A103 AERODYNAMIC PRINCIPLES

References: FAA-H-8083-25A, Pilot's Handbook of Aeronautical Knowledge, Chapter 3 (pgs 4-10) and Chapter 4 (pgs 1-39)

OBJECTIVE: Students will understand the fundamental aerodynamic principles and forces acting on an aircraft in flight.

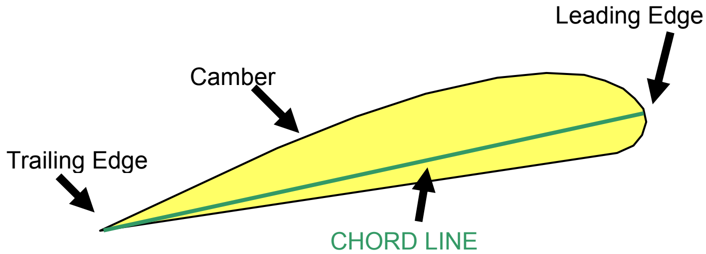
STANDARDS: This lesson is complete when the student can explain the fundamental aerodynamic principles and forces of flight.

AIRFOIL

Aerodynamics deals with the motion of objects through the air and the forces that are produced and used to control these movements.

An aircraft utilizes airfoils to create the force called LIFT. Airfoils come in many different sizes and shapes which reflect the type of flying that the aircraft is designed to do. The aircraft speed, maneuverability, takeoff and landing distance, payload, range, and economics are just a few of the considerations to be made in airfoil design. The aircraft is actually composed of a number of airfoils. The wings, horizontal stabilizer, vertical stabilizer, propeller, and other components are all airfoils.

AIRFOIL— any surface, such as a wing, propeller, rudder, or even a trim tab, which provides aerodynamic force when it interacts with a moving stream of air.

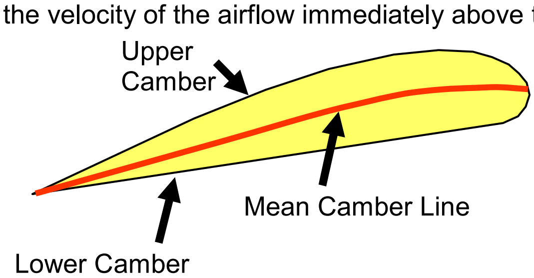


LEADING EDGE— the part of an airfoil that meets the airflow first.

TRAILING EDGE— the part of the airfoil where the airflow over the upper surface rejoins the lower surface airflow.

CHORD LINE— an imaginary straight line drawn through an airfoil from the leading edge to the trailing edge.

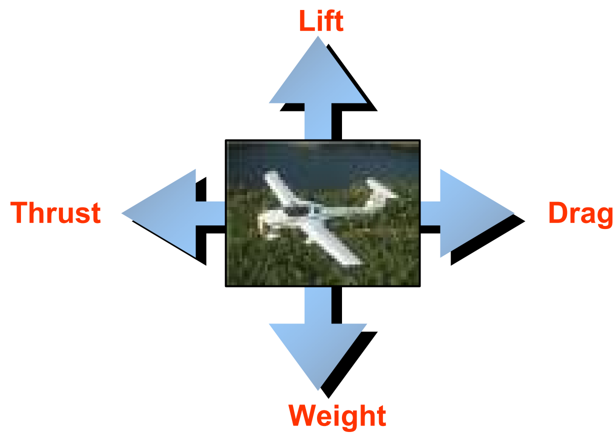
CAMBER— the camber of an airfoil is the characteristic curve of its upper and lower surfaces. The upper camber is more pronounced, while the lower camber is comparatively flat. This causes the velocity of the airflow immediately above the wing to be much higher than that below the wing.



FOUR FORCES
There are four forces acting on an airplane in flight; lift, weight, thrust, and drag. The study of these forces and their respective roles is part of aerodynamics. During this lesson you will first learn how these forces work together to achieve straight-and-level, unaccelerated flight. This means that the airplane is not turning, climbing, descending or changing airspeed.

The four forces acting on an airplane in flight are:
Lift - is the upward force created by the effect of airflow as it passes around the wings.
Weight - is the force that opposes lift and is caused by the downward pull of gravity.
Thrust - is created by the powerplant that propels the airplane forward through the air.
Drag – is the resistance of the atmosphere to the relative motion of an aircraft.

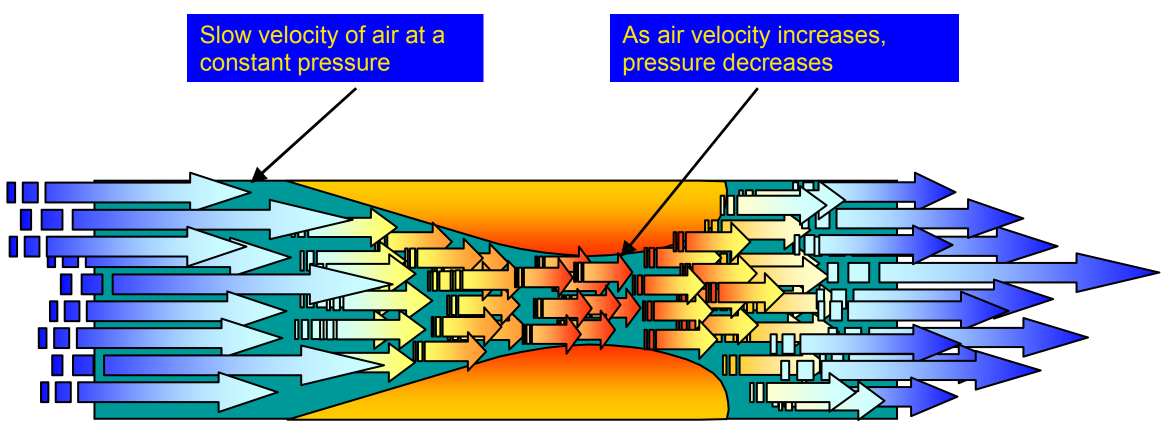
In steady-state, unaccelerated flight: The vertical forces are equal; and the horizontal forces are equal.



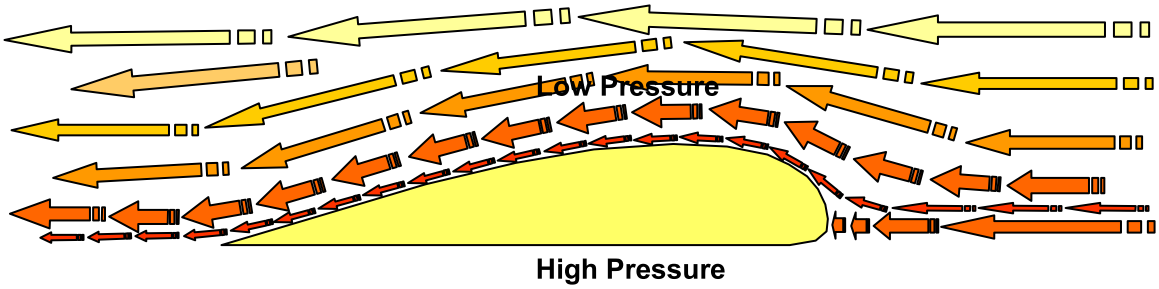
LIFT
There are two basic principles that govern the force of LIFT.
1- Bernoulli's Principle of Pressure
2- Newton's Third Law of Motion

One of the principles of lift was discovered by a Swiss physicist named Bernoulli when he observed what happed to air as it passed through a tube. The principle states that: "as the velocity of a fluid or gas increases, its pressure decreases".

He also found that with a constant velocity, the pressure of the air remains the same at both ends of the tube. If a constriction is placed in the middle of the tube, the same amount of air has to go through a smaller area. This increases the velocity and decreases the pressure.

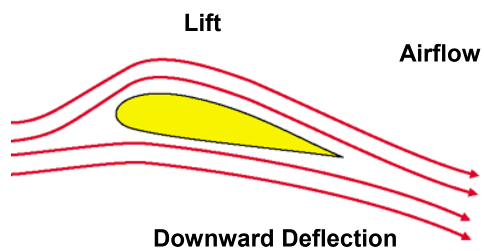


If you replace the constriction with an airfoil such as a wing, the same principle applies. As oncoming air meets at the leading edge of the airfoil, it separates. Part of the airflow goes over the top and part of the airflow goes below. Since the airflow going over the top is compressed, it must travel faster. The result is a greater decrease in air pressure above the wing.

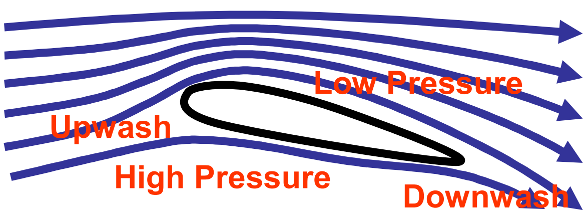


Because the pressure below the wing is greater, the wing is lifted.

