**: 50 minutes - *Improve Proficiency (Dual)* ● Solo ■ **Flight 3**: 30 minutes - *Improve Proficiency* ● Pre-Checkride ■ **Flight 4**: 20 minutes - *Demonstrate Proficiency* ● **Debrief**: 10 minutes (*per flight*)	● Airplane Checklist ● Whiteboard / Markers (optional) ● Model Airplane (optional)
Student Actions	**Instructor Actions**
● Ask any questions, receive study material for the next lesson. ● Watch linked video. ● Review listed references.	● Deliver the ground lesson (below). ● Demonstrate the maneuver in flight. ● Debrief after each flight.

Completion Standards

- **Ground**: Student can explain the purpose of the maneuver and how to execute it properly.
  - Can explain the critical angle of attack, left-turning tendencies, factors that affect stall speed.
- **Flight**: Student can perform the maneuver to the applicable ACS standards.
  - Establishes a level flight (or a coordinated turn) in the specified configuration at a normal rotation airspeed.
  - Increases power to full, continually increases pitch smoothly to cause a stall. Maintains a specified heading ±10° if in straight flight; maintain a specified angle of bank not to exceed 20°, ±10° if in turning flight, while inducing the stall.
  - **Private Pilot**: Acknowledges first indication of the stall, and continues to a full stall.
  - **Commercial/CFI**: Acknowledges first indication of the stall, and (optionally) continues to a full stall.
  - Promptly recovers and climbs at Vx or Vy to return to the original altitude and heading.
  - See expanded Completion Standards below.

References

- ERAUSpecialVFR - “Power On Stalls”
    - YouTube - https://www.youtube.com/watch?v=Wf-1bGziMME
- FAA-H-8083-3C (Airplane Flying Handbook) - Chapter 3, Page 10 [Trim Control], Chapter 3, Page 11-17 [Level Turns], Chapter 5, Page 8-9 [Coordinated Flight/Angle of Attack], Chapter 5, Page 12-16 [Stalls/Stall Recognition/Stall Recovery], Chapter 5, Page 18 [Full Stalls, Power-On]
- FAA-H-8083-25C (Pilot’s Handbook of Aeronautical Knowledge) - Chapter 5, Page 2-5 [Thrust, Lift, and Angle of Attack], Chapter 5, Page 25-26 [Stalls], Chapter 5, Page 30-33 [Left Turning Tendencies], Chapter 5, Page 34-35 [Load Factors and Stalling Speeds]
- FAA-S-ACS-6C (Private Pilot ACS) - Area VII Task C
- FAA-S-ACS-7B (Commercial Pilot ACS) - Area VII Task C
- FAA-S-ACS-25 (CFI ACS) - Area X Task D

Ground Lesson Outline

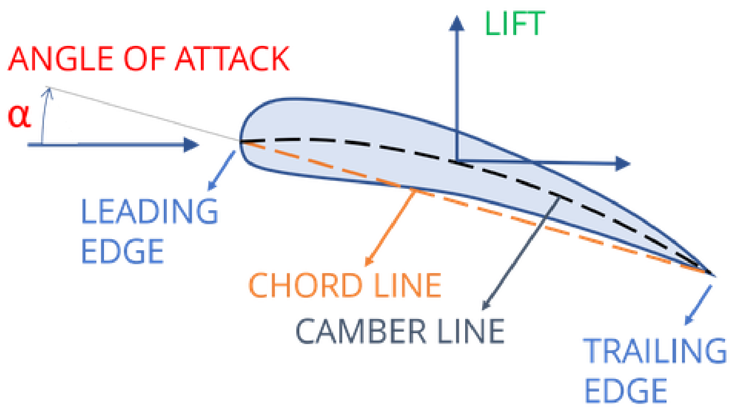
- Stalls
    - Angle of attack, relative wind, chord line, Lift/Drag, Induced Drag, Parasite Drag
    - Critical Angle of Attack
- Recovery from a Stalled Condition
    - CG and Natural Recovery Tendency, Dangers of an Aft CG
    - Secondary Stall
- Stall Speed
    - Vs, Vs0
- Bank Angle and Load Factor
- Factors that affect stall speed
    - Load factor, CG, Weight, Coordination
- Left Turning Tendencies
    - Torque reaction, spiraling slipstream, P-factor
- Power and downwash
- The Departure Stall
    - Risk of uncoordinated stall/spin
- Warning Signs
- Safety considerations
    - Use of checklists, Visual traffic scanning
- Maneuver Description - step-by-step
    - Entry position, airspeed, etc.
- Expanded Completion Standards

