the back pressure" or "increase pitch attitude" implies raising the airplane's nose in relation to the natural horizon and the terms "decreasing the pitch attitude" or "decrease pitch attitude" means lowering the nose in relation to the natural horizon. The pilot's primary reference is the natural horizon.

For all practical purposes, the airplane's airspeed remains constant in straight-and-level flight if the power setting is also constant. Intentional airspeed changes, by increasing or decreasing the engine power, provide proficiency in maintaining straight-and-level flight as the airplane's airspeed is changing. Pitching moments may also be generated by extension and retraction of flaps, landing gear, and other drag producing devices, such as spoilers. Exposure to the effect of the various configurations should be covered in any specific airplane checkout.

A common error of a beginner pilot is attempting to hold the wings level by only observing the airplane's nose. Using this method, the nose's short horizontal reference line can cause slight deviations to go unnoticed; however, deviations from level flight are easily recognizable when the pilot references the wingtips and, as a result, the wingtips should be the pilot's primary reference for maintaining level bank attitude. This technique also helps eliminate the potential for flying the airplane with one wing low and correcting heading errors with the pilot holding opposite rudder. A pilot with a bad habit of dragging one wing low and compensating with opposite rudder pressure will have difficulty in mastering other flight maneuvers.

Common errors in the performance of straight-and-level flight are:

- Attempting to use improper pitch and bank reference points on the airplane to establish attitude.
- Forgetting the location of preselected reference points on subsequent flights.
- Attempting to establish or correct airplane attitude using flight instruments rather than the natural horizon.
- "Chasing" the flight instruments rather than adhering to the principles of attitude flying.
- Mechanically pushing or pulling on the flight controls rather than exerting accurate and smooth pressure to affect change.
- Not scanning outside the cockpit to look for other aircraft traffic, weather and terrain influences, and not maintaining situational awareness.
- A tight palm grip on the flight controls resulting in a desensitized feeling of the hand and fingers, which results in overcontrolling the airplane.

Figure 3-8. *Nose reference for level flight.*

- Habitually flying with one wing low or maintaining directional control using only the rudder control.
- Failure to make timely and measured control inputs when deviations from straight-and-level flight are detected.
- Inadequate attention to sensory inputs in developing feel for the airplane.

Trim Control

Proper trim technique is an important and often overlooked basic flying skill. An improperly trimmed airplane requires constant flight control pressures from the pilot, produces tension and fatigue, distracts the pilot from outside visual scanning, and contributes to abrupt and erratic airplane attitude control inputs.

Trim control surfaces are required to offset any constant flight control pressure inputs provided by the pilot. For example, elevator trim is a typical trim in light GA airplanes and is used to null the pressure exerted by the pilot on the pitch flight control, which is being held to produce the tail down force required for a specific angle of attack (AOA). *[Figure 3-9]* This relieves the pilot from holding a constant pressure on the flight controls to maintain a particular pitch attitude and provides an opportunity for the pilot to divert attention to other tasks, such as evaluating the airplane's attitude in relation to the natural horizon, scanning for aircraft traffic, and maintaining situational awareness.

Because of their relatively low power, speed, and cost constraints, not all light airplanes have a complete set (elevator, rudder, and aileron) trim controls that are adjustable from inside the cockpit. Nearly all light airplanes are equipped with at least a cockpit adjustable elevator trim. As airplanes increase in power, weight, and complexity, cockpit adjustable trim systems for the rudder and aileron may be available.

In airplanes where multiple trim axes are available, the rudder should be trimmed first. Rudder, elevator and then aileron should be trimmed next in sequence; however, if the airspeed is varying, continuous attempts to trim the rudder and aileron produces unnecessary pilot workload and distraction. Attempts to trim the rudder at varying airspeeds are impractical in many propeller airplanes because of the built-in compensation for the effect of a propeller's left turning tendencies. The correct procedure is when the pilot has established a constant airspeed and pitch attitude, the pilot should then hold the wings level with aileron flight control pressure while rudder control pressure is trimmed out. Finally, aileron trim should then be adjusted to relieve any aileron flight control pressure.

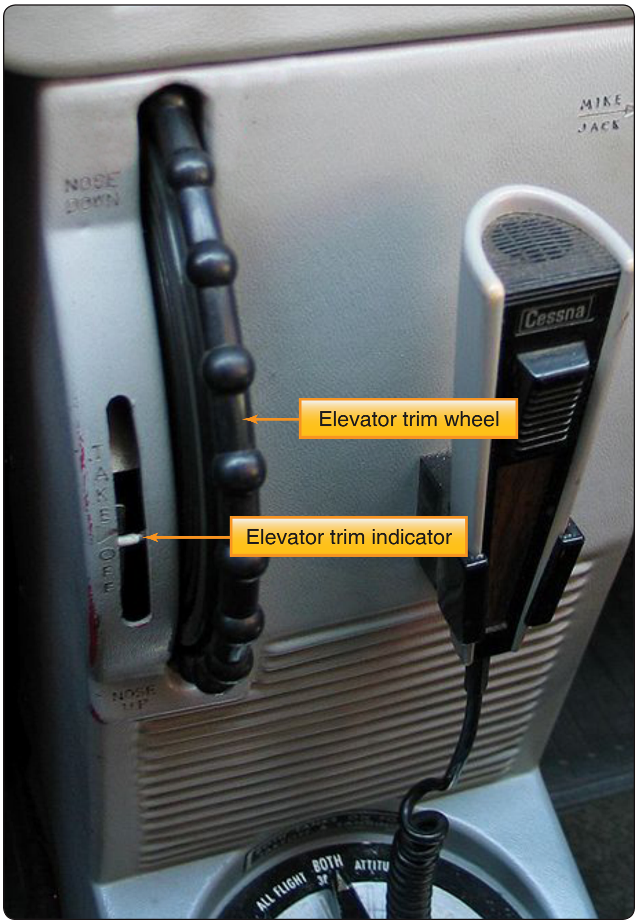

Figure 3-9. *Elevator trim is used in airplanes to null the pressure exerted by the pilot on the pitch flight control.*

A properly trimmed airplane is an indication of good piloting skills. Any control forces that the pilot feels should be a result of deliberate flight control pressure inputs during a planned change in airplane attitude, not a result of forces being applied by the airplane. A common trim control error is the tendency for the pilot to overcontrol the airplane with trim adjustments. Attempting to fly the airplane with the trim is a common fault in basic flying technique even among experienced pilots. The airplane attitude must be established first and held with the appropriate flight control pressures, and then the flight control pressures trimmed out so that the airplane maintains the desired attitude without the pilot exerting flight control pressure.

Level Turns

A turn is initiated by banking the wings in the desired direction of the turn through the pilot's use of the aileron flight controls. Left aileron flight control pressure causes the left wing to lower in relation to the pilot. Right aileron flight control pressure causes the right wing to lower in relation to the pilot. In other words, to turn left, lower left wing with aileron by left stick. To turn right, lower right wing with right stick. Depending on bank angle and airplane engineering, at many bank angles, the airplane will continue to turn with ailerons neutralized. So the sequence should be like the following: (1) bank airplane, adding either enough power or pitching up to compensate for the loss of lift (change in vector angle of lift); (2) neutralize controls as necessary to stop bank from increasing and hold desired bank angle; (3) use the opposite stick (aileron) to return airplane to level; (4) then take that control out to again neutralize the ailerons (along with either power or pitch reduction) for level flight. *[Figure 3-10]*

A turn is the result of the following:

- The ailerons bank the wings and so determine the rate of turn for a given airspeed. Lift is divided into both vertical and horizontal lift components as a result of the bank. The horizontal component of lift moves the airplane toward the banked direction.
- The elevator pitches the nose of the airplane up or down in relation to the pilot and perpendicular to the wings. If the pilot does not add power, and there is sufficient airspeed margin, the pilot must slightly increase the pitch to increase wing lift enough to replace the wing lift being diverted into turning force so as to maintain the current altitude.
- The vertical fin on an airplane does not produce lift. Rather the vertical fin on an airplane is a stabilizing surface and produces no lift if the airplane is flying straight ahead. The vertical fin's purpose is to keep the aft end of the airplane behind the front end.
- The throttle provides thrust which may be used for airspeed to tighten the turn.
- The pilot uses the rudder to offset any adverse yaw developed by wing's differential lift and the engine/propeller. The rudder does not turn the airplane. The rudder is used to maintain coordinated flight.