Additional lift is also provided by the downward deflection of air as it strikes the bottom of the wing. This can be explained by Newton's third law of motion. "For every action there is an equal and opposite reaction." The reaction of the air striking the bottom of the wing is an upward or lifting force.



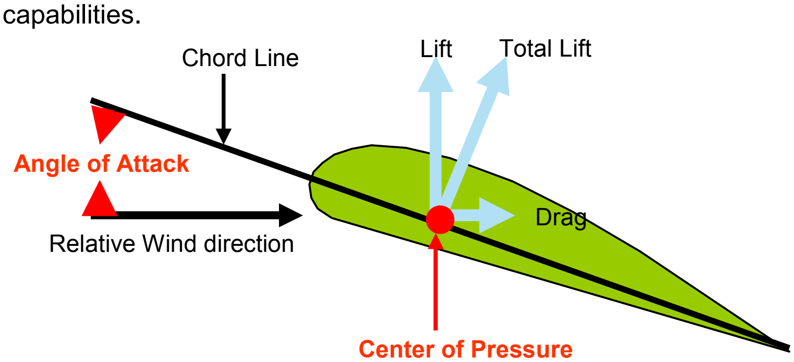
LIFT comes from a combination of pressure differential due to Bernoulli's Pressure Principle and action-reaction from Newton's Third Law of Motion.



A few more terms for the production of lift need to be defined.

RELATIVE WIND— the direction of the airflow with respect to the wing. If a wing moves forward horizontally, the relative wind moves backward horizontally. Relative wind is parallel to and opposite the flight path of the airplane.

ANGLE OF ATTACK— the acute angle between the chord line of the airfoil and the direction of the relative wind. It is important in the production of lift. If the angle of attack is too great, that would cause the air to separate from the top portion of the airfoil, causing a stall, or loss of lift capabilities.



CENTER OF PRESSURE— a point along the wing chord line where lift is considered to be concentrated. For this reason, the center of pressure is commonly referred to as the center of lift.

CONTROLLING LIFT
Lift is necessary to get an aircraft off the ground and to keep it up in the air. It is important that the pilot understands how this force of lift is made and how to control it.

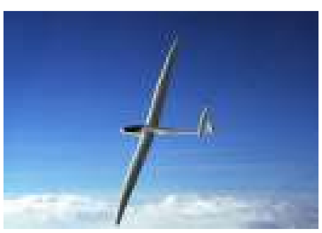
The equation for lift is: $L = \frac{1}{2} \rho V^2 S C_L$
Lift is measured in pounds
ρ is the density of the air
V is the velocity of the air
S is the area of the wing
C_L is the coefficient of lift that comes from the angle of attack

The pilot controls how much lift is being made chiefly through the velocity and the angle of attack of the airplane. If all other factors remain constant, doubling an airplane's airspeed develops four times more lift. Along with any increase in lift, however, there is an increase in drag.

In addition, an increase in angle of attack increases lift. For lift to remain constant, airspeed and angle of attack must be used in conjunction with each other.

The amount of lift that a wing can produce depends on several factors. One of these factors is wing design which includes the shape or plan form of the wing. A straight wing has good slow flight characteristics but is not structurally efficient in terms of lift and drag. A swept back or delta wing (used in jets) is much better at higher speeds. A tapered wing has good slow flight characteristics and has a relatively efficient design.

Another wing design factor is the aspect ratio or the relationship between the wing's length and width. The aspect ratio can be found by dividing the wing span by the average wing chord. At a given angle of attack, the larger the aspect ratio, the less drag produced for the same amount of lift. General aviation training aircraft normally have aspect ratios of 7 to 9 while the aspect ratios of gliders are between 20 and 30. The aspect ratio of the DA20-C1 is 10.2.



The third way of controlling lift is by changing the configuration of the wing. Lowering the flaps can increase the lifting efficiency of the wing and decrease the airspeed at which the aircraft stalls. As flaps extend, they change the camber and the chord line of the wing in the area of the flaps.

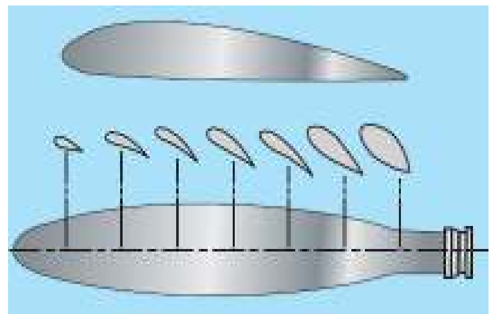
This not only produces the lower pressure above the wing, due to the change in camber, but it also changes the angle of attack of the wing. Suppose that with the flaps up, the angle of attack is 5 degrees. By lowering the flaps, which changes the chord line, the angle of attack has increased to 10 degrees. This higher angle of attack produces more lift and more drag.

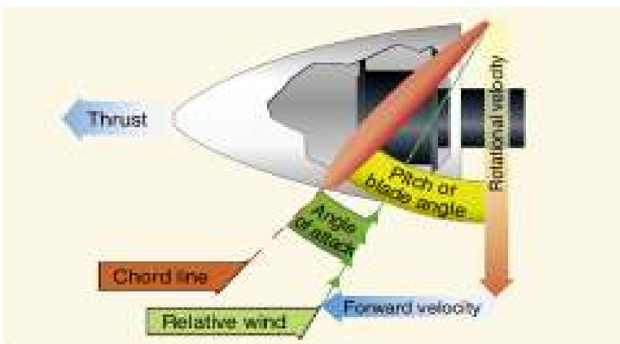
Frost – Does not change the basic aerodynamic shape of the wing, but the roughness of its surface spoils the smooth flow of air, thus causing an increase in drag and an early airflow separation over the wing, resulting in a loss of lift. It is most important that all frost is removed from all the lifting surfaces prior to takeoff.

Weight is caused by the downward pull of gravity. The center of gravity (CG) is considered as a point at which all the weight of the airplane is concentrated. The CG is of major importance in aircraft stability. When lift exceeds weight, the airplane gains altitude. When weight exceeds lift, the airplane loses altitude.

The weight of the aircraft in unaccelerated flight is its weight under the force of 1 gravitational unit (G). When the aircraft is turning or accelerating, the weight is effectively increased by the force of Gs that it is experiencing. As the effective weight changes during aircraft maneuvering, the amount of lift must also change. The importance of weight and center of gravity will be discussed more in the AIRPLANE PERFORMANCE chapter.

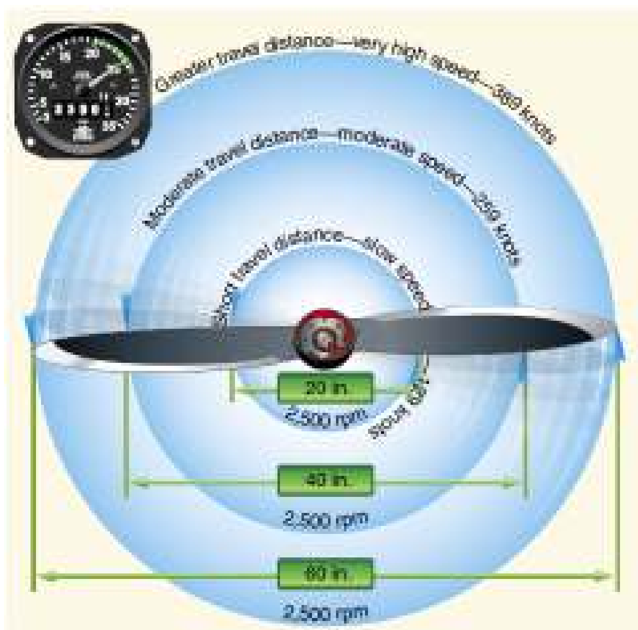
Thrust - The thrust necessary to overcome drag and propel the airplane through the air is produced by the power plant. If you look closely at the propeller, it is a twisted airfoil. As the propeller turns, a low pressure area is created in front of each rotating blade. This provides the thrust that propels the airplane forward. Excess thrust is needed for an aircraft to climb.

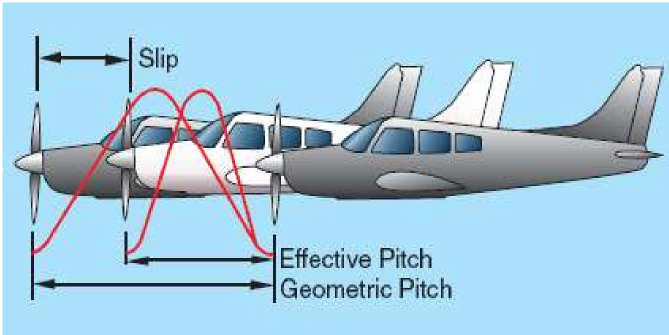




For any single revolution of the propeller, the amount of air handled depends on the blade angle, which determines how big a "bite" of air the propeller takes. Propeller slip is the difference between the geometric pitch of the propeller and its effective pitch.