Common Errors

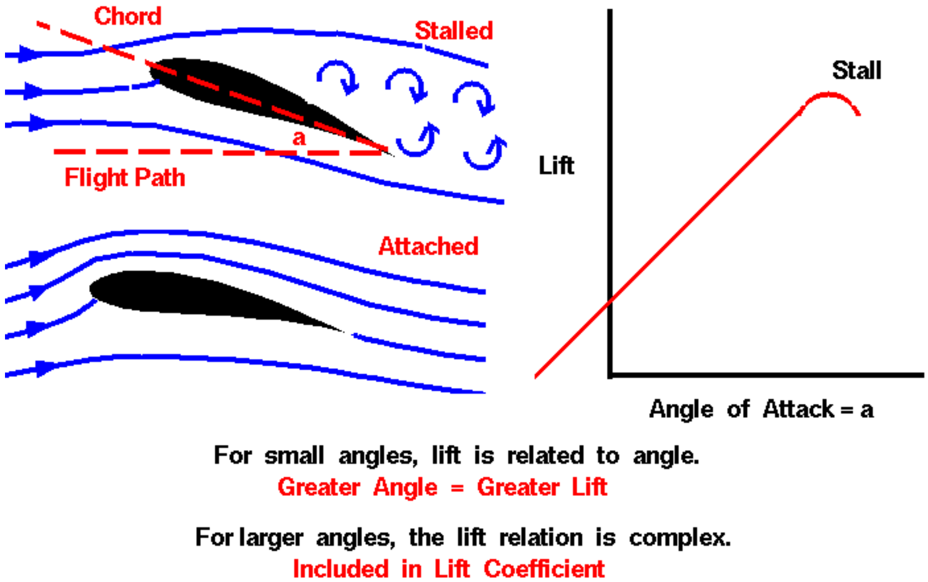
- Failure to establish the specified configuration prior to entry.
- Improper pitch, heading, yaw, and bank control during straight-ahead stalls.
- Improper pitch, yaw, and bank control during turning stalls.
- Rough and/or uncoordinated use of flight controls.
- **Failure to recognize the first indications of a stall.**
- **Failure to achieve a stall.**
- **Improper torque correction.**
- Poor stall recognition and delayed recovery.
- Excessive altitude loss or excessive airspeed during recovery.
- **Secondary stall during recovery.**

Ground Lesson Content

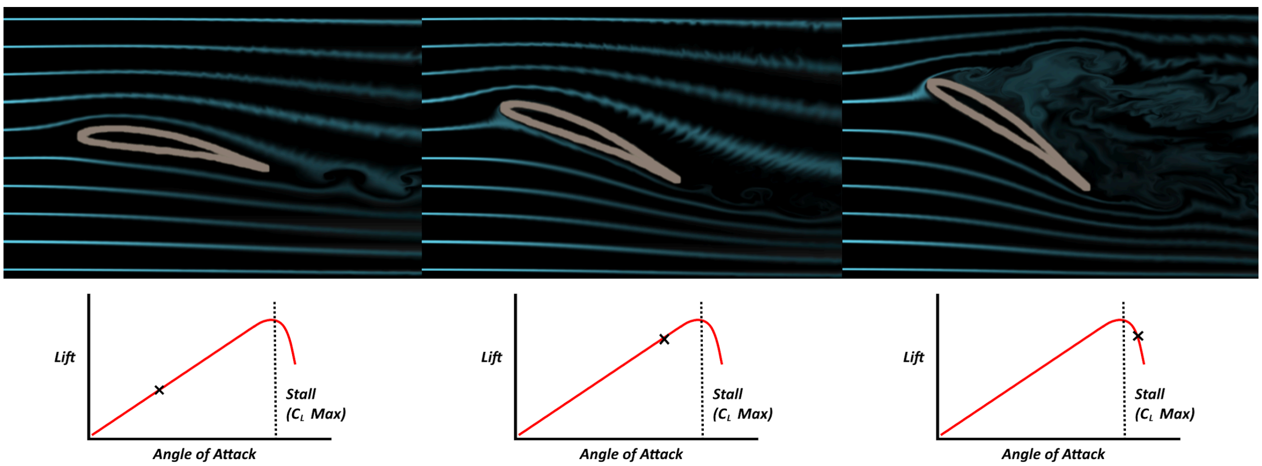
- **Stalls -** An aerodynamic *stall* is what happens when a wing 'stops flying'. Wings (also known as *airfoils*) are designed to redirect air downwards (resulting in an upwards force, called *lift*) by smoothly and efficiently acting on the air both below *and* above them. As physical objects moving through the air, there is also inherently air resistance (a rearwards force called *drag*) opposing them.
  - The amount of lift a wing produces is controlled by its design (which is fixed), and is also proportional to its *angle of attack* (which is variable). **The angle of attack is the angle between the wing's *chord line* and the *relative wind*.**