Figure 3-10. *Level turn to the left.*

For purposes of this discussion, turns are divided into three classes: shallow, medium, and steep.

- Shallow turns—bank angle is approximately 20° or less. This shallow bank is such that the inherent lateral stability of the airplane slowly levels the wings unless aileron pressure in the desired direction of bank is held by the pilot to maintain the bank angle.
- Medium turns—result from a degree of bank between approximately 20° to 45°. At medium bank angles, the airplane's inherent lateral stability does not return the wings to level flight. As a result, the airplane tends to remain at a constant bank angle without any flight control pressure held by the pilot. The pilot neutralizes the aileron flight control pressure to maintain the bank.
- Steep turns—result from a degree of bank of approximately 45° or more. The airplane continues in the direction of the bank even with neutral flight controls unless the pilot provides opposite flight control aileron pressure to prevent the airplane from overbanking. The amount of opposite flight control pressures is dependent on various factors, such as bank angle and airspeed. In general, a noticeable level of opposite aileron flight control pressure is required by the pilot to prevent overbanking.

When an airplane is flying straight and level, the total lift is acting perpendicular to the wings and to the Earth. As the airplane is banked into a turn, total lift is the resultant of two components: vertical and horizontal. *[Figure 3-11]* The vertical lift component continues to act perpendicular to the Earth and opposes gravity. The horizontal lift component acts parallel to the Earth's surface opposing centrifugal force. These two lift components act at right angles to each other, causing the resultant total lifting force to act perpendicular to the banked wing of the airplane. It is the horizontal lift component that begins to turn the airplane and not the rudder.

In constant altitude, constant airspeed turns, it is necessary to increase the AOA of the wing when rolling into the turn by increasing back pressure on the elevator, as well as the addition of power to counter the loss of speed due to increased drag. This is required because total lift has

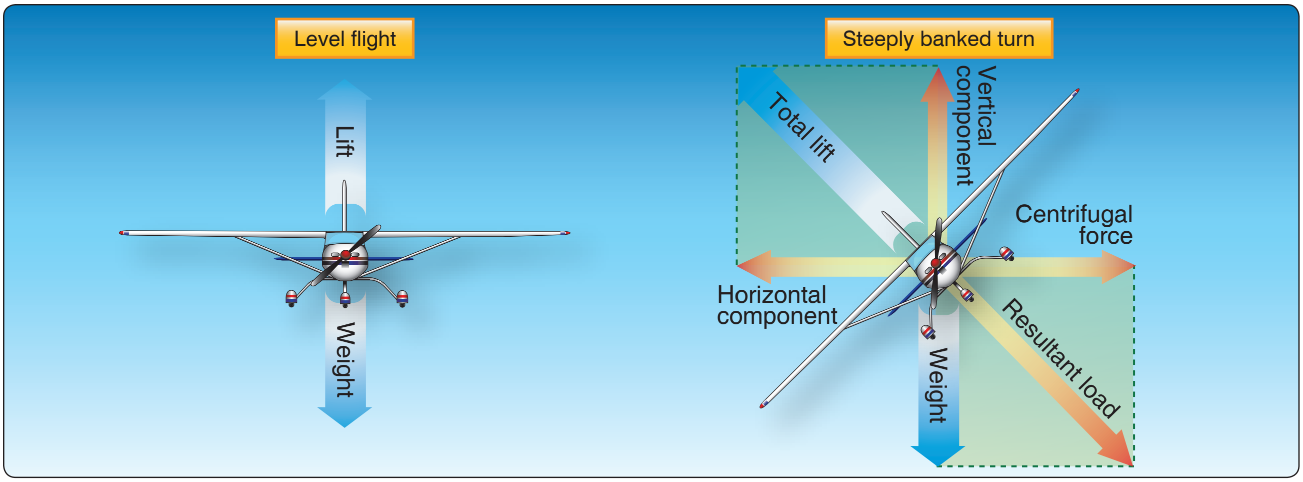

Figure 3-11. *When the airplane is banked into a turn, total lift is the resultant of two components: vertical and horizontal.*

divided into vertical and horizontal components of lift. In order to maintain altitude, the total lift (since total lift acts perpendicular to the wing) must be increased to meet the vertical component of lift requirements (to balance weight and load factor) for level flight.

The purpose of the rudder in a turn is to coordinate the turn. As lift increases, so does drag. When the pilot deflects the ailerons to bank the airplane, both lift and drag are increased on the rising wing and, simultaneously, lift and drag are decreased on the lowering wing. *[Figure 3-12]* This increased drag on the rising wing and decreased drag on the lowering wing results in the airplane yawing opposite to the direction of turn. To counteract this adverse yaw, rudder pressure is applied simultaneously with aileron in the desired direction of turn. This action is required to produce a coordinated turn. Coordinated flight is important to maintaining control of the airplane. Situations can develop when a pilot is flying in uncoordinated flight and depending on the flight control deflections, may support pro-spin flight control inputs. This is especially hazardous when operating at low altitudes, such as when operating in the airport traffic pattern. Pilots must learn to fly with coordinated control inputs to prevent unintentional loss of control when maneuvering in certain situations.

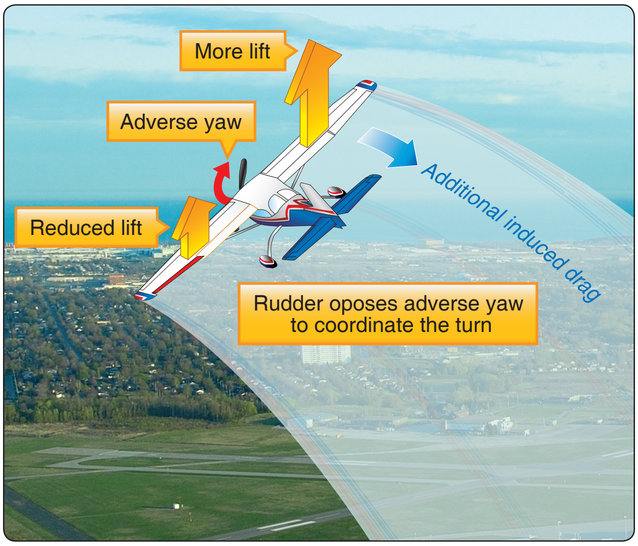

Figure 3-12. *The rudder opposes adverse yaw to help coordinate the turn.*

During uncoordinated flight, the pilot may feel that they are being pushed sideways toward the outside or inside of the turn. *[Figure 3-13]* A skid is when the pilot may feel that they are being pressed toward the outside of the turn and toward the inside of the turn during a slip. The ability to sense a skid or slip is developed over time and as the "feel" of flying develops, a pilot should become highly sensitive to a slip or skid without undue reliance on the flight instruments.