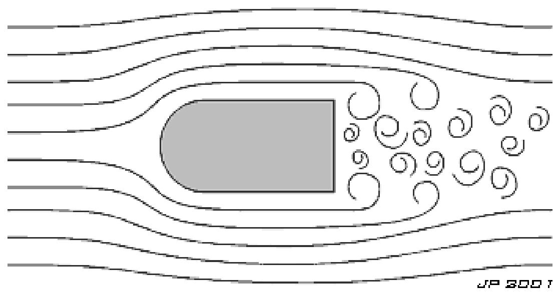
Geometric pitch is the theoretical distance a propeller should advance in one revolution; effective pitch is the distance it actually advances. Thus, geometric or theoretical pitch is based on no slippage, but actual or effective pitch includes propeller slippage in the air.





Drag is the force acting opposite to thrust. Drag is created by the movement of the airplane through the air.

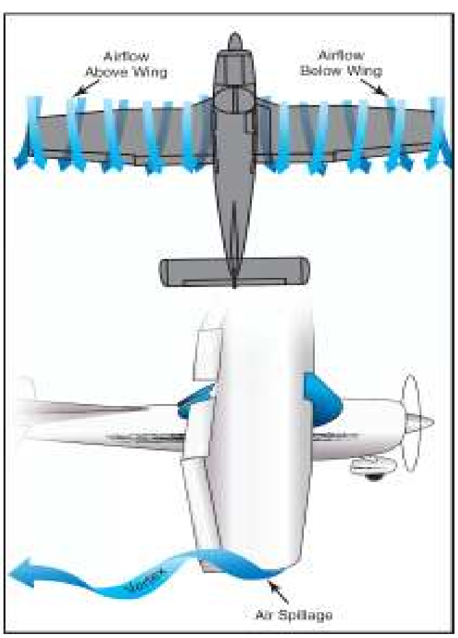
There are two types of drag: **parasite** and **induced**. Parasite drag includes all the drag not related to the production of lift. It is generated by those areas of the airplane which disrupt the otherwise streamlined flow of air. This includes parts protruding into the airflow such as the landing gear, rough surfaces, and the mixing of the air such as where the wing and the fuselage meet. As the speed of the airplane increases, the effects of parasite drag also increase. Parasite drag is composed of form drag, skin friction drag and interference drag.



Form drag is produced by the shape of the object moving through the air. Form drag develops from the turbulent wake caused by separation of airflow from a surface. Aerodynamic streamlining reduces, but does not eliminate this drag. Depending on the aircraft design, the form drag of an object increases as the square of the velocity; thus doubling the airspeed increases the drag four times.

Skin friction drag is the result of the smoothness of the surface of the airfoil. The smoother the surface, with fewer protrusions, the less skin friction drag produced.

Interference drag is caused by the interaction of the airflow around the various aircraft components. As the air flows around the various airfoils, it interacts with other airflows and causes more drag. For example, the airflow over the wing will interfere with the airflow around the fuselage. Also, if two objects, like antennae, are placed adjacent to one another, the resulting turbulence may cause far more interference drag than if they were placed further apart.

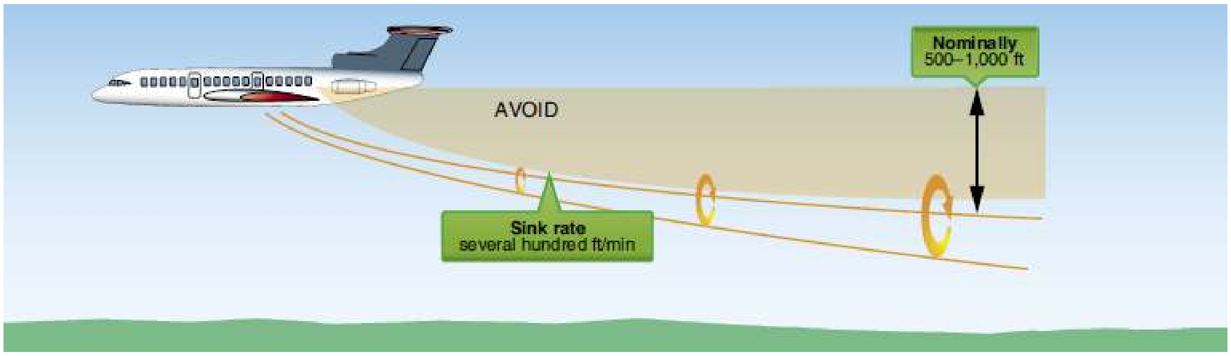


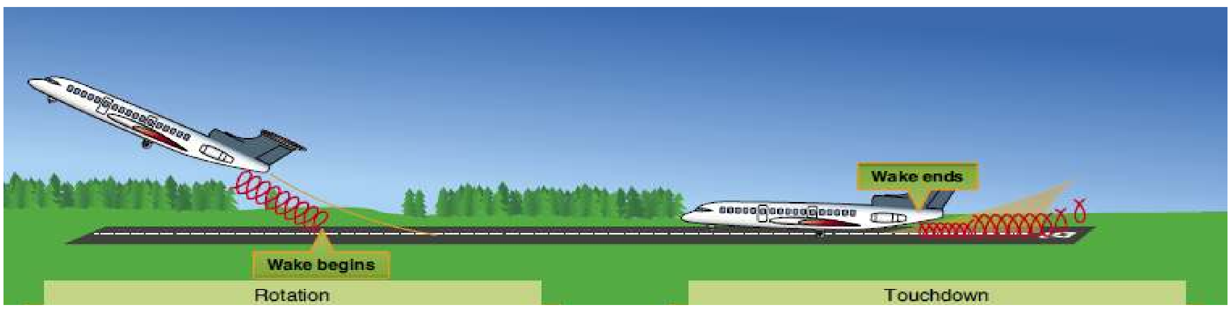
In contrast, **induced drag** is a byproduct of lift. It is drag that is incurred as a result of the production of lift. It increases with the increase in the angle of attack. It is caused by the spanwise airflow around the wing. It also decreases with velocity.

Everything in nature seeks its lowest energy level. The higher pressure air on the bottom of the wing slips around the wingtip into the lower pressure area above the wing. This causes a lateral flow along the wing and it imparts a rotational velocity to the air. This vortex then trails behind the wingtip. The pressure differential between the top and bottom of the wing increases with the angle of attack and the strength of the wingtip vortex also increases.

Induced drag is greatest when the aircraft is heavy, slow and clean.

This induced drag is also known as wake turbulence. Wake turbulence from aircraft that are larger than yours can totally upset your aircraft and cause you to lose control and crash. Wake turbulence is avoided by flying above the flight path of an aircraft that is larger than yours. Wake turbulence lasts about 3-5 minutes depending on the size of the aircraft. The larger the aircraft is, the stronger is the wake turbulence.





There are three classes of aircraft for wake turbulence separation minima:

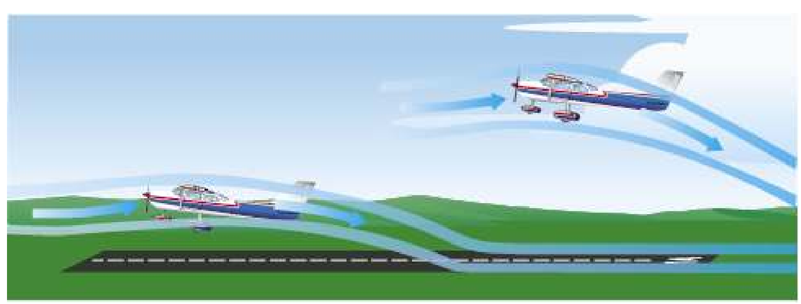
Heavy − Aircraft capable of takeoff weights of more than 255,000 pounds whether or not they are operating at this weight during a particular phase of flight.

Large − Aircraft of more than 41,000 pounds, maximum certificated takeoff weight, up to 255,000 pounds.

Small − Aircraft of 41,000 pounds or less maximum certificated takeoff weight.

