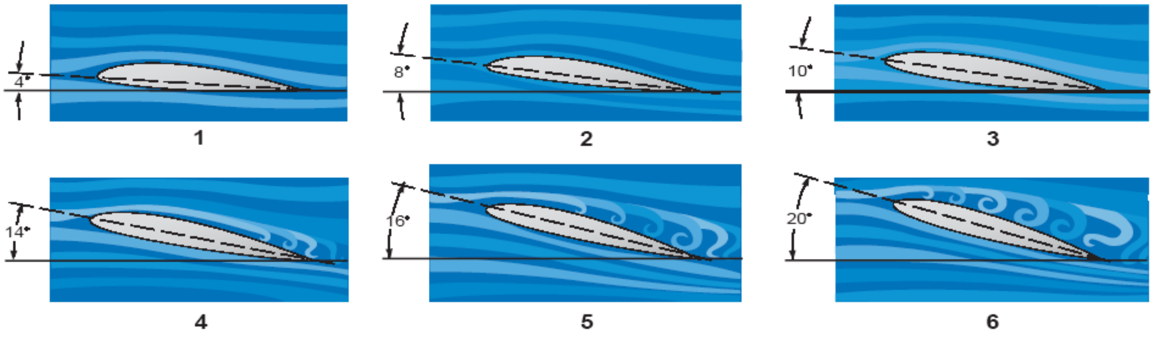
STALL AND SPIN CONSIDERATIONS

I. Stalls

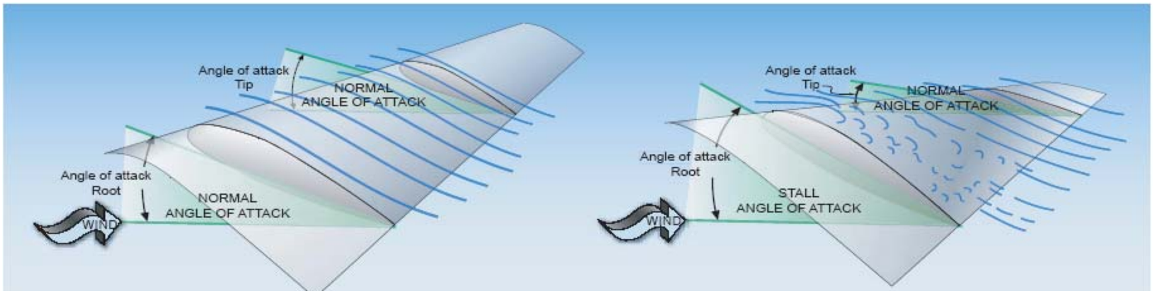
A. A stall is the loss of lift and the increase in drag that occur when an airplane is flown at an angle of attack greater than the angle for maximum lift. The angle of attack for maximum lift is also called the critical angle of attack. Thus, a stall occurs whenever the critical angle of attack is exceeded.

B. The stall speed is the speed at which the critical angle of attack is exceeded in a given airplane configuration and at a given load factor.

1. When the angle of attack is increased to approximately 18° to 20° on most airfoils, the airstream can no longer follow the upper curvature of the wing because of the excessive change in direction. This angle is the critical angle of attack.
    - a. As the critical angle of attack is approached, the airstream begins separating from the rear of the upper wing surface. As the angle of attack is further increased, the airstream is forced to flow straight back, away from the top surface of the wing and from the area of highest camber. See the figure that follows.
    - b. This causes a swirling or burbling of the air as it attempts to follow the upper surface of the wing. When the critical angle of attack is reached, the turbulent airflow, which appeared near the trailing edge of the wing at lower angles of attack, quickly spreads forward over the entire upper wing surface.
    - c. This results in a sudden increase in pressure on the upper wing surface and a considerable loss of lift. Due to both this loss of lift and the increase in form drag (a larger area of the wing and fuselage is exposed to the airstream), the remaining lift is insufficient to support the airplane, and the wing stalls.
    - d. To recover from a stall, the angle of attack must be decreased so that the airstream can once again flow smoothly over the wing surface.
        - i. Remember the angle of attack is the angle between the chord line and the relative wind, not between the chord line and the horizon.
        - ii. An airplane can be stalled in any attitude of flight with respect to the horizon, at any airspeed, and at any power setting because **exceeding the critical angle of attack is the only requirement for a stall to occur.**