Turn Radius

To understand the relationship between airspeed, bank, and radius of turn, it should be noted that the rate of turn at any given true airspeed depends on the horizontal lift component. The horizontal lift component varies in proportion to the amount of bank. Therefore, the rate of turn at a given airspeed increases as the angle of bank is increased. On the other hand, when a turn is made at a higher airspeed at a given bank angle, the inertia is greater and the horizontal lift component required for the turn is greater, causing the turning rate to become slower. *[Figure 3-14]* Therefore, at a given angle of bank, a higher airspeed makes the radius of turn larger because the airplane turns at a slower rate.

As the radius of the turn becomes smaller, a significant difference develops between the airspeed of the inside wing and the airspeed of the outside wing. The wing on the outside of the turn travels a longer path than the inside wing, yet both complete their respective paths in the same unit of time.

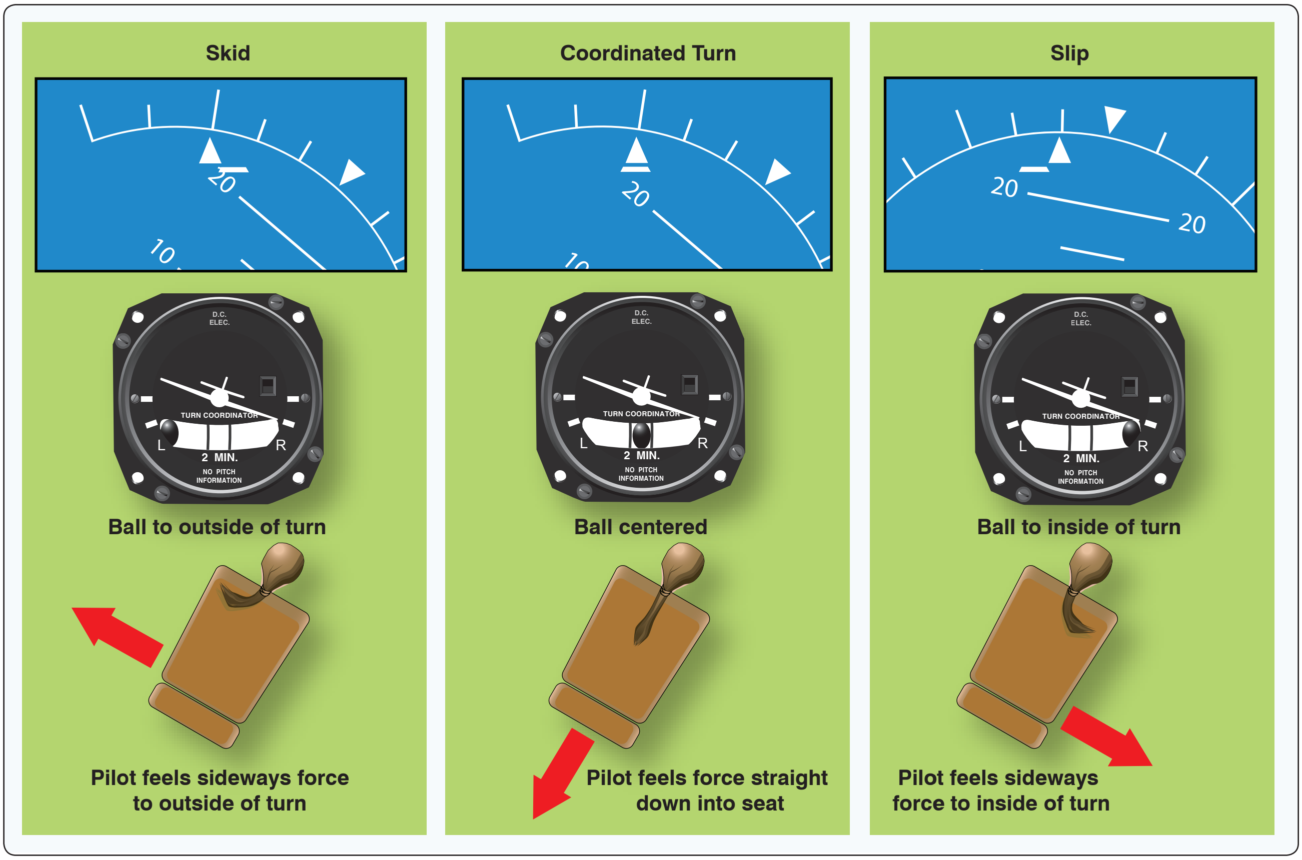

Figure 3-13. *Indications of a slip and skid.*

Therefore, the outside wing travels at a faster airspeed than the inside wing and, as a result, it develops more lift. This creates an overbanking tendency that must be controlled by the use of opposite aileron when the desired bank angle is reached. *[Figure 3-15]* Because the outboard wing is developing more lift, it also produces more drag. The drag causes a slight slip during steep turns that must be corrected by use of the rudder.

Establishing a Turn

On most light single-engine airplanes, the top surface of the engine cowling is fairly flat, and its horizontal surface to the natural horizon provides a reasonable indication for initially setting the degree of bank angle. *[Figure 3-16]* The pilot should then cross-check the flight instruments to verify that the correct bank angle has been achieved. Information

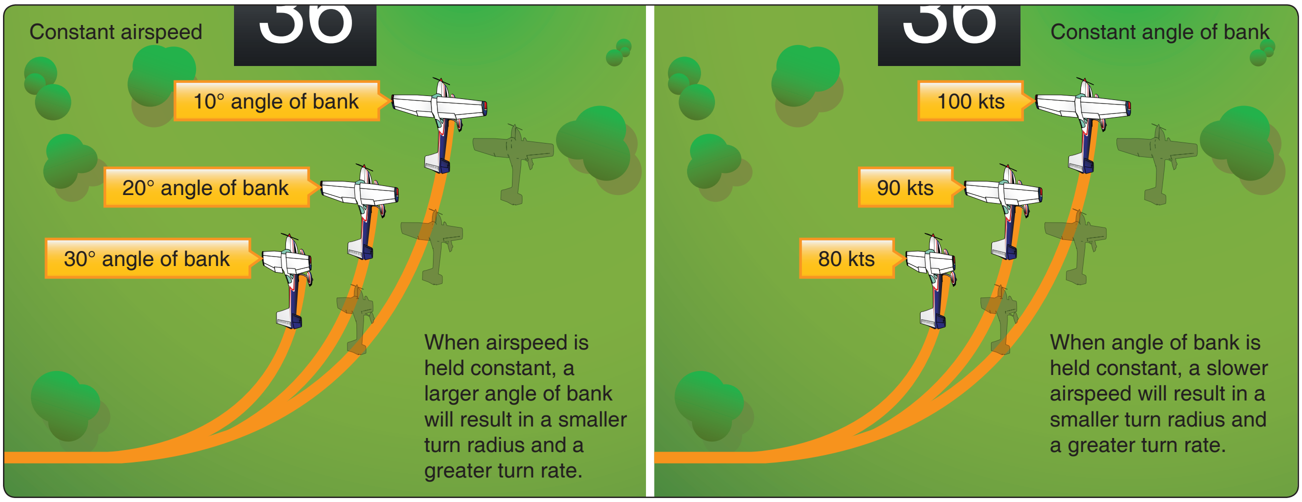

Figure 3-14. *Angle of bank and airspeed regulate rate and radius of turn.*

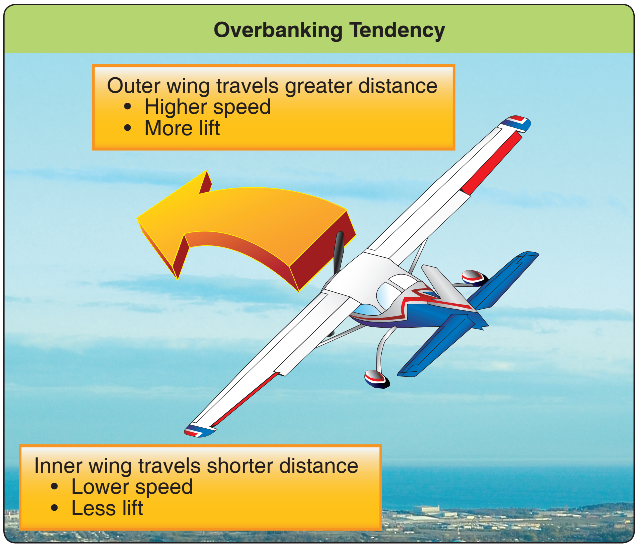

Figure 3-15. *Overbanking tendency.*

obtained from the attitude indicator shows the angle of the wing in relation to the horizon.