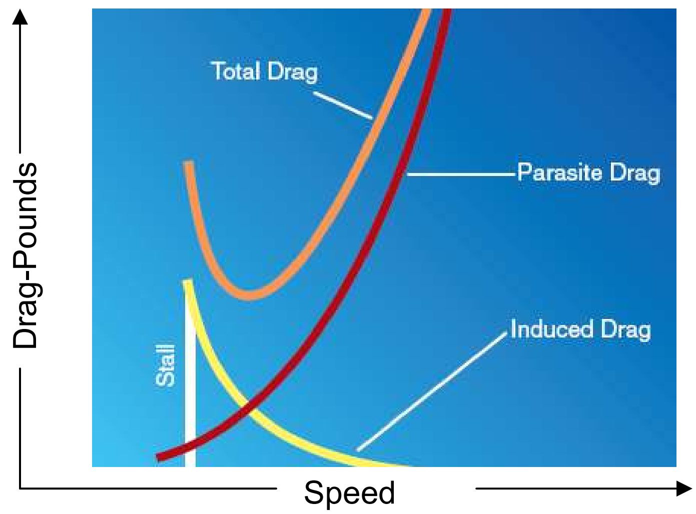
Ground effect is due to the interference of the surface of the earth with the airflow patterns about the aircraft in flight. This alters the wing's upwash, downwash, and wingtip vortices. Ground effect reduces the induced drag proportionate to the distance of the aircraft above the ground.

At one wingspan above the ground, the reduction in induced drag is 1.4%.
At one fourth the wingspan, the reduction is 23.5%.
At one tenth the wingspan, the reduction is 47.6%.



Drag Curves. For any aircraft, there is a curve to represent changes in induced drag with respect to velocity and a curve to represent changes in parasite drag with respect to velocity.

When the two drag curves (induced and parasite) are combined and the values added together, the result is a total drag curve. There is a point where the drag is at a minimum. This point is known as L/D Max. Flying the airplane at this speed provides the least amount of drag and the best glide ratio and other performance benefits. In the DA20-C1, this speed is 73 kts in the Cruise flap configuration. At this speed (in no wind conditions and max gross weight) the DA20-C1 has a glide ratio of 11 to 1, which means the airplane will glide 1.8 miles for every 1,000 feet of altitude loss.

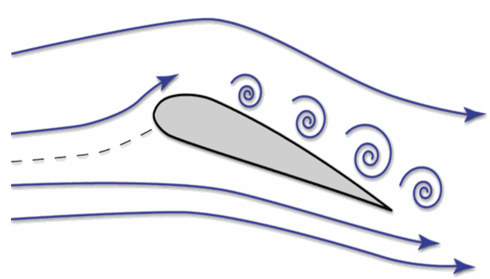


Note: Any deviation in airspeed from 73 kts, whether an increase or decrease, will result in decreased glide performance. Pilots can control the amount of lift produced in flight by changing individually, or in combination, the airplane's airspeed, angle of attack, and the wing configuration (such as lowering the flaps).

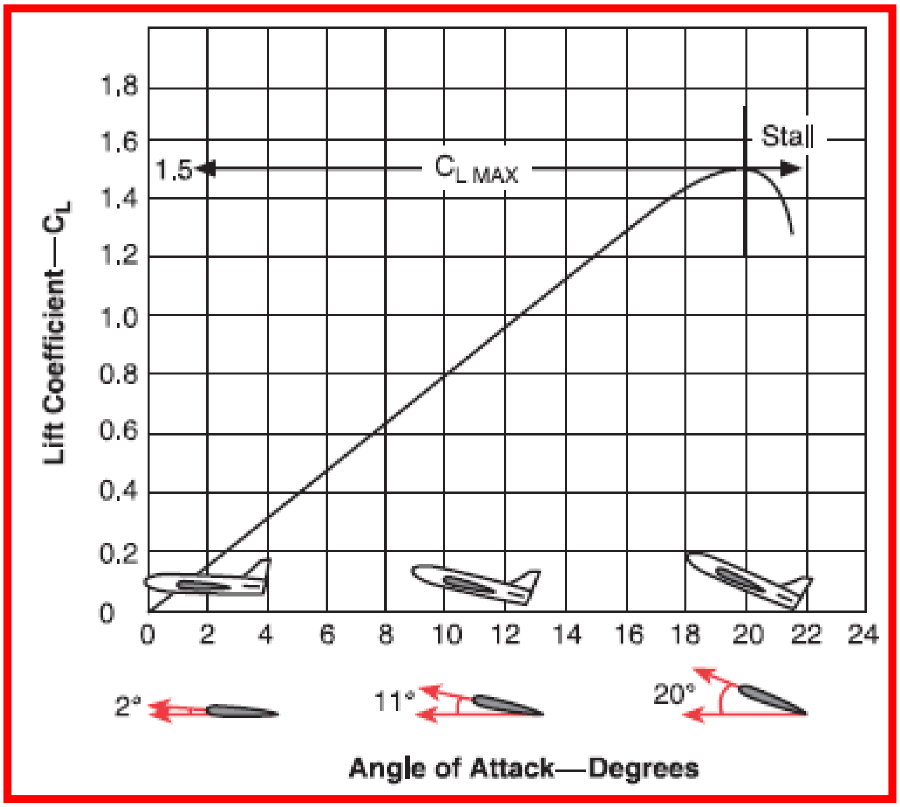
STALL

If you want to maintain the same amount of lift, at a slower airspeed you must increase the angle of attack. However, you can increase angle of attack only so much. For every airfoil, there is a specific angle of attack where the maximum amount of lift is obtained. This point is called C_L Max or the maximum coefficient of lift at the critical angle of attack. Beyond this point (C_L Max) the airflow will not remain smooth and becomes so turbulent that the airflow separates from the airfoil, which then no longer creates lift. At this point, the wing is in a stalled condition. In order for the wing to fly again, the angle of attack must be reduced below the critical angle of attack.

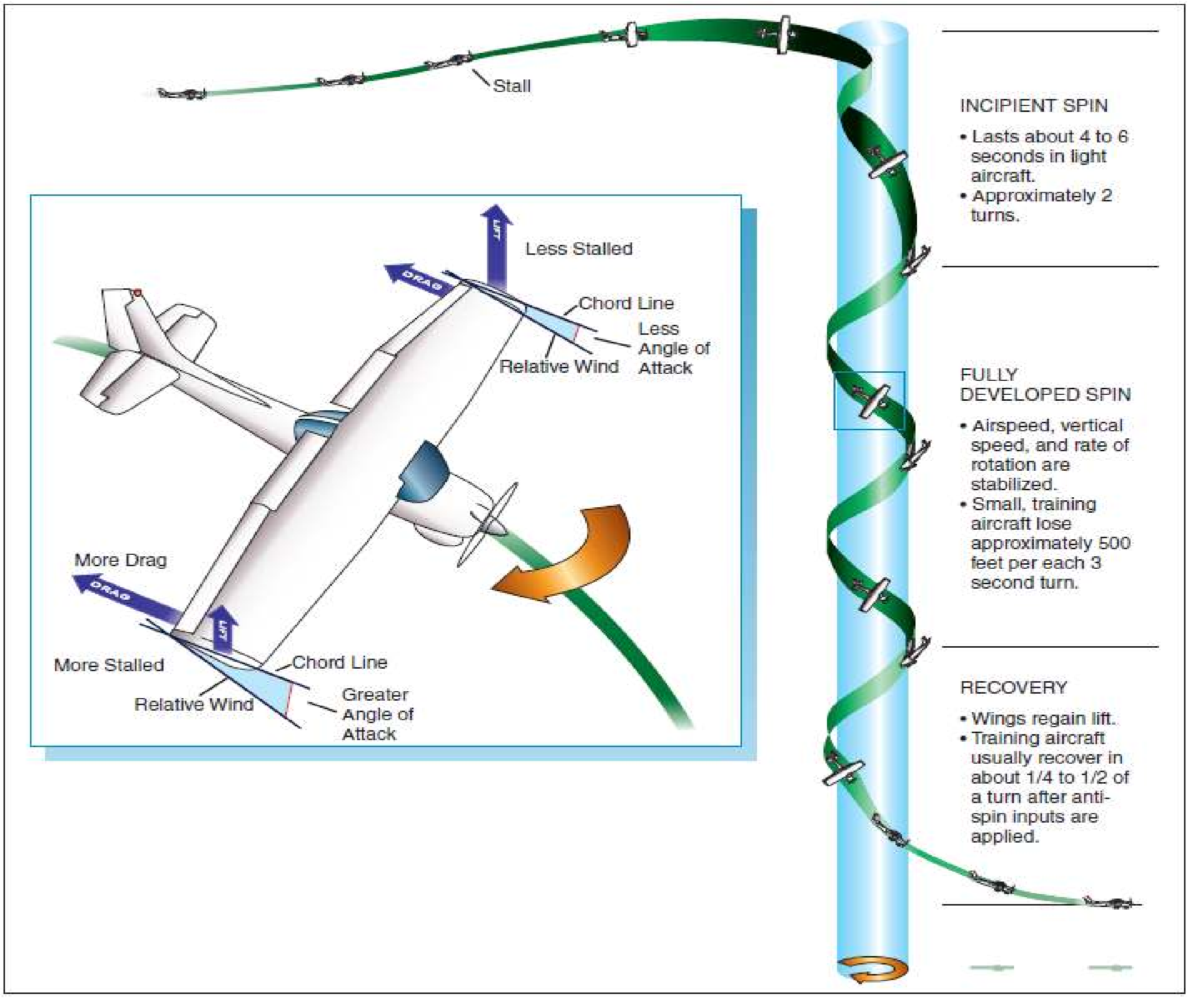
STALL: Separation of airflow and resulting loss of lift due to the critical angle of attack being exceeded. When the wing is below the critical angle of attack the airflow smoothes out and the wing produces lift again. An airplane wing stalls whenever the critical angle of attack is exceeded. A stall can occur in ***any*** flight attitude and at ***any*** airspeed.