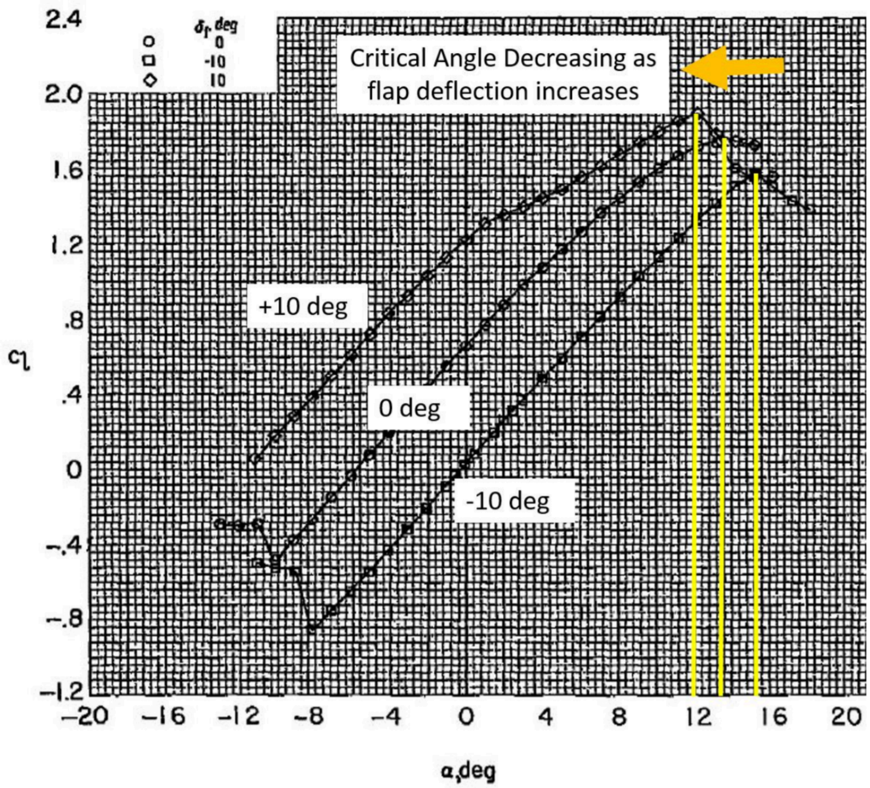
  - It is important to realize that the relative wind is not always horizontal. **The relative wind is created by the motion of the airplane itself through the air, and can be from any direction.** An airplane diving at the ground may have a relative wind that is nearly vertical, and an airplane flying level will have a relative wind that is horizontal.
  - Airfoils produce two types of drag:
    - **Induced Drag -** Induced drag is drag that is produced because lift is produced. The force an airfoil produces is perpendicular to its chord line, and airfoils only produce lift when flying at an angle to the relative wind. This means that some of that force acts upward (lift), and some acts rearward (drag). **More lift always means more induced drag.**
    - **Parasite Drag -** Parasite drag is just the drag that is created by moving any solid object through the air, and is not associated with the production of lift. **Parasite drag increases as the square of the airspeed**.
  - As the angle of attack increases, wings produce increasing amounts of lift. As the wing moves at a low angle of attack, the air moving over its upward surface moves as a smooth flow, which is *attached* (tends to follow the contours of the wing). Airflow at low angles of attack generates relatively little drag. As the angle of attack increases, the flow becomes more turbulent, and at some point, the air flowing over the wing's upper surface cannot remain attached, and becomes very turbulent. At this point, the lift produced by the wing drops dramatically, with a corresponding dramatic increase in drag. The angle at which the lift is at maximum, before decreasing rapidly, is called the *critical angle of attack*. Once a wing exceeds the critical angle of attack, it is said to be *stalled*. (It 'stops flying') **An important property of wings is that they always stall at the same critical angle of attack, regardless of airspeed!**