The pilot's seating position in the airplane is important as it affects the interpretation of outside visual references. A common problem is that a pilot may lean away from the turn in an attempt to remain in an upright position in relation to the horizon. This should be corrected immediately if the pilot is to properly learn to use visual references. *[Figure 3-17]*

Because most airplanes have side-by-side seating, a pilot does not sit on the airplane's longitudinal axis, which is where the airplane rotates in roll. The pilot sits slightly off to one side, typically the left, of the longitudinal axis. Due to parallax error, this makes the nose of the airplane appear to rise when making a left turn (due to pilot lowering in relation to the longitudinal axis) and the nose of the airplane appear to descend when making right turns (due to pilot elevating in relation to the longitudinal axis). *[Figure 3-18]*

Beginning pilots should not use large aileron and rudder control inputs. This is because large control inputs produce rapid roll rates and allows little time for the pilot to evaluate and make corrections. Smaller flight control inputs result in slower roll rates and provide for more time to accurately complete the necessary pitch and bank corrections.

Some additional considerations for initiating turns are the following:

- If the airplane's nose starts to move before the bank starts, the rudder is being applied too soon.
- If the bank starts before the nose starts turning or the nose moves in the opposite direction, the rudder is being applied too late.
- If the nose moves up or down when entering a bank, excessive or insufficient elevator back pressure is being applied.

After the bank has been established, all flight control pressures applied to the ailerons and rudder may be relaxed or adjusted, depending on the established bank angle, to compensate for the airplane's inherent stability or overbanking tendencies. The airplane should remain at the desired bank angle with the proper application of aileron pressures. If the desired bank angle is shallow, the pilot needs to maintain a small amount of aileron pressure into the direction of bank including rudder to compensate for yaw effects. For medium bank angles, the ailerons and rudder should be neutralized. Steep bank angles require opposite aileron and rudder to prevent the bank from steepening.

Back pressure on the elevator should not be relaxed as the vertical component of lift must be maintained if altitude is to be maintained. Throughout the turn, the pilot should reference the natural horizon, scan for aircraft traffic, and occasionally cross-check the flight instruments to verify performance. A reduction in airspeed is the result of increased drag but is generally not significant for shallow bank angles. In steeper turns, additional

Figure 3-16. *Visual reference for angle of bank.*

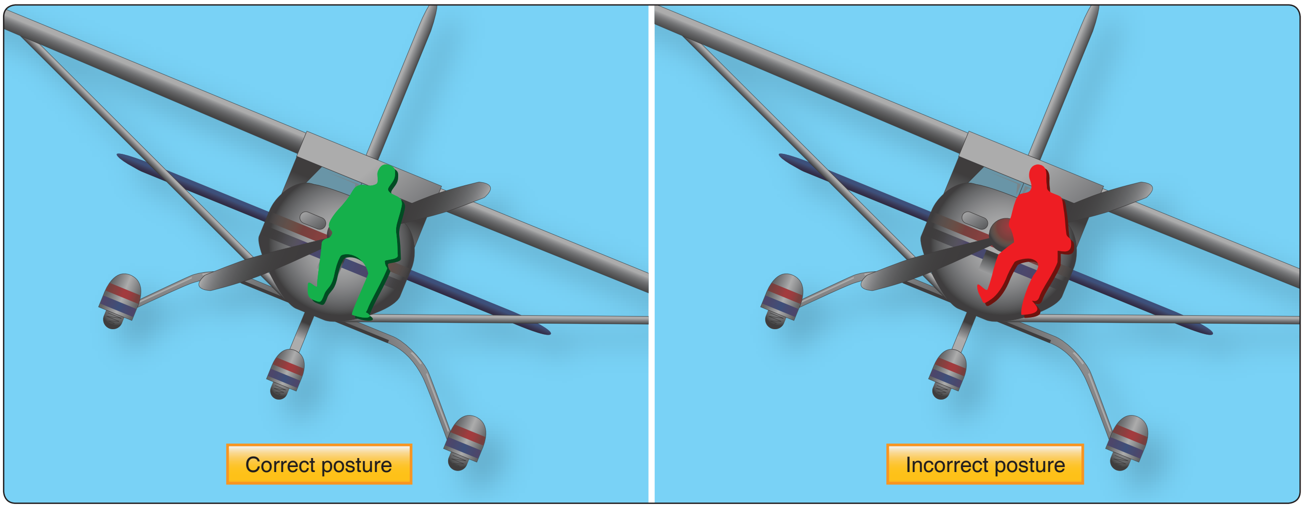

Figure 3-17. *Correct and incorrect posture while seated in the airplane.*

power may be required to maintain airspeed. If altitude is not being maintained during the turn, the pitch attitude should be corrected in relation to the natural horizon and cross-checked with the flight instruments to verify performance.

Steep turns require accurate, smooth, and timely flight control inputs. Minor corrections for pitch attitude are accomplished with proportional elevator back pressure while the bank angle is held constant with the ailerons. However, during steep turns, it is not uncommon for a pilot to allow the nose to get excessively low resulting in a significant loss in altitude in a very short period of time. The recovery sequence requires that the pilot first reduce the angle of bank with coordinated use of opposite aileron and rudder and then increase the pitch attitude by increasing elevator back pressure. If recovery from an excessively nose-low, steep bank condition is attempted by use of the elevator only, it only causes a steepening of the bank and unnecessary stress on the airplane. Steep turn performance can be improved by an appropriate application of power to overcome the increase in drag and trimming additional elevator back pressure as the bank angle goes beyond 30°. This tends to reduce the demands for large control inputs from the pilot during the turn.

Since the airplane continues turning as long as there is any bank, the rollout from the turn must be started before reaching the desired heading. The amount of lead required to rollout on the desired heading depends on the degree of bank used in the turn. A rule of thumb is to lead by one-half the angle of bank. For example, if the bank is 30°, lead the rollout by 15°. The rollout from a turn is similar to the roll-in except the flight controls are applied in the opposite direction. Aileron and rudder are applied in the direction of the rollout or toward the high wing. As the angle of bank decreases, the elevator pressure should be relaxed as necessary to maintain altitude. As the wings become level, the flight control pressures should