There are various types of stalls: Imminent Stall, Power-Off Stall, Power-On Stall, Secondary Stall, Accelerated Stall, Cross Control Stall and Elevator Trim Stall. These are just different ways that the airplane can enter a stall.



A spin occurs when both wings are stalled and there is a yawing moment due to uncoordinated flight.



AERODYNAMICS OF MANEUVERING FLIGHT

Whenever an airplane changes its flight attitude or position in flight, it rotates about one or more of three axes, which are imaginary lines that pass through the airplane's center of gravity (CG). The axes of an airplane can be considered as imaginary axles around which the airplane turns, much like the axle around which a wheel rotates. At the point where all three axes intersect, each is at a 90° angle to the other two.

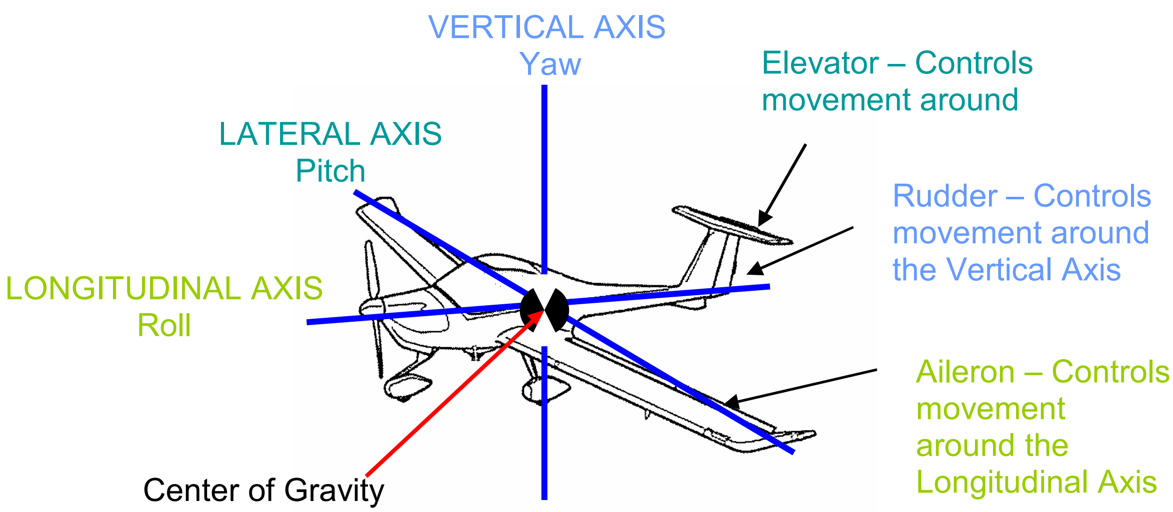
The vertical axis passes vertically through the center of gravity. The movement about this axis is called yaw. The pilot controls the yaw about the vertical axis with the rudder pedals. When the pilot's foot pushes the right rudder pedal forward, the rudder moves to the right which forces the tail of the airplane to move to the left and the nose to move to the right.

The lateral axis extends crosswise from wingtip to wingtip and passes through the center of gravity. The movement about this axis is called pitch. The pilot controls the pitch about the lateral axis with the control stick. When the pilot pushes the control stick forward, the elevator moves down and forces the tail of the airplane to move up and the nose to move down.

The longitudinal axis extends lengthwise through the fuselage from the nose to the tail and passes through the center of gravity. The movement about this axis is called roll. The pilot controls the roll about the longitudinal axis with the control stick. When the pilot pushes the control stick to the right, the left aileron moves down and the right aileron moves up and forces the airplane to roll to the right.

As the right aileron moves down, the angle of attack and the camber increase on the right wing. This provides more lift on the right wing. As the left aileron moves up, the angle of attack and camber on the left wing decrease which produces less lift. This difference in lift between the left and right wing causes the airplane to roll about the longitudinal axis. The airplane will remain in a banked attitude until you move the control stick to the right. This reverses the process and creates a roll back toward wings level.

AXES OF ROTATION



Note that in flight, the rudder is not used to turn the airplane. The primary function of the rudder is to align the fuselage with the direction of flight also known as overcoming adverse yaw. The horizontal component of lift turns the airplane.

TURNING FLIGHT
To better understand how an airplane turns, it helps to visualize the forces acting on an airplane in a turn.

CENTRIPETAL FORCE— A center-seeking force directed inward toward the center of rotation created by the horizontal component of lift in turning flight.

CENTRIFUGAL FORCE — An outward force, that opposes centripetal force, resulting from the effect of inertia during a turn.

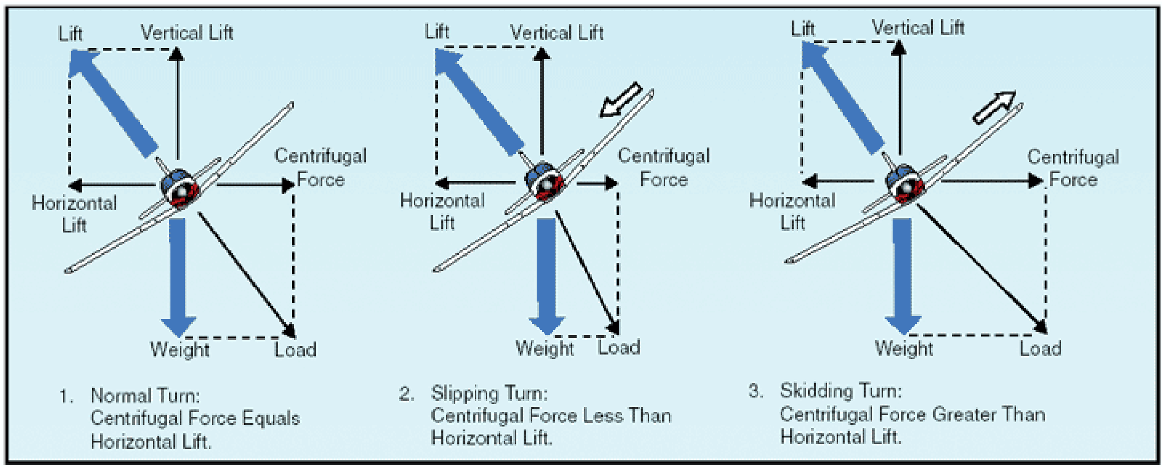
LOAD FACTOR— The ratio of the load supported by the airplane's wings to the actual weight of the aircraft and its contents. Load factor is also referred to as G loading.

Moving objects travel in a straight line unless something acts on them to create a turn. This turning force is called centripetal or center seeking force. The force acting opposite of the turn is called centrifugal force.

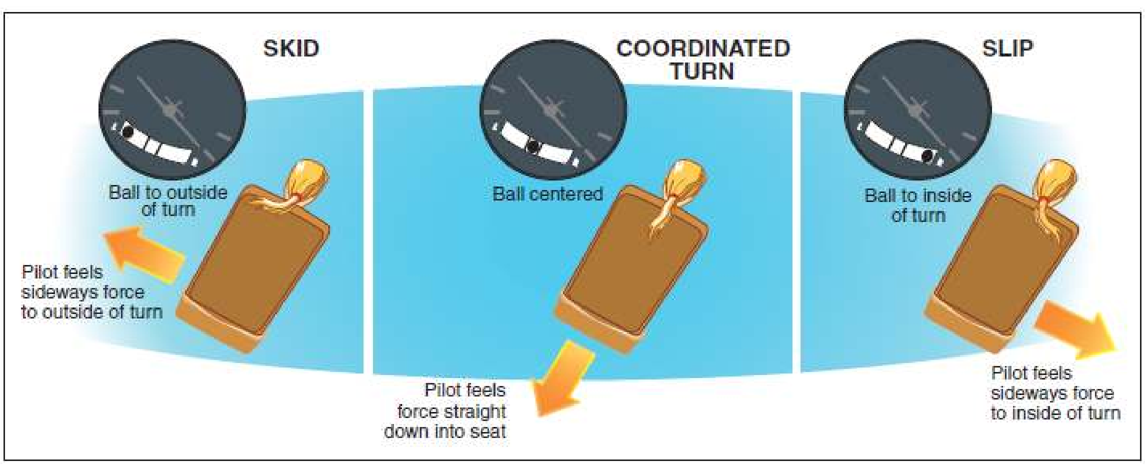
To turn an airplane you must create a centripetal force by initiating a bank. As you enter a turn from straight-and-level flight, at a constant airspeed, lift is one of the four basic forces that changes. Banking the airplane inclines the direction of lift so that it not only acts vertically but also has a horizontal component. The combination of these two components is the total lift produced by the wings.