2. Most light airplanes are designed so that the wings will stall progressively outward from the wing roots to the wingtips. Some wings are designed with washout; i.e., the wingtips have less angle of incidence than the wing roots.
    a. The **angle of incidence** is the angle between the chord line of the wing and the longitudinal axis of the airplane.
    b. Thus, during flight, the tips of such wings have a smaller angle of attack than the wing roots.



    c. A stall is caused by exceeding the critical angle of attack. Since the wing roots will exceed the critical angle of attack before the wingtips, the roots will stall first. You may have noticed that the ailerons on some training airplanes appear to be bent upward near the wingtips. The bending is not the result of damage, but is evidence of washout – the manufacturer's design tool to control the stall progression..
    d. Another means of forcing the wing to stall progressively outward from the wing roots to the wingtips is to include stall strips (sometimes called flow strips) at the wing root and/or swept-back sections at the wing root.
        i. The stall strips are wedge-shaped metal strips mounted on the leading edge of the wing near the root.
        ii. They are designed to cause early airflow separation (with the associated buffeting) near the wing root.
        e. The wings are designed to stall outward from the wing root to the wingtip so that control of the ailerons (which are located toward the tips of the wings) will be available at high angles of attack and give the airplane more stable stalling characteristics.
3. The following variables affect an airplane's stall characteristics and stall speed:
    a. **Configuration:** Flaps, landing gear (if retractable), and other configuring devices can affect an airplane's stall speed. Flap extension will generally increase the lifting ability of the wings, thus reducing the stall speed. This effect is illustrated by the colored arcs on the airspeed indicator, where the lower airspeed limit of the white arc (V_{S0}, power-off stall speed with gear and flaps in the landing configuration) is less than the lower airspeed limit of the green arc (V_{S1}, power-off stall speed, normally, with the flaps and gear up).
    b. **Load factor:** Load factor is the ratio of the lifting force produced by the wings to the actual weight of the airplane and its contents, usually expressed in Gs. When the airplane is subjected to a load factor that is greater than 1 G (in a level turn, for example), the wings are required to support a load that is greater than the airplane's weight. The increased load is the result of inertia, sometimes referred to as "centrifugal force."

i. When you feel pressed downward in your seat during a level turn, you are feeling the effect of increased load factor.

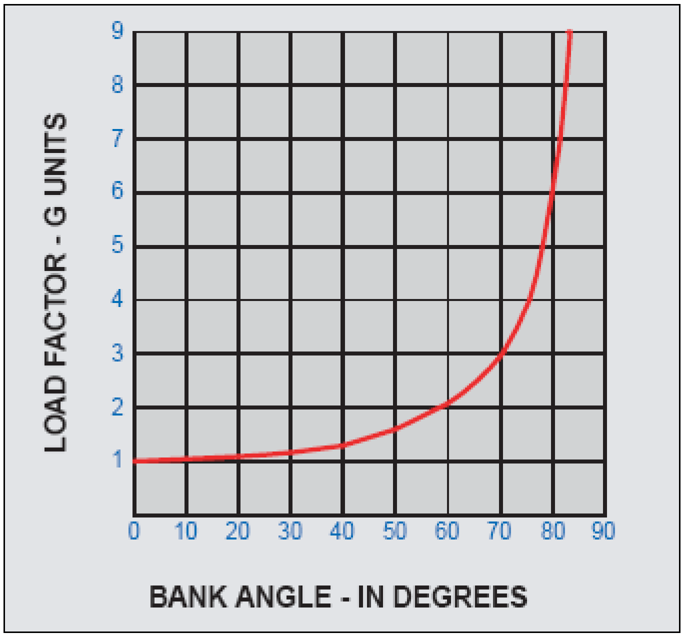
ii This sensation of increased weight is also called “pulling Gs.”