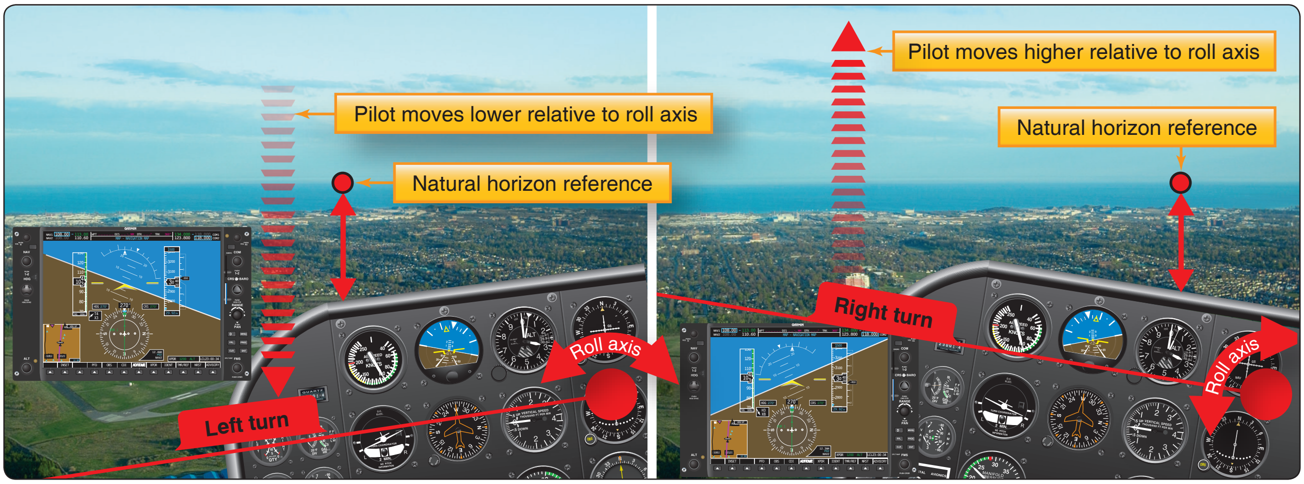

Figure 3-18. *Parallax view.*

be smoothly relaxed so that the controls are neutralized as the airplane returns to straight-and-level flight. If trim was used, such as during a steep turn, forward elevator pressure may be required until the trim can be adjusted. As the rollout is being completed, attention should be given to outside visual references, as well as the flight instruments to determine that the wings are being leveled and the turn stopped.

For outside references, select the horizon and another point ahead. If those two points stay in alignment, the airplane is tracking to that point as long as there is not a crosswind requiring a crab angle. It would also be a good idea to include VFR references for heading as well and pitch. A pilot holds course in VFR by tracking to a point in front of the compass, with only glances at the compass to ensure he or she is still on course. This reliance on a surface point does not work when flying over water or flat snow covered surfaces. In these conditions, the pilot must rely on the compass or gyro-heading indicator.

Because the elevator and ailerons are on one control, practice is required to ensure that only the intended pressure is applied to the intended flight control. For example, a beginner pilot is likely to unintentionally add pressure to the pitch control when the only bank was intended. This cross-coupling may be diminished or enhanced by the design of the flight controls; however, practice is the appropriate measure for smooth, precise, and accurate flight control inputs. For example, diving when turning right and climbing when turning left in airplanes is common with stick controls, because the arm tends to rotate from the elbow joint, which induces a secondary arc control motion if the pilot is not extremely careful. Likewise, lowering the nose is likely to induce a right turn, and raising the nose to climb tends to induce a left turn. These actions would apply for a pilot using the right hand to move the stick. Airplanes with a control wheel may be less prone to these inadvertent actions, depending on control positions and pilot seating. In any case, the pilot must retain the proper sight picture of the nose following the horizon, whether up, down, left or right and isolate undesired motion. It is essential that flight control coordination be developed because it is the very basis of all fundamental flight maneuvers.

Common errors in level turns are:

- Failure to adequately clear in the direction of turn for aircraft traffic.
- Gaining or losing altitude during the turn.
- Not holding the desired bank angle constant.
- Attempting to execute the turn solely by instrument reference.
- Leaning away from the direction of the turn while seated.
- Insufficient feel for the airplane as evidenced by the inability to detect slips or skids without reference to flight instruments.
- Attempting to maintain a constant bank angle by referencing only the airplane's nose.
- Making skidding flat turns to avoid banking the airplane.
- Holding excessive rudder in the direction of turn.
- Gaining proficiency in turns in only one direction.
- Failure to coordinate the controls.

Climbs and Climbing Turns

When an airplane enters a climb, it changes its flightpath from level flight to a climb attitude. In a climb, weight no longer acts in a direction solely perpendicular to the flightpath. When an airplane enters a climb, excess lift must be developed to overcome the weight or gravity. This requirement to develop more lift results in more induced drag, which either results in decreased airspeed and/or an increased power setting to maintain a minimum airspeed in the climb. An airplane can only sustain a climb when there is sufficient thrust to offset increased drag; therefore, climb rate is limited by the excess thrust available.

The pilot should know the engine power settings, natural horizon pitch attitudes, and flight instrument indications that produce the following types of climb:

Normal climb—performed at an airspeed recommended by the airplane manufacturer. Normal climb speed is generally higher than the airplane's best rate of climb. The additional airspeed provides for better engine cooling, greater control authority, and better visibility over the nose of the airplane. Normal climb is sometimes referred to as cruise climb.

Best rate of climb (V_Y)—produces the most altitude gained over a given amount of time. This airspeed is typically used when initially departing a runway without obstructions until it is safe to transition to a normal or cruise climb configuration. Best angle of climb (V_X)—performed at an airspeed that produces the most altitude gain over a given horizontal distance. The best angle of climb results in a steeper climb, although the airplane takes more time to reach the same altitude than it would at best rate of climb airspeed. The best angle of climb is used to clear obstacles, such as a strand of trees, after takeoff. *[Figure 3-19]*

It should be noted that as altitude increases, the airspeed for best angle of climb increases and the airspeed for best rate of climb decreases. Performance charts contained in the Airplane Flight Manual or Pilot's Operating Handbook

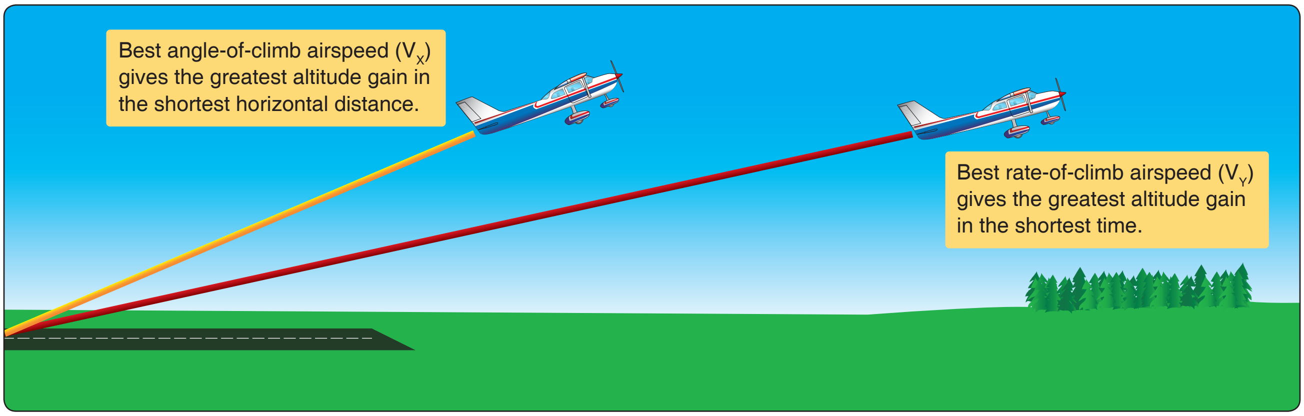

Figure 3-19. *Best angle of climb verses best rate of climb.*

(AFM/POH) must be consulted to ensure that the correct airspeed is used for the desired climb profile at the given environmental conditions. There is a point at which the best angle of climb airspeed and the best rate of climb airspeed intersect. This occurs at the absolute ceiling at which the airplane is incapable of climbing any higher. *[Figure 3-20]*

Establishing a Climb

A straight climb is entered by gently increasing back pressure on the elevator flight control to the pitch attitude referencing the airplane's nose to the natural horizon while simultaneously increasing engine power to the climb power setting. The wingtips should be referenced in maintaining the climb attitude while cross-checking the flight instruments to verify performance. In many airplanes, as power is increased, an increase in slipstream over the horizontal stabilizer causes the airplane's pitch attitude to increase greater than desired. The pilot should be prepared for slipstream effects but also for the effect of changing airspeed and changes in lift. The pilot should be prepared to use the required flight control pressures to achieve the desired pitch attitude.