Because of the turn, the vertical component of lift is reduced. This means that in order to maintain altitude, you must increase lift by increasing back control stick pressure and therefore the angle of attack until the vertical component of lift equals weight. You would slow down and/or lose altitude if you did not also add power!

The horizontal component of lift or centripetal force causes the airplane to turn. It is opposed by centrifugal force. In a steady state turn these forces are balanced.



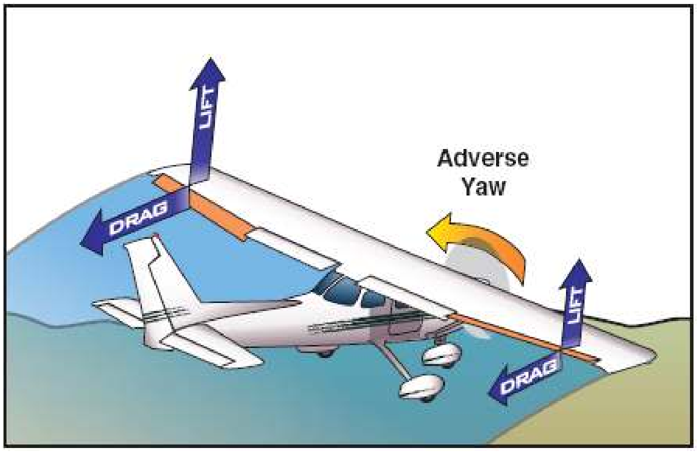
The primary flight controls are all used to perform an aerodynamically coordinated turn. Too much rudder results in a skid where the tail skids to the outside of the turn. Too little rudder results in a slip where the airplane slips to the inside of the turn.



Turning flight causes two additional forces to occur, adverse yaw and the overbanking tendency.

ADVERSE YAW

You will recall that when you deflect the ailerons to bank the airplane, roll is produced by the unbalanced production of lift. The wing with the down aileron produces more lift than the wing with the up aileron. The wing producing increased lift is also producing increased drag, which is always a by product of lift.



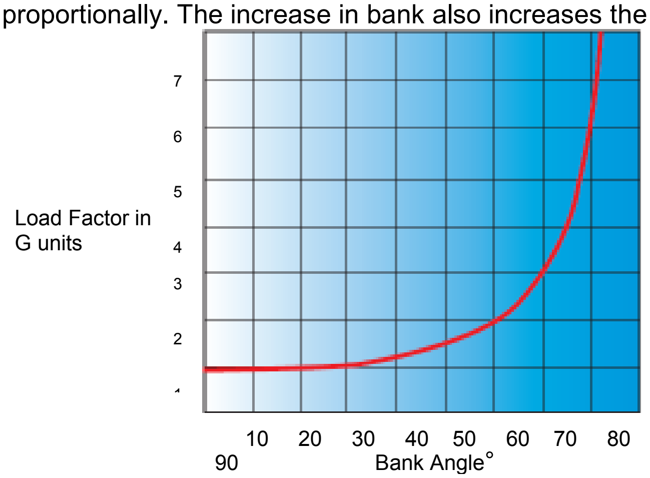
Since one wing is producing more lift than the other, a yawing force is created causing the nose of the airplane to move to the outside of the turn. This is called adverse yaw.

You overcome this yawing tendency by applying rudder in the direction of the roll during a turn. When you move the ailerons in the opposite direction to roll out of the turn, you must apply rudder pressure in the direction of the roll.

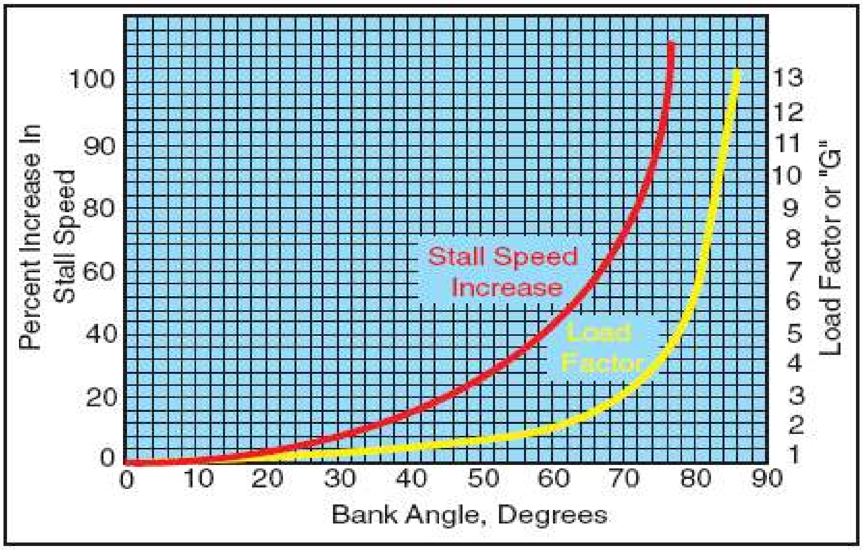
OVERBANKING TENDENCY
More lift from the outside wing also causes the wing to continue to roll the airplane in the direction of the turn. Move the control stick slightly in the opposite direction of the turn to control this force. This occurs during steep turns.

LOAD FACTOR
The resultant of weight and centrifugal force is the load that the wings must support. It can be expressed as load factor or Gs. Load factor is the ratio of the load supported by the wings divided by the weight of the airplane. In straight and level flight, the wings only have to produce the lift necessary to offset gravity. Therefore, the load factor is expressed as 1 G (the load factor = 1 G) or one times the force of gravity.

When you enter a turn the wings must support the weight of the airplane and produce the lift necessary to turn the airplane. When you reach 60° of bank, the additional lift is increased to twice the lift of the airplane, or 2 Gs. As the bank angle gets steeper, the load factor increases proportionally. The increase in bank also increases the stall speed of the airplane.

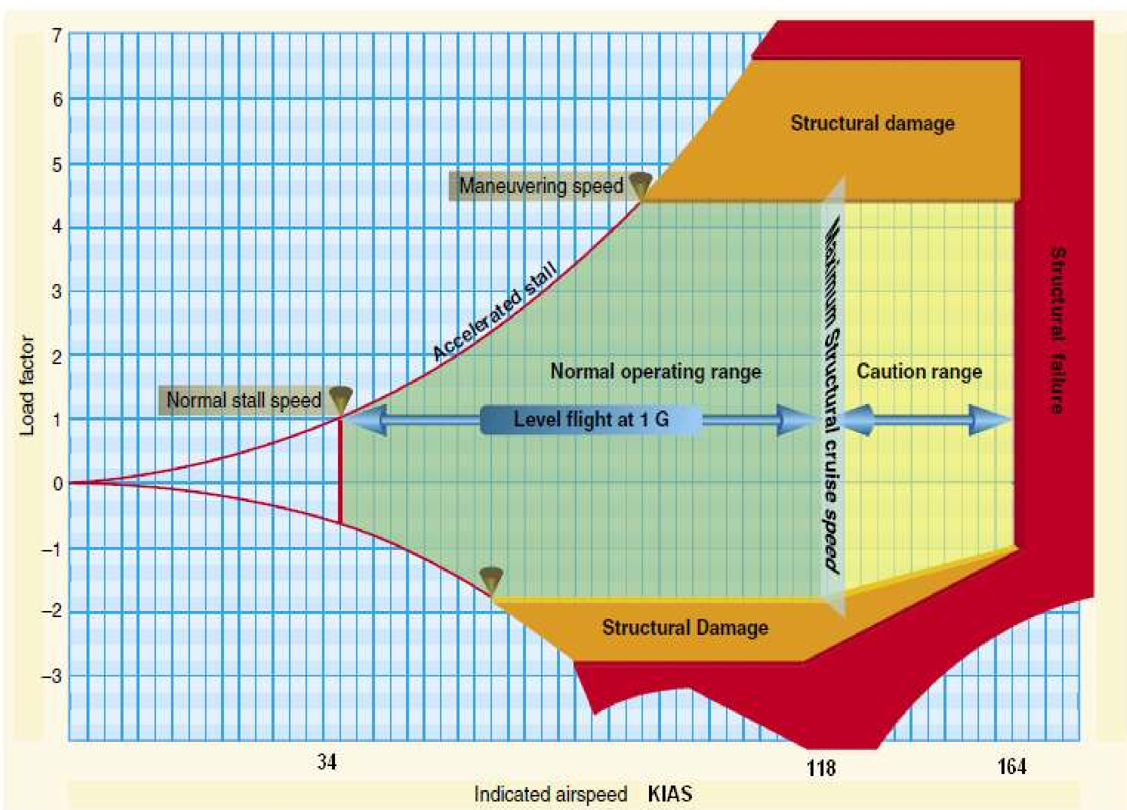


This graph shows that at bank angles of less than 45º, the load factor (and stall speed) gradually increases. At steeper bank angles, the load factor (and stall speed) increases significantly.
In addition to causing an increase in stall speed, excessively high load factors can overstress airplane components.