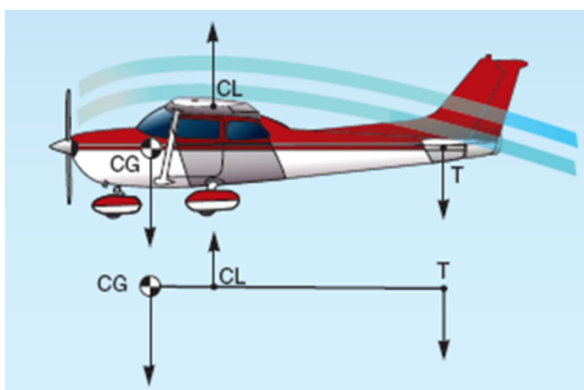
- Below is an airfoil in the normal (low angle of attack), high lift (high angle of attack), and stalled condition, along with the corresponding angle of attack vs lift graph:



- Although a given wing always stalls at the same angle of attack, most airplanes have wings that can actually change their design to some extent. The addition of *flaps* changes the aerodynamics of a wing by lengthening the chord line and changing the overall curvature of the wing (called *camber*). In most cases, flaps add more lift, but significantly more drag. Because of the increased camber, flaps allow airplanes to produce more lift for a given angle of attack. However, **flaps generally *decrease* the critical angle of attack at which the wing stalls.**



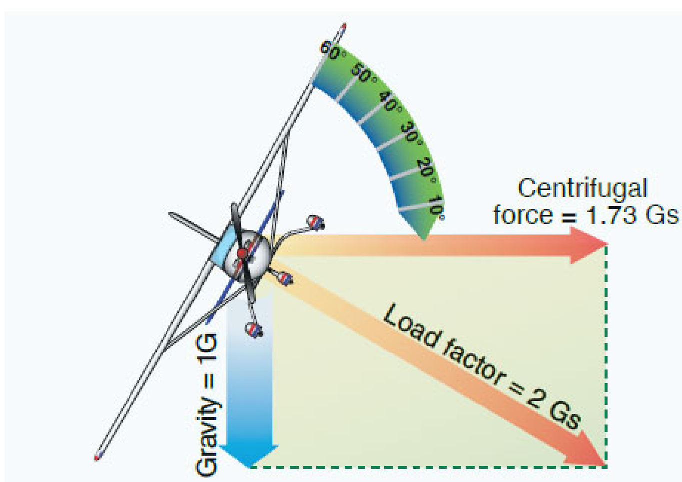
- **Recovery from a Stalled Condition -** A wing which is stalled is now producing very little lift relative to the drag it is producing. It has 'stopped flying'. **The only way to recover from the stall and to get the wing flying again is to reduce the angle of attack!**
  - Airplanes are designed so that they have a natural tendency to recover from a stall. They are designed so that during flight, they rotate around a point called the *Center of Lift*. The *Center of Gravity* is the 'balance point'. (Imagine balancing an object on a fingertip) **A well-designed airplane's Center of Gravity is always forward of the Center of Lift.**



  - This design causes a natural tendency for the airplane to nose down, reducing the angle of attack. To counteract this, the horizontal stabilizer and elevator surfaces of an airplane are designed to produce a *downward* force, which 'holds up' the heavier nose area by pivoting the airplane around the Center of Lift. **When an airplane stalls, if the elevator pressure is relaxed, the Center of Gravity will fall naturally.**

- When an airplane Center of Gravity is too close to the Center of Lift, or even behind it, a very dangerous situation exists where there is no natural tendency to recover from a stall. **In fact, if the Center of Gravity is too far rearward (aft), a stall may be unrecoverable!**
- For pilots of most airplanes this is very simple: **if the wing stalls, release back elevator pressure**. Some wings and airplane designs require more deliberate pilot action to recovery quickly from a stall, such as moving the elevator forward, but **most airplanes will recover simply by releasing the control pressures.**
- **Secondary Stalls -** If the release of control pressure is insufficient, or too brief, it is possible to enter a *secondary stall*, where the wing does not completely recover from the stall and enters a second, deeper stall. **It is important to reduce angle of attack enough to fully recover from the stall before increasing angle of attack again!**