iii. An airplane’s stall speed increases in proportion to the square root of the load factor. EXAMPLE: An airplane with a normal unaccelerated stall speed of 45 kt. can be stalled at 90 kt. when subjected to a load factor of 4 Gs. This load might be experienced in a 75° bank level turn.

iv. A stall entered from straight-and-level flight or from an unaccelerated straight climb will not produce additional load factors. However other normal maneuvers canl produce additional load factors and the associated higher stalling speeds.

v. **Why does stall speed increase as load factor increases?** The stall speed increases above the unaccelerated stall speed at increased load factors because the wing is required to produce lift equal to a load that is greater than the airplane’s weight. The amount of lift generated by a given wing at a given altitude is directly related to its angle of attack and airspeed. Therefore, the stall speed increases when load factor increases because, for any given airspeed, the wing is required to be at a higher angle of attack in order to generate sufficient lift to support the increased load. Accordingly, the critical angle of attack will be reached at a higher airspeed because the margin between the required angle of attack for sufficient lift at any given airspeed and the critical angle of attack (which remains constant) is reduced.

vi. Increased load factors will cause an airplane’s stall speed to increase as the angle of bank increases. **Stall speed increases as bank angle increases** because load factor increases as bank angle increases.



This Clearly shows the importance of using moderate bank angles (no more than 30°) when flying at reduced airspeeds (e.g., in the traffic pattern).

c. **Center of gravity (CG):** Because the CG location affects both the required angle of attack and airplane stability, it has a significant effect on stall speed and ease of recovery. As the CG is moved aft, the airplane flies at a lower angle of attack for a given airspeed because of reduced tail-down force required from the horizontal stabilizer. Tail-down force is necessary to counteract the intentional nose-heaviness of the airplane. When nose-heaviness is reduced by moving the CG aft, the tail-down force must also be reduced to achieve equilibrium.
    i. The reduction of tail-down force reduces the total load that must be supported by the wings. Thus, the critical angle of attack will be exceeded (causing the airplane to stall) at a lower airspeed because the margin between the required angle of attack for any given airspeed and the critical angle of attack is increased. However, the airplane is less stable because the CG is closer to the center of lift.
    ii. With an extremely aft CG (i.e., aft of the center of lift), the airplane loses its natural tendency to pitch nose down, making stall recovery more difficult.
    iii. Stall recovery is also more difficult because the leverage of the elevators is reduced by the shortened distance from the CG.
    iv. If a spin is entered, the balance of forces on the airplane may result in a flat spin, from which recovery may be impossible.
    v. A forward CG location will cause the critical angle of attack to be reached (and the airplane to stall) at a higher airspeed. However, stall recovery is easier because the airplane has a greater tendency to pitch nose down and the elevator is a greater distance from the CG.

d. **Weight:** Although the distribution of weight has the most direct effect on stability and stall speed, increased gross weight also affects an airplane's flight characteristics, regardless of the CG location.
    i. A higher angle of attack is required at any given airspeed to produce the additional lift required to support the greater weight.
    ii. Thus, the critical angle of attack will be exceeded (causing the airplane to stall) at a higher airspeed because of the reduced margin between the required angle of attack and the critical angle of attack.

e. **Snow, ice, or frost on the wings:** Even a small accumulation of snow, ice, or frost on an airplane can cause an increase in the stall speed. It changes the shape and/or texture of the wing, disrupting the smooth airflow over the surface and thus increasing drag and decreasing lift.

f. **Turbulence:** Turbulence can cause an airplane to stall at a significantly higher airspeed than in smooth conditions.
    i. Vertical gust or wind shear can cause a sudden change in the relative wind and result in an abrupt increase in the angle of attack and are most hazardous at low airspeeds and low altitudes, such as during takeoff and landing.
    ii. When flying in moderate to severe turbulence or strong crosswinds, a higher-than-normal approach speed should be maintained.
    iii. In turbulent cruise flight, maintain an airspeed well above the indicated stall speed and below V_A (maneuvering speed).