If a climb is started from cruise flight, the airspeed gradually decreases as the airplane enters a stabilized climb attitude. The thrust required to maintain straight-and-level flight at a given airspeed is not sufficient to maintain the same airspeed in a climb. Increase drag in a climb stems from increased lift demands made upon the wing to increase altitude. Climbing requires an excess of lift over that necessary to maintain level flight. Increased lift will generate more induced drag. That increase in induced drag is why more power is needed and why a sustained climb requires an excess of thrust.

For practical purposes gravity or weight is a constant. Even using a vector diagram to show where more lift is necessary because the lift vector from the wings is no longer perpendicular to the wings, therefore more lift is needed from the wings which requires more thrust from the powerplant.

The power should be advanced to the recommended climb power. On airplanes equipped with an independently controllable-pitch propeller, this requires advancing the propeller control prior to increasing engine power. Some airplanes may be equipped with cowl flaps to facilitate effective engine cooling. The position of the cowl flaps should be set to ensure cylinder head temperatures remain within the manufacturer's specifications.

Engines that are normally aspirated experience a reduction of power as altitude is gained. As altitude increases, air density decreases, which results in a reduction of power. The indications show a reduction in revolutions per minute (rpm) for airplanes with fixed pitch propellers; airplanes that are equipped with controllable propellers show a decrease in manifold pressure. The pilot should reference the engine instruments to ensure that climb power is being

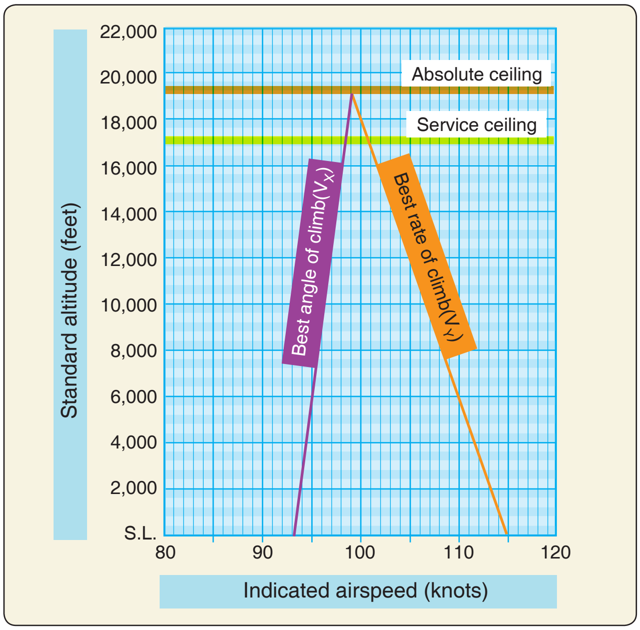

Figure 3-20. *Absolute ceiling.*

Figure 3-21. *Climb indications.*

maintained and that pressures and temperatures are within the manufacturer's limits. As power decreases in the climb, the pilot must continually advance the throttle or power lever to maintain specified climb settings.

The propeller effects during a climb and high power settings must be understood by the pilot. The propeller in most airplanes rotates clockwise when seen from the pilot's position. As pitch attitude is increased, the center of thrust from the propeller moves to the right and becomes asymmetrical. This asymmetric condition is often called "P-factor." This is the result of the increased AOA of the descending propeller blade, which is the right side of the propeller disc when seen from the cockpit. As the center of propeller thrust moves to the right, a left turning yawing moment moves the nose of the airplane to the left. This is compensated by the pilot through right rudder pressure. In addition, torque that acts opposite to the direction of propeller rotation causes the airplane to roll to the left. Under these conditions, torque and P-factor cause the airplane to roll and yaw to the left. To counteract this, right rudder and aileron flight control pressures must be used. During the initial practice of climbs, this may initially seem awkward; however, after some experience the correction for propeller effects becomes instinctive.

As the airspeed decreases during the climb's establishment, the airplane's pitch attitude tends to lower unless the pilot increases the elevator flight control pressure. Nose-up elevator trim should be used so that the pitch attitude can be maintained without the pilot holding back elevator pressure. Throughout the climb, since the power should be fixed at the climb power setting, airspeed is controlled by the use of elevator pressure. The pitch attitude to the natural horizon determines if the pitch attitude is correct and should be cross-checked to the flight instruments to verify climb performance. *[Figure 3-21]*

To return to straight-and-level flight from a climb, it is necessary to begin leveling-off prior to reaching the desired altitude. Level-off should begin at approximately 10 percent of the rate of climb. For example, if the airplane is climbing at 500 feet per minute (fpm), leveling off should begin 50 feet prior to reaching the desired altitude. The pitch attitude must be decreased smoothly and slowly to allow for the airspeed to increase; otherwise, a loss of altitude results if the pitch attitude is changed too rapidly without allowing the airspeed to increase proportionately.

After the airplane is established in level flight at a constant altitude, climb power should be retained temporarily so that the airplane accelerates to the cruise airspeed. When the airspeed reaches the desired cruise airspeed, the throttle setting and the propeller control, if equipped, should be set to the cruise power setting and the airplane re-trimmed.

Climbing Turns

In the performance of climbing turns, the following factors should be considered.

- With a constant power setting, the same pitch attitude and airspeed cannot be maintained in a bank as in a straight climb due to the increase in the total lift required.
- The degree of bank should not be too steep. A steep bank significantly decreases the rate of climb. The bank should always remain constant.
- It is necessary to maintain a constant airspeed and constant rate of turn in both right and left turns. The coordination of all flight controls is a primary factor.
- At a constant power setting, the airplane climbs at a slightly shallower climb angle because some of the lift is being used to turn the airplane.

All the factors that affect the airplane during level constant altitude turns affect the airplane during climbing turns. Compensation for the inherent stability of the airplane, overbanking tendencies, adverse yaw, propeller effects, reduction of the vertical component of lift, and increased drag must be managed by the pilot through the manipulation of the flight controls.

Climbing turns may be established by entering the climb first and then banking into the turn or climbing and turning simultaneously. During climbing turns, as in any turn, the loss of vertical lift must be compensated by an increase in pitch attitude. When a turn is coupled with a climb, the additional drag and reduction in the vertical component of lift must be further compensated for by an additional increase in elevator back pressure. When turns are simultaneous with a climb, it is most effective to limit the turns to shallow bank angles. This provides for an efficient rate of climb. If a medium or steep banked turn is used, climb performance is degraded or possibly non-existent.

Common errors in the performance of climbs and climbing turns are:

- Attempting to establish climb pitch attitude by primarily referencing the airspeed indicator resulting in the pilot chasing the airspeed.
- Applying elevator pressure too aggressively resulting in an excessive climb angle.
- Inadequate or inappropriate rudder pressure during climbing turns.
- Allowing the airplane to yaw during climbs usually due to inadequate right rudder pressure.
- Fixation on the airplane's nose during straight climbs, resulting in climbing with one wing low.
- Failure to properly initiate a climbing turn with a coordinated use of the flight controls, resulting in no turn but rather a climb with one wing low.
- Improper coordination resulting in a slip that counteracts the rate of climb, resulting in little or no altitude gain.
- Inability to keep pitch and bank attitude constant during climbing turns.
- Attempting to exceed the airplane's climb capability.
- Applying forward elevator pressure too aggressively during level-off resulting in a loss of altitude or G-force substantially less than one G.