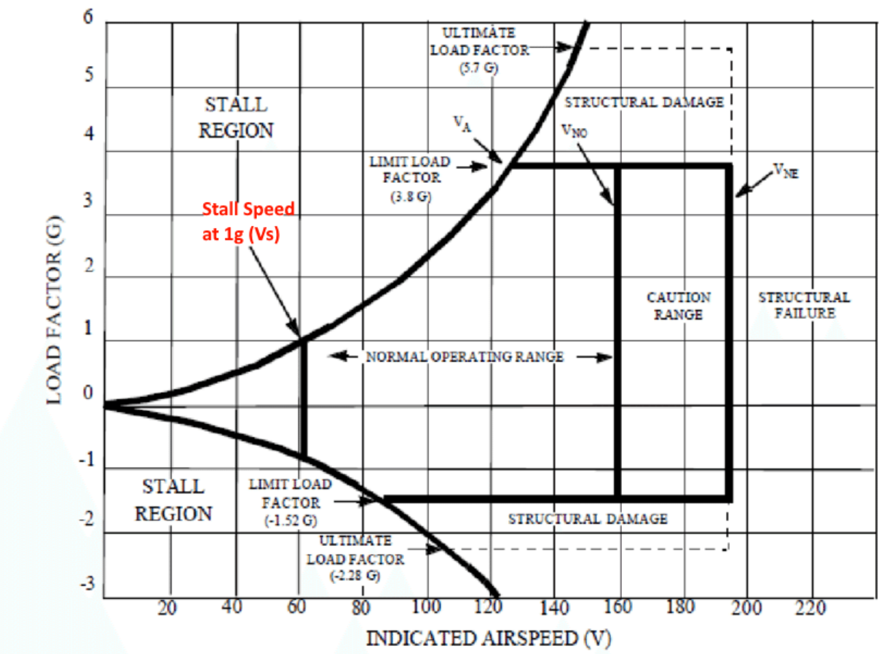
- **Stall Speed -** Although the angle of attack is the only *true* measure of when a wing will stall, most aircraft do not have a way to display angle of attack directly. Because most flight is conducted in approximately the same conditions, *airspeed* is a good approximation of angle of attack in many conditions, with some important limits.
  - Airplane POHs list stall speeds that are valid only for ‘unaccelerated’ (*generally straight, not turning*), coordinated flight at a given weight and center of gravity.
  - Recall that flaps can change the critical angle of attack, so airplane POHs also list stall speeds for different configurations, usually at least:
    - **Vs -** Stall speed in the *clean* (no flaps) configuration.
    - **Vs_0 -** Stall speed in the *landing* (usually with flaps) configuration.
- **Bank Angle and Load Factor -** As an airplane turns, its weight remains the same, and therefore the upward component of lift must remain equal to its weight. During a turn, some of the lift must be directed towards the center of the turn, reducing the upward component of lift. If no pilot corrections were applied, the airplane would not produce any more than the normal 1g of lift, and the airplane would begin to descend. In order to correct for the loss of vertical lift, and maintain a level altitude, the wing must produce more lift, which requires increased *back elevator pressure*. This increased back elevator pressure will cause the wing to fly at a ***higher angle of attack***, producing the increased lift that is required. This can be felt by the pilot as a higher than normal G-force.
  - In order to maintain 1g of vertical lift, while also turning, the wing must produce more than 1g of total lift. The amount of total lift is called the ***load factor***.



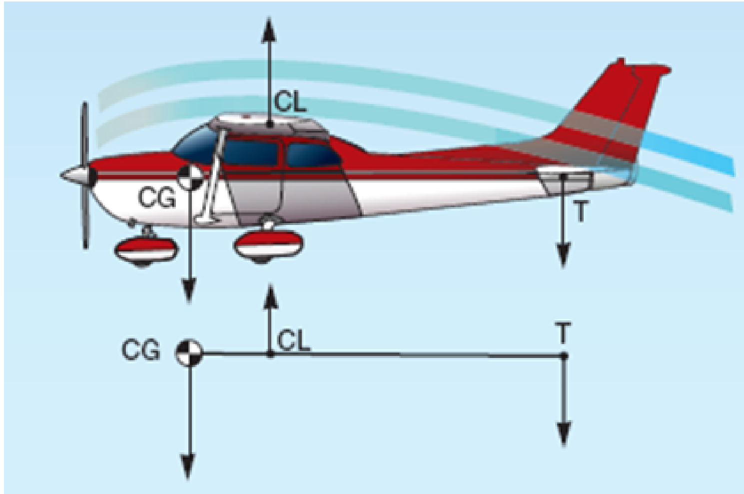
  - As the bank angle increases, the load factor required to maintain level flight increases slowly at first, but increases rapidly, especially at bank angles beyond 45 degrees. The load factor created by a *level, coordinated* turn **depends only on the bank angle**. Note that **airspeed does not affect the load factor of a turn.**

- While flying at a higher angle of attack necessary to meet the demands of a higher load factor, the wing will produce more *induced drag*. This will result in the airspeed decreasing unless power is added to compensate for the increased drag.