II. **Spins**

A. A spin, as defined in the FAA's *Airplane Flying Handbook* is an aggravated stall that results in “autorotation,” where the airplane follows a downward corkscrew path.

1. There are two prerequisites for a spin to develop, and that if either of these elements are not present, a spin cannot occur. The prerequisites are:
    a. A stall
    b. A yawing motion
2. If the nose of the airplane is allowed to yaw at the beginning of a stall, the wing will drop in the direction of the yaw.
    a. Unless rudder is applied to keep the nose from yawing, the airplane will begin to slip toward the lowered wing.
    b. The slip will cause the airplane to weathervane into the relative wind, i.e., toward the lowered wing, thus continuing the yaw.
3. At the same time, the airplane will continue rolling toward the lowered wing. due to the upward motion of the relative wind against its surfaces.
    a. The lowered wing therefore has an increasingly greater angle of attack,
    b. The lowered wing will then be well beyond the critical angle of attack and will suffer an extreme loss of lift and an increase in drag.
    c. However, the rising wing, since the relative wind is striking it at a smaller angle, will have a smaller angle of attack than the opposite wing. The rising wing, in effect, becomes less stalled and thus develops some lift so that the airplane continues to roll.
    d. As the autorotation continues, the aerodynamic and inertial forces will balance and the airplane will settle in a stabilized spin.
4. In order for a spin to develop, both of the airplane’s wings must first be stalled; then one wing becomes less stalled than the other as the spin develops.

B. A spin may be broken down into three phases.

1. The incipient phase is the transient period between a full stall and a fully developed spin, when aerodynamic and inertial forces have not yet achieved equilibrium. The incipient spin usually occurs in approximately 4 to 6 sec. and consists of approximately the first two turns.
2. The steady-state phase is that portion of the spin in which it is fully developed and the aerodynamic forces are in balance.
    a. A flat spin can develop during the steady-state phase when the spin axis is located near the airplane’s CG. This can happen when the airplane’s CG is located aft of the CG aft limit.
3. The recovery phase begins when controls are applied to stop the spin and ends when level flight is attained.
    a. In many airplanes under typical power, trim, configuration, and loading conditions, the recovery phase will begin as soon as pro-spin control inputs are removed (i.e., as soon as elevator back pressure is released to break the stall).
    b. Observation of this phenomenon is sometimes incorrectly interpreted to mean that a proper spin recovery procedure involves simply “letting go of the controls.” While such a procedure may result in spin recovery **if sufficient altitude is available**, significantly more altitude will be lost than if proper techniques are used. In addition, there are certain power, trim, configuration, and loading conditions under which positive forward elevator pressure will be required to break the stall and effect recovery.

c. Accordingly, proper spin recovery procedures, as outlined in the airplane's *Pilot’s Operating Handbook*, should always be used.

C. The intentional spinning of an airplane for which spins are not specifically approved is prohibited and extremely dangerous.

1. Single-engine normal category airplanes are placarded against intentional spins. However, to provide a margin of safety when recovery from a stall is delayed, these airplanes are tested during certification and must be able to recover from a one-turn spin or a 3-sec. spin, whichever takes longer, in not more than one additional turn during recovery.
2. Acrobatic category airplanes must recover from any point in a spin, in not more than one and one-half additional turns during recovery. Prior to normal recovery, the spin test must proceed for six turns or 3 sec., whichever takes longer, with flaps retracted, and one turn or 3 sec., whichever takes longer, with flaps extended.
3. A utility category airplane must meet the requirements for either the normal or acrobatic category.
4. As the pilot of an airplane placarded against spins, you must assume that the airplane may become uncontrollable in a spin.