Decreasing the weight of the aircraft decreases the stall speed and increases the safety margin between normal cruise speed and stall speed. A lower weight means that less lift is required to support the aircraft. Therefore, the airplane can travel at a slower airspeed or at a lower angle of attack to create the needed amount of lift. This is desirable because it gives the pilot a larger buffer between the normal cruise speed/angle of attack and the stall speed/critical angle of attack.

The flight operating strength of an airplane is presented on a graph whose vertical scale is based on load factor. The diagram is called a Vg diagram—velocity versus "g" loads or load factor. Each airplane has its own Vg diagram which is valid at a certain weight and altitude.



MANEUVERING SPEED (V_A)

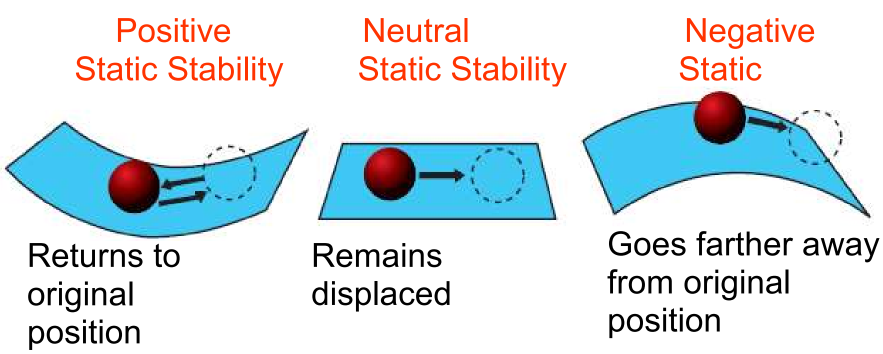
This is the maximum speed at which a full, abrupt control movement can be made without overstressing the airframe. The aircraft is designed to withstand a certain amount of stress or force before the structure is permanently damaged. This force limit is expressed as the G limits. When you are maneuvering an aircraft, the G limit is reached as the result of the acceleration of the aircraft in a different direction. Using Newton's Second Law of Motion, F=MA, as the weight of the aircraft decreases and the force from the flight control surfaces remain the same, the acceleration will increase. Therefore, the maneuvering speed decreases as the weight of the aircraft decreases.

This speed is not marked on the airspeed indicator due the change for the aircraft weight. Therefore, the pilot must know the weight and maneuvering speed for the aircraft before using abrupt control inputs. This maneuvering speed must not be exceeded when maneuvering the aircraft or flying in turbulent air. The airframe could be overstressed and damaged or destroyed.

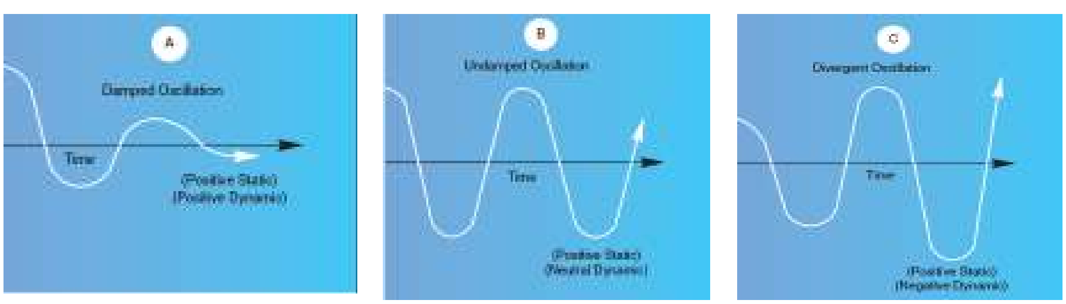
STABILITY

Airplanes are designed for many purposes. Most must have a degree of stability to perform their respective roles. Stability is a design characteristic that causes an airplane to return to steady flight after being disturbed. Consider two types of stability: Static and Dynamic Stability.

Static stability is the initial tendency displayed by an object after it is disturbed from equilibrium. We can use a marble to demonstrate static stability. When the marble is resting at the bottom of a cup, it is in equilibrium. If it is disturbed, its initial tendency is to return to its original position. This tendency to return to its original position is referred to as positive static stability. A marble that remains in its new position once it has been moved represents neutral static stability. When the marble moves farther away from its original position, it represents negative static stability.



How an object responds over time (as opposed to its initial reaction) is called Dynamic Stability and can be positive, neutral, or negative.



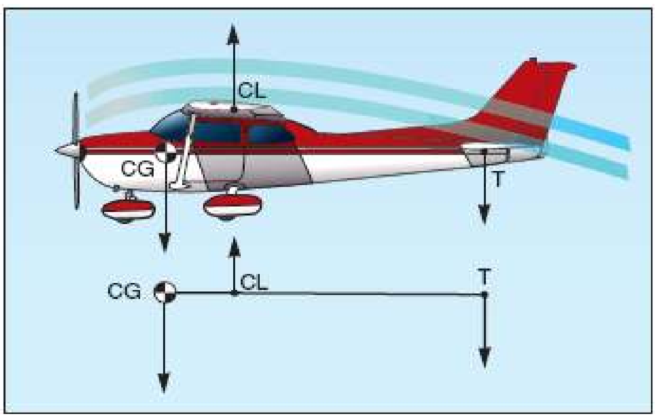
Positive Dynamic Stability   Neutral Dynamic Stability   Negative Dynamic Stability

(A) An airplane with both positive dynamic and positive static stability does not immediately return to its original attitude after displacement. It goes through a series of oscillations with each one getting smaller.

(B) An airplane with positive static and neutral dynamic stability is also characterized by oscillations. But this time the oscillations remain the same size and the airplane will not return to its original position.

(C) Initial reaction of an airplane with positive static but negative dynamic stability is to return to equilibrium. However, instead of the oscillations getting smaller, they increase in size, making the airplane difficult to control.

General aviation airplanes are designed to have both positive static and positive dynamic stability. To understand how this is accomplished we must first look at how this works in relation to the three axes of flight.



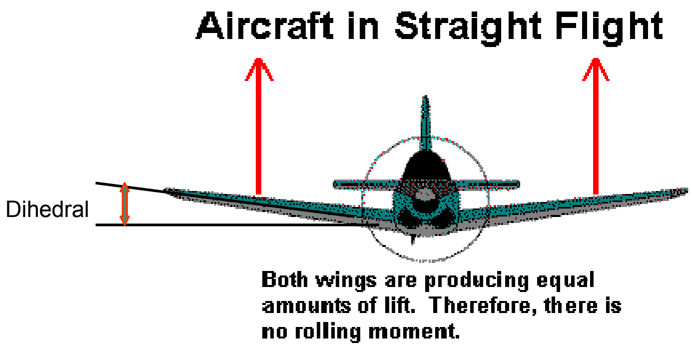
Longitudinal stability about the lateral axis is normally obtained by locating the center of gravity ahead of the center of lift, which is the point along the wing where lift is concentrated. This creates a slight nose heavy condition. To balance this condition, a tail down or nose up force is created by installation of a horizontal stabilizer with a slight negative angle of attack.

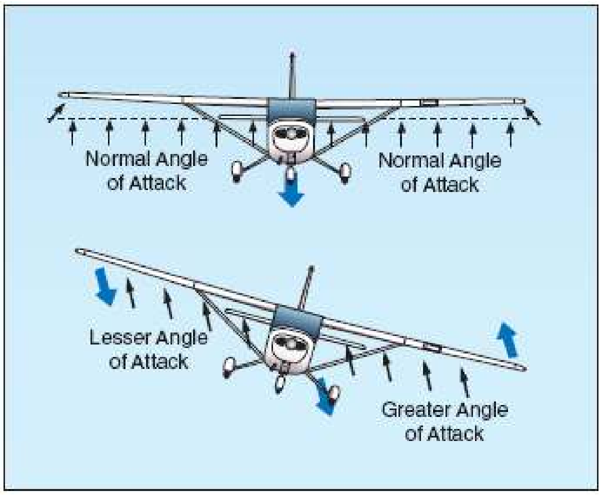
The tail-down force (T) is made by the horizontal stabilizer which is actually an upside down wing producing lift in the downward direction. This balances the nose-down force from the center of gravity (CG). When the airflow over the horizontal stabilizer is reduced, the downward lift is decreased and the tail moves up which makes the nose go down.