- **Factors that affect Stall Speed**
    - **Load Factor** - As the load factor increases in a turn, it is important to recognize that **the stall speed also increases**. We can see this relationship depicted in a so-called *Vg diagram*, shown below. The Stall Speed we normally see for our aircraft, Vs or Vs_0, applies only to 'unaccelerated' flight--that is, flight at 1g load factor. Observe from the Vg diagram that as the load factor increases, the stall speed also increases. **Note that the wing can stall at any airspeed!** If the load factor is high enough, the wing will either stall, or suffer structural failure.
    - Flying at low airspeeds requires that **bank angles be kept very low** to minimize the increase in load factor.

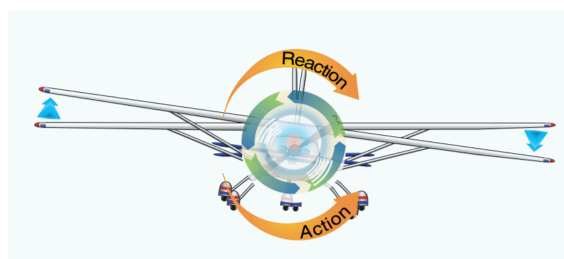


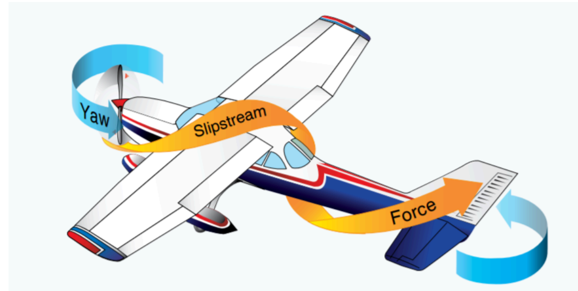
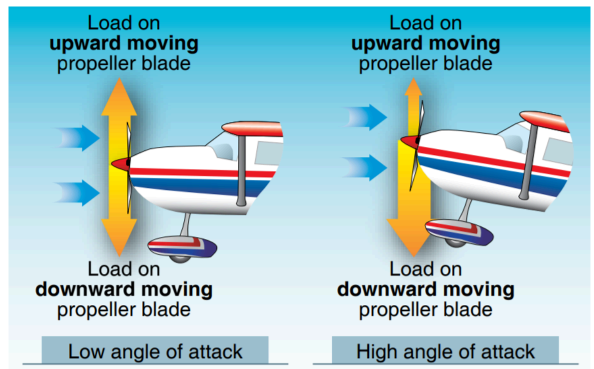
- **Center of Gravity** - When conventionally designed airplanes fly, the center of gravity is always *in front of* the center of lift. You can think of the center of lift as a sort of pivot point in a seesaw. Because the horizontal stabilizer is far behind the center of lift, it produces *downward* force (essentially lift, but downward) to keep the nose of the airplane level. This downward force opposes the upward force of the main wing, requiring it to produce slightly more lift to compensate. Also, because any airfoil that produces lift also produces drag, the amount of drag caused by the horizontal stabilizer depends on the force it must produce.
    - When the center of gravity is further forward, the horizontal stabilizer must produce more downward force, and therefore it creates more drag and causes the main wing to fly at a higher angle of attack for the same airspeed. We know that a wing will always stall at the same angle of attack, so we also know that **as the center of gravity moves further forward, the airplane will stall at a higher airspeed.**



- Weight - Likewise, when flying at higher weights, the total load on the wing is higher, again resulting in a higher angle of attack for the same airspeed. **Heavier aircraft stall at a higher airspeed.**
- **Coordination** - Airplanes flying in an uncoordinated fashion generate a considerable amount of increased drag, and the fuselage may blanket one wing or the other, increasing the stall speed. **This can actually cause the left and right wing to stall at a different airspeed! This is a *very* dangerous situation and must be avoided.**

- **Left-Turning Tendencies** - Because slow flight requires a relatively high power setting, and is flown at a high angle of attack, airplanes during slow flight are subject to more pronounced left-turning tendencies.