Descents and Descending Turns

When an airplane enters a descent, it changes its flightpath from level flight to a descent attitude. *[Figure 3-22]* In a descent, weight no longer acts solely perpendicular to the flightpath. Since induced drag is decreased as lift is reduced in order to descend, excess thrust will provide higher airspeeds. The weight/gravity force is about the same. This causes an increase in total thrust and a power reduction is required to balance the forces if airspeed is to be maintained.

The pilot should know the engine power settings, natural horizon pitch attitudes, and flight instrument indications that produce the following types of descents:

Partial power descent—the normal method of losing altitude is to descend with partial power. This is often termed cruise or en route descent. The airspeed and power setting recommended by the AFM/POH for prolonged descent should be used. The target descent rate should be 500 fpm. The desired airspeed, pitch attitude, and power combination should be preselected and kept constant.

Descent at minimum safe airspeed—a nose-high, power-assisted descent condition principally used for clearing

Figure 3-22. *Descent indications.*

obstacles during a landing approach to a short runway. The airspeed used for this descent condition is recommended by the AFM/POH and is normally no greater than 1.3 V_{SO}. Some characteristics of the minimum safe airspeed descent are a steeper-than-normal descent angle, and the excessive power that may be required to produce acceleration at low airspeed should "mushing" and/or an excessive rate of descent be allowed to develop.

Emergency descent—some airplanes have a specific procedure for rapidly losing altitude. The AFM/POH specifies the procedure. In general, emergency descent procedures are high drag, high airspeed procedures requiring a specific airplane configuration (such as power to idle, propellers forward, landing gear extended, and flaps retracted) and a specific emergency descent airspeed. Emergency descent maneuvers often include turns.

Glides

A glide is a basic maneuver in which the airplane loses altitude in a controlled descent with little or no engine power; forward motion is maintained by gravity pulling the airplane along an inclined path and the descent rate is controlled by the pilot balancing the forces of gravity and lift. To level off from a partial power descent using a 1,000 feet per minute descent rate, use 10 percent (100 feet) as the lead point to begin raising the nose to stop descent and increasing power to maintain airspeed.

Although glides are directly related to the practice of power-off accuracy landings, they have a specific operational purpose in normal landing approaches, and forced landings after engine failure. Therefore, it is necessary that they be performed more subconsciously than other maneuvers because most of the time during their execution, the pilot will be giving full attention to details other than the mechanics of performing the maneuver. Since glides are usually performed relatively close to the ground, accuracy of their execution and the formation of proper technique and habits are of special importance.

The glide ratio of an airplane is the distance the airplane travels in relation to the altitude it loses. For example, if an airplane travels 10,000 feet forward while descending 1,000 feet, its glide ratio is 10 to 1.

The best glide airspeed is used to maximize the distance flown. This airspeed is important when a pilot is attempting to fly during an engine failure. The best airspeed for gliding is one at which the airplane travels the greatest forward distance for a given loss of altitude in still air. This best glide airspeed occurs at the highest lift-to-drag ratio (L/D). *[Figure 3-23]* When gliding at airspeed above or below the best glide airspeed, drag increases. Any change in the gliding airspeed results in a proportional change in the distance flown. *[Figure 3-24]* As the glide airspeed is increased or decreased from the best glide airspeed, the glide ratio is lessened.

Variations in weight do not affect the glide angle provided the pilot uses the proper airspeed. Since it is the L/D ratio that determines the distance the airplane can glide, weight does not affect the distance flown; however, a heavier airplane must fly at a higher airspeed to obtain the same glide ratio. For example, if two airplanes having the same L/D ratio but different weights start a glide from the same altitude, the heavier airplane gliding at a higher airspeed arrives at the same touchdown point in a shorter time. Both airplanes cover the same distance, only the lighter airplane takes a longer time.

Since the highest glide ratio occurs at maximum L/D, certain considerations must be given for drag producing components of the airplane, such as flaps, landing gear, and cowl flaps. When drag increases, a corresponding decrease in pitch attitude is required to maintain airspeed. As the pitch is lowered, the glide path steepens and reduces the distance traveled. To maximize the distance traveled during a glide, all drag producing components must be eliminated if possible.

Wind affects the gliding distance. With a tailwind, the airplane glides farther because of the higher groundspeed. Conversely, with a headwind, the airplane does not glide as far because of the slower groundspeed. This is important for a pilot to understand and manage when dealing with engine-related emergencies and any subsequent forced landing.

Certain considerations must be given to gliding flight. These considerations are caused by the absence of the propeller slipstream, compensation for p-factor in the airplane's design, and the effectiveness of airplane control surfaces

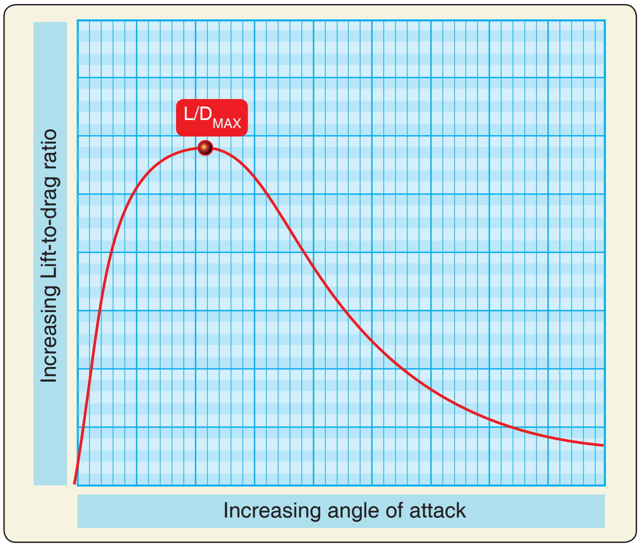

Figure 3-23. *L/D$_{MAX}$.*

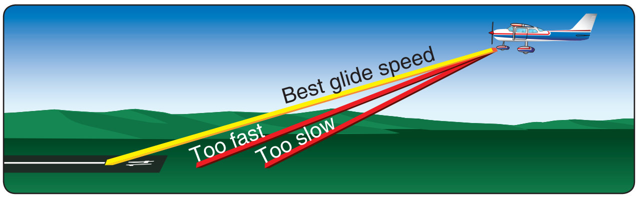

Figure 3-24. *Best glide speed provides the greatest forward distance for a given loss of altitude.*

at slow speeds. With the absent propeller effects and the subsequent compensation for these effects, which is designed into many airplanes, it is likely that, during glides, slight left rudder pressure is required to maintain coordinated flight. In addition, the deflection of the flight controls to effect change is greater due to the relatively slow airflow over the control surfaces.

Minimum sink speed is used to maximize the time that the airplane remains in flight. It results in the airplane losing altitude at the lowest rate. Minimum sink speed occurs at an airspeed less than the best glide speed. It is important that pilots realize that flight at the minimum sink airspeed results in less distance traveled. Minimum sink speed is useful in flight situations where time in flight is more important than distance flown. An example is ditching an airplane at sea. Minimum sink speed is not an often published airspeed but generally is a few knots less than best glide speed.