With the CG forward of the center of lift (CL), and with an aerodynamic tail-down force, the result is that the airplane always tries to return to a safe flying attitude, hence positive static and dynamic stability.

The center of gravity is very important in achieving longitudinal stability. If the airplane is loaded with the center of gravity too far aft, the airplane will assume a nose up rather than a nose down attitude. The inherent stability will be lost and down elevator will not correct the situation and control of the airplane will be lost. With the CG too far forward, the tail-down force cannot overcome the nose-down force. The airplane will be too stable and not controllable.

Stability along the longitudinal axis is called lateral stability. Positive lateral stability is the tendency of an airplane to roll back toward a wings level attitude following displacement by an external force such as a gust of wind or inadvertent control movement. The most common design features used to attain positive lateral stability is with dihedral (the upswept angle of the wing with respect to a horizontal plane). Wing dihedral refers to the way that the wings are tilted in toward the center of the plane. As shown in the diagram, dihedral can apply to the entire wing surface, just the wing tips, or a combination of both, called polyhedral. The use of wing dihedral makes the plane stable along the longitudinal axis.

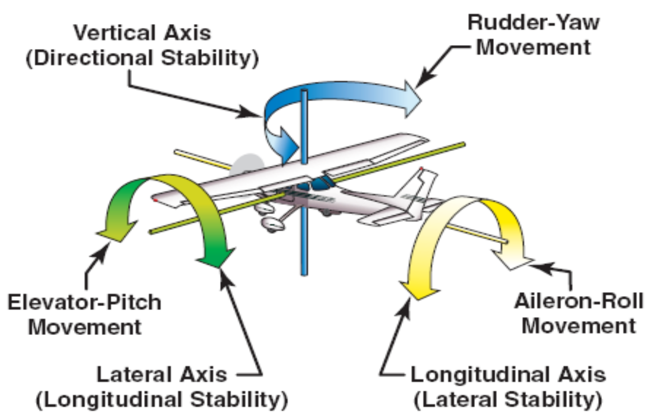




When an airplane with wing dihedral is displaced in a roll, it will immediately begin to slip in the direction of the lower wing. This creates a higher angle of attack on the low wing, which in turn increases the lift on that wing and tends to roll back to the original attitude of wings level.

Stability about the vertical axis is referred to as directional stability. When an airplane yaws to the right or left, the large vertical stabilizer surface that is behind the center of gravity acts like a weather vane. This forces the nose of the aircraft back toward its original position.

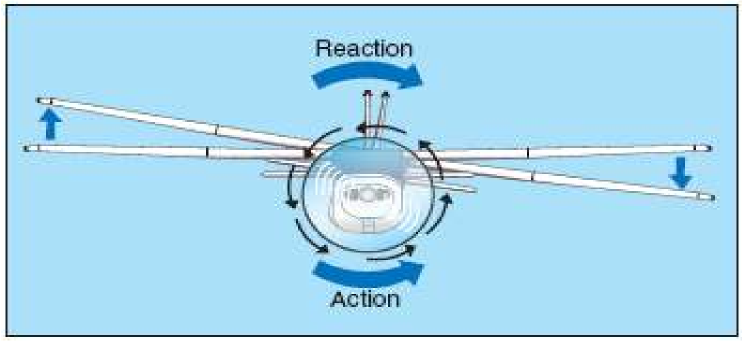
This chart summarizes the airplane stability and control about the three axes.



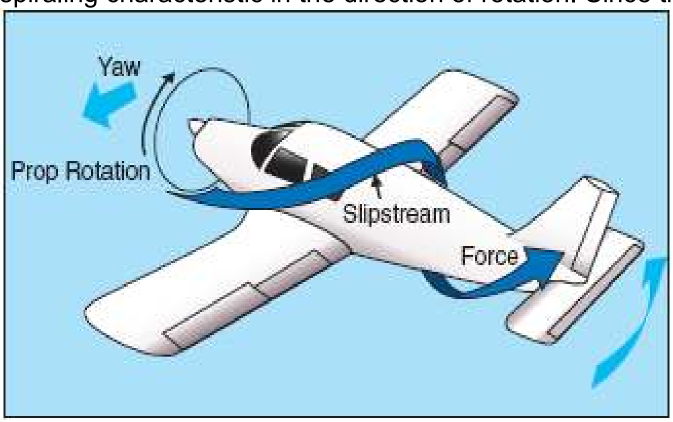
PRIMARY CONTROL SURFACE	AIRPLANE MOVEMENT	AXES OF ROTATION	TYPE OF STABILITY
Aileron	Roll	Longitudinal	Lateral
Elevator/ Stabilator	Pitch	Lateral	Longitudinal
Rudder	Yaw	Vertical	Directional

TURNING TENDENCIES

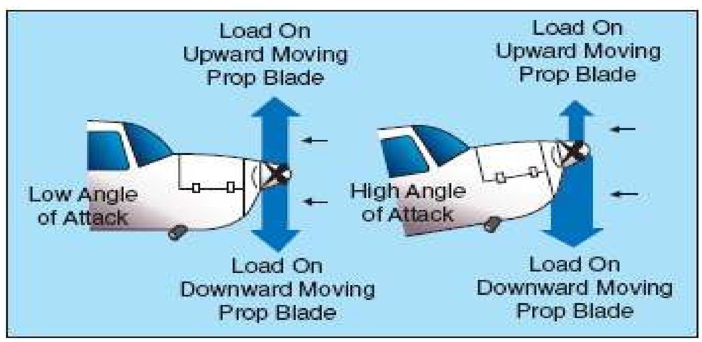
Propeller driven airplanes have strong turning tendencies which you will have to compensate for during various phases of flight. These turning tendencies are based on the direction of rotation of the propeller in relation to the airframe. One of these tendencies is Torque, which is Newton's third law of motion at work. For every action there is an equal and opposite reaction. The force required to spin a propeller clockwise as viewed from the cockpit acts on the rest of the airframe as a force in the opposite direction. The airframe tries to rotate counter-clockwise about the longitudinal axis.



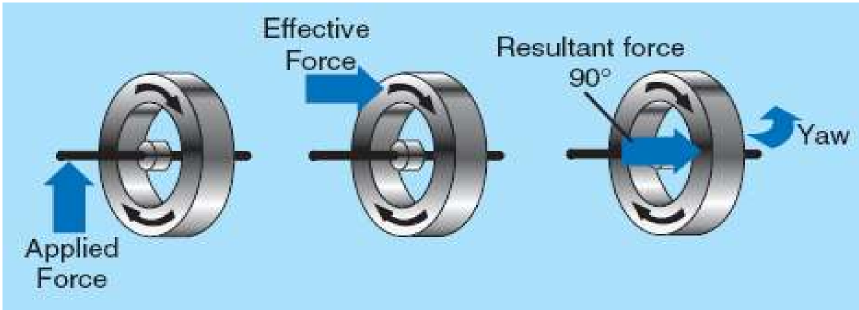
Another turning tendency is Spiraling Slipstream. The airflow behind a propeller takes on a spiraling characteristic in the direction of rotation. Since the propeller is rotating clockwise, the slipstream above the fuselage crosses left to right as it moves aft. This causes the vertical stabilizer to move to the right. This causes the nose of the airplane to yaw to the left. Aircraft design has counteracting forces for most of these turning tendencies, especially during cruising flight. However, at high power settings and high angles of attack, such as those used for takeoff and climb out, you will have to apply right rudder pressure to keep the airplane from turning.



A third turning tendency is P-Factor. This tendency is more pronounced at high angles of attack. When the propeller plane of rotation is perpendicular to the relative wind, the ascending and descending propeller blades have equal angles of attack. If you rotate the airplane to a nose high attitude without changing the relative wind, the descending blade of the propeller has a higher angle of attack. The net result is that more thrust is produced on the right side of the airplane than on the left. This causes a turning tendency to the left.



The fourth turning tendency is Gyroscopic Precession. Precession is the resultant action, or deflection, of a spinning rotor when a deflecting force is applied to its rim. When a force is applied, the resulting force takes effect 90° ahead of and in the direction of rotation. The rotating propeller of an airplane makes a very good gyroscope and thus has similar properties. Any time a force is applied to deflect the propeller out of its plane of rotation, the resulting force is 90° ahead of and in the direction of rotation and in the direction of application, causing a pitching moment, a yawing moment, or a combination of the two depending upon the point at which the force was applied.



When the DA20-C1 is rotating during takeoff, the propeller plane of rotation is being forced upward which results in a turning tendency to the right. Once the propeller has stabilized in the new plane, the tendency is gone.