○ **Torque Reaction** - As the engine turns the propeller to move the air, Newton's laws of motion require an equal and opposite reaction. In particular, as the propeller turns clockwise (from the pilot's point of view), **the airplane wants to rotate (bank) opposite the propeller rotation, to the left**. In order to counteract this, airplanes are generally designed so that the left wing makes slightly more lift than the right wing (which also produces slightly more drag), but these design features are tuned for cruising flight. At higher power settings, this will produce a noticeable left-turning tendency.	

○ **Spiraling Slipstream** - As the airflow moves through the propeller and around the fuselage, wings, and control surfaces, it is spinning. The spinning propeller imparts a considerable spiraling motion to the slipstream, and **because the vertical tail surface extends only above, and not below, the spiraling slipstream pushes the tail slightly right, leading to left yaw.**	
○ **P-Factor** - As the airplane bites into the oncoming air, it is important to realize that it is just a rotating wing, and it has an angle of attack just as any other wing. However, because the engine is mounted in a fixed orientation relative to the airplane, when the airplane itself is flying at a high angle of attack, the angle of attack of the descending blade is considerably different (higher) than the ascending blade. **This produces more thrust on the right side of the propeller disc, and pushes the nose to the left.**	

- ○ Specifically, a high power setting produces a high torque reaction and a larger spiraling slipstream effect, and the high angle of attack makes P-factor very pronounced, **especially in a turn to the right**. Rudder pressure to maintain coordinated flight may be significant.

- **Power and Downwash** - Recall that the rear horizontal stabilizer and elevator surfaces act *downward* to counterbalance the heavy nose section. It is important to realize that the air flowing around the airplane is disturbed by the wing and the propeller. In fact, the wing 'bends' the airflow over the top such that the horizontal stabilizer usually flies at a higher angle of attack than it would seem from simply observing its angle relative to the airplane itself.
  - ○ Thrust from the propeller also contributes to this effect, and when the airplane is flying at high power settings, the amount of downwash experienced by the horizontal stabilizer is increased, improving its effectiveness, and there is a natural tendency to move it *down* (resulting in pitching the airplane *up*).

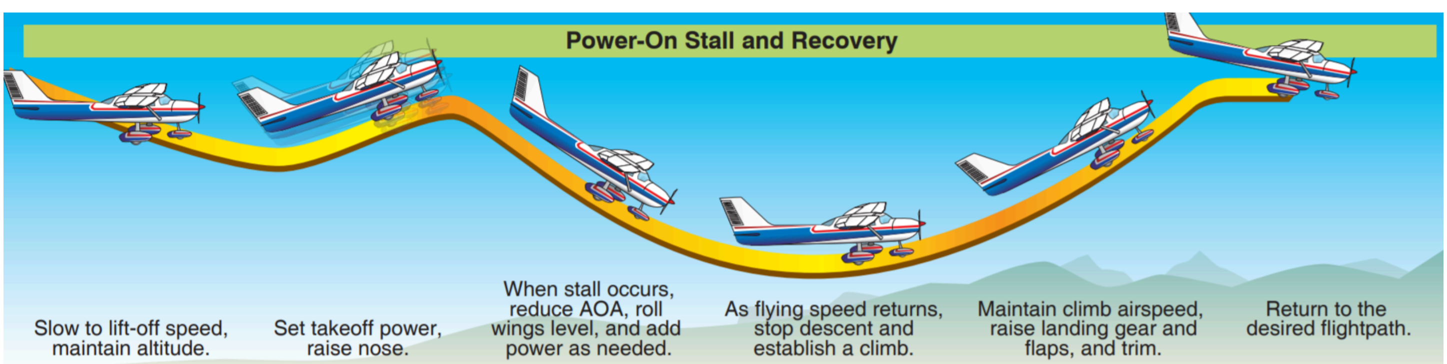
- **The Departure Stall** - The power-on stall is often known as the *departure stall*, and as the name indicates, **it is meant to simulate a stall that might occur if the airplane over-rotates on departure (takeoff), or attempts to climb too steeply afterwards**. Sometimes this can also occur if the airplane isn't performing well (high altitude, heavy, hot, etc.) and the pilot is continually pitching up beyond Vx in an attempt to clear terrain.