In an emergency, such as an engine failure, attempting to apply elevator back pressure to stretch a glide back to the runway is likely to lead the airplane landing short and may even lead to loss of control if the airplane stalls. This leads to a cardinal rule of airplane flying that a student pilot must understand and appreciate: The pilot must never attempt to "stretch" a glide by applying back-elevator pressure and reducing the airspeed below the airplane's recommended best glide speed. The purpose of pitch control during the glide is to maintain the maximum L/D, which may require fore or aft flight control pressure to maintain best glide airspeed.

To enter a glide, the pilot should close the throttle and, if equipped, advance the propeller lever forward. With back pressure on the elevator flight control, the pilot should maintain altitude until the airspeed decreases to the recommended best glide speed. In most airplanes, as power is reduced, propeller slipstream decreases over the horizontal stabilizer, which decreases the tail-down force, and the airplane's nose tends to lower immediately. To keep pitch attitude constant after a power change, the pilot must counteract the pitch down with a simultaneous increase in elevator back pressure. If the pitch attitude is allowed to decrease during glide entry, excess airspeed is carried into the glide and retards the attainment of the correct glide angle and airspeed. Speed should be allowed to dissipate before the pitch attitude is decreased. This point is particularly important for fast airplanes as they do not readily lose their airspeed—any slight deviation of the airplane's nose downwards results in an immediate increase in airspeed. Once the airspeed has dissipated to best glide speed, the pitch attitude should be set to maintain that airspeed. This should be done with reference to the natural horizon and with a quick reference to the flight instruments. When the airspeed has stabilized, the airplane should be trimmed to eliminate any flight control pressures held by the pilot. Precision is required in maintaining the best glide airspeed if the benefits are to be realized.

A stabilized, power-off descent at the best glide speed is often referred to as normal glide. The beginning pilot should memorize the airplane's attitude and speed with reference to the natural horizon and noting the sounds made by the air passing over the airplane's structure, forces on the flight controls, and the feel of the airplane. Initially, the beginner pilot may be unable to recognize slight variations in airspeed and angle of bank by vision or by the pressure required on the flight controls. The instructor should point out that an increase in sound levels denotes increasing speed, while a decrease in sound levels indicates decreasing speed. When a sound level change is perceived, a beginning pilot should cross-check the visual and pressure references. The beginning pilot must use all three airspeed references (sound, visual, and pressure) consciously until experience is gained, and then must remain alert to any variation in attitude, feel, or sound.

After a solid comprehension of the normal glide is attained, the beginning pilot should be instructed in the differences between normal and abnormal glides. Abnormal glides are those glides conducted at speeds other than the best glide speed. Glide airspeeds that are too slow or too fast may result in the airplane not being able to make the intended landing spot, flat approaches, hard touchdowns, floating, overruns, and possibly stalls and an accident.

Gliding Turns

The absence of the propeller slipstream, loss of effectiveness of the various flight control surfaces at lower airspeeds, and designed-in aerodynamic corrections complicates the task of flight control coordination in comparison to powered flight for the inexperienced pilot. These principles should be thoroughly explained by the flight instructor so that the beginner pilot may be aware of the necessary differences in coordination.

Three elements in gliding turns that tend to force the nose down and increase glide speed are:

- Decrease in lift due to the direction of the lifting force
- Excessive rudder inputs as a result of reduced flight control pressures

- The normal stability and inherent characteristics of the airplane to nose-down with the power off

These three factors make it necessary to use more back pressure on the elevator than is required for a straight glide or a level turn; and therefore, have a greater effect on control coordination. In rolling in or out of a gliding turn, the rudder is required to compensate for yawing tendencies; however, the required rudder pedal pressures are reduced as result of the reduced forces acting on the control surfaces. Because the rudder forces are reduced, the pilot may apply excessive rudder pedal pressures based on their experience with powered flight and overcontrol the aircraft causing slips and skids rather than coordinated flight. This may result in a much greater deflection of the rudder resulting in potentially hazardous flight control conditions.

Some examples of this hazard:

- A low-level gliding steep turn during an engine failure emergency. If the rudder is excessively deflected in the direction of the bank while the pilot is increasing elevator back pressure in an attempt to retain altitude, the situation can rapidly turn into an unrecoverable spin.
- During a power-off landing approach. The pilot depresses the rudder pedal with excessive pressure that leads to increased lift on the outside wing, banking the airplane in the direction of the rudder deflection. The pilot may improperly apply the opposite aileron to prevent the bank from increasing while applying elevator back pressure. If allowed to progress, this situation may result in a fully developed cross-control condition. A stall in this situation almost certainly results in a rapid and unrecoverable spin.

Level-off from a glide is really two different maneuvers depending on the type of glide:

1. In the event of a complete power failure, the best glide speed should be held until necessary to reconfigure for the landing, with planning for a steeper approach than usual when partial power is used for the approach to landing. A 10 percent lead (100 feet if the decent rate is 1,000 feet per minute) factor should be sufficient. That is what is given in the Instrument flying Handbook, so that should be the general rule of thumb for all publications.
2. In the case of a quicker descent or simulated power failure training, power should be applied as the 10% lead value appears on the altimeter to allow a slow but positive power application to maintain or increase airspeed while raising the nose to stop the descent. Retrim as necessary.

The level-off from a glide must be started before reaching the desired altitude because of the airplane's downward inertia. The amount of lead depends on the rate of descent and what airspeed is desired upon completion of the level off. For example, assume the aircraft is in a 500 fpm rate of descent, and the desired final airspeed is higher than the glide speed. The altitude lead should begin at approximately 100 feet above the target altitude and at the lead point, power should be increased to the appropriate level flight cruise power setting when the desired final airspeed is higher than the glide speed. At the lead point, power should be increased to the appropriate level flight cruise power setting. The airplane's nose tends to rise as airspeed and power increases and the pilot must smoothly control the pitch attitude so that the level-off is completed at the desired altitude and airspeed. When recovery is being made from a gliding turn, the back pressure on the elevator control, which was applied during the turn, must be decreased or the airplane's nose will pitch up excessively high resulting in a rapid loss of airspeed. This error requires considerable attention and conscious control adjustment before the normal glide can be resumed.

Common errors in the performance of descents and descending turns are:

- Failure to adequately clear for aircraft traffic in the turn direction or descent.
- Inadequate elevator back pressure during glide entry resulting in an overly steep glide.
- Failure to slow the airplane to approximate glide speed prior to lowering pitch attitude.
- Attempting to establish/maintain a normal glide solely by reference to flight instruments.
- Inability to sense changes in airspeed through sound and feel.
- Inability to stabilize the glide (chasing the airspeed indicator).
- Attempting to "stretch" the glide by applying back-elevator pressure.
- Skidding or slipping during gliding turns due to inadequate appreciation of the difference in rudder forces as compared to turns with power.
- Failure to lower pitch attitude during gliding turn entry resulting in a decrease in airspeed.
- Excessive rudder pressure during recovery from gliding turns.
- Inadequate pitch control during recovery from straight glide.

- Cross-controlling during gliding turns near the ground.
- Failure to maintain constant bank angle during gliding turns.

Chapter Summary

The four fundamental maneuvers of straight-and-level flight, turns, climbs, and descents are the foundation of basic airmanship. Effort and continued practice are required to master the fundamentals. It is important that a pilot consider the six motions of flight: bank, pitch, yaw and horizontal, vertical, and lateral displacement. In order for an airplane to fly from one location to another, it pitches, banks, and yaws while it moves over and above, in relationship to the ground, to reach its destination. The airplane must be treated as an aerodynamic vehicle that is subject to rigid aerodynamic laws. A pilot must understand and apply the principles of flight in order to control an airplane with the greatest margin of mastery and safety.