- Departure stalls can occur both in straight climbs, or in climbing turns. Because of the large right-rudder forces required to mitigate left-turning tendencies at high power settings, departure stalls involve a high risk of stalling while in uncoordinated flight. The most dangerous case being stalling while in a skidding turn. In any case, the airplane stalls, and if uncoordinated, very probably enters an aggravated stalled condition called a *spin*. **Spins may be unrecoverable at low altitude, but they require a stall to occur, so stalling the airplane at low altitude must be prevented at all costs!**
- Additionally, it is nearly always the case that during a departure stall, because of the strong left-turning tendencies, the airplane is slightly uncoordinated. **It is very common for one wing to drop dramatically. Do not attempt to correct this with aileron, as the down aileron (on the lower wing) increases the angle of attack and stalls that wing further!** This is the beginning of a spin! Correction should be made by using *opposite rudder*.

- **Warning Signs** - Stalls do not occur without warning. The airplane will behave quite differently as airspeed is reduced and the stall approaches:
  - **Loss of Control Effectiveness** - Maintaining pitch or bank will require large control movements.
  - **Buffet** - The stall *buffet* is the roughness or bumpiness that precedes an aerodynamic stall, caused by the increasingly turbulent airflow over the wing.
  - **Stall Warning Horn** - Most planes have an audible stall warning horn that activates a few knots before the stall.

- **Safety Considerations**
  - As with any maneuver, the **use of checklists is important**. Before beginning the maneuver, perform a pre-maneuver checklist, including performing clearing turns and identifying possible emergency landing sites.
  - It is crucial to not become so focused on performing the maneuver that an unsafe situation is created. Maintain situational awareness, make appropriate practice area radio calls, and **remember to continuously scan for traffic!**

Maneuver Description



- **Entry Altitude** - Stalls should always be performed at a safe altitude, in case of a delayed or inadequate recovery, or other problems. The maneuver should be performed such that accounting for altitude loss during the stall, the final altitude is no lower than 1,500 feet AGL. Additionally, a power-on stall creates a larger risk of an inadvertent spin. Therefore it is best to begin the maneuver **at least 2,000 feet AGL**.

- **Entry Airspeed** - The maneuver should be started by slowing the airplane down to a normal rotation airspeed, usually just below Vx.
- **Checklists** - Pilots must perform a pre-maneuver checklist before beginning the maneuver.
- **Configuration** - Configure the airplane for takeoff (generally no flaps).
- **Entry Power and Pitch** - Pitch the airplane to climb at approximately Vx and apply full power.
- **Bank** - If requested, begin a turn in the specified direction. The bank angle should be *less than* **20 degrees** to keep a low load factor.
- **Stall** - Continue to pitch the airplane up smoothly. Acknowledge (call out) the first indications of an approaching stall (especially the buffet or stall warning horn). **Maintain coordination**, hold back elevator pressure and allow the airplane to stall. (*For Commercial Pilot students, recover at first indication of the stall, if requested*)
- **Recovery** - Promptly **reduce back elevator pressure, and level the wings. If the airplane is uncoordinated during the stall, one wing may drop very aggressively. Do not use aileron to raise the dropped wing, as this will deepen the stall, use opposite rudder!** Once the airplane has regained flying airspeed, establish a climb at Vx or Vy to get back to the pre-maneuver altitude.
- **Coordination** - Due to the strong left-turning tendencies present at high power settings during power-on stalls, **proper coordination is essential**. Special attention should be given to proper rudder input during turns. Remaining coordinated throughout the maneuver will reduce the probability of a dramatic wing drop.
- **This is a visual maneuver!** Eyes should remain outside the cockpit as much as possible to scan for traffic and to hold heading.

Expanded Completion Standards

- The pilot can explain the purpose of the power-on stall maneuver and understands the critical angle of attack, factors that affect stall speed, left-turning tendencies, the risk of an uncoordinated stall, and other factors that affect the maneuver.
- The pilot can perform the maneuver to the following standards:
    - Pilot clears the area, performs a pre-maneuver/before-landing checklist, and selects an altitude not less than 2,000ft AGL.
    - Pilot configures the airplane as specified by the evaluator.
    - Pilot establishes level flight at an airspeed approximately equal to normal rotation speed.
    - Pilot applies full power and begins a properly coordinated climb (or turning climb) by continually increasing pitch to cause a stall. Maintains a specified heading ±10° if in straight flight; maintain a specified angle of bank not to exceed 20°, ±10° if in turning flight, while inducing the stall.
    - Pilot acknowledges (calls out) first indication of the stall.
        - **Private Pilots**: Allow the airplane to stall.
        - **Commercial Pilots/CFI**: Recovers at first indication, if requested, otherwise, allow the airplane to stall.
    - Recovers *promptly* from the stall by reducing pitch, and leveling wings.
    - Climb at Vx or Vy, as appropriate, and return to the original altitude and heading.