



THE FOUR FUNDAMENTALS

There are four fundamental basic flight maneuvers upon which all flying tasks are based: straight-and-level flight, turns, climbs, and descents. All controlled flight consists of either one, or a combination or more than one, of these basic maneuvers. If a student pilot is able to perform these maneuvers well, and the student's proficiency is based on accurate "feel" and control analysis rather than mechanical movements, the ability to perform any assigned maneuver will only be a matter of obtaining a clear visual and mental conception of it. The flight instructor must impart a good knowledge of these basic elements to the student, and must combine them and plan their practice so that perfect performance of each is instinctive without conscious effort. The importance of this to the success of flight training cannot be overemphasized. As the student progresses to more complex maneuvers, discounting any difficulties in visualizing the maneuvers, most student difficulties will be caused by a lack of training, practice, or understanding of the principles of one or more of these fundamentals.

EFFECTS AND USE OF THE CONTROLS

In explaining the functions of the controls, the instructor should emphasize that the controls never change in the results produced in relation to the pilot. The pilot should always be considered the center of movement of the airplane, or the reference point from which the movements of the airplane are judged and described. The following will always be true, regardless of the airplane's attitude in relation to the Earth.

- When back pressure is applied to the elevator control, the airplane's nose rises in relation to the pilot.
- When forward pressure is applied to the elevator control, the airplane's nose lowers in relation to the pilot.
- When right pressure is applied to the aileron control, the airplane's right wing lowers in relation to the pilot.
- When left pressure is applied to the aileron control, the airplane's left wing lowers in relation to the pilot.
- When pressure is applied to the right rudder pedal, the airplane's nose moves (yaws) to the right in relation to the pilot.

- When pressure is applied to the left rudder pedal, the airplane's nose moves (yaws) to the left in relation to the pilot.

The preceding explanations should prevent the beginning pilot from thinking in terms of "up" or "down" in respect to the Earth, which is only a relative state to the pilot. It will also make understanding of the functions of the controls much easier, particularly when performing steep banked turns and the more advanced maneuvers. Consequently, the pilot must be able to properly determine the control application required to place the airplane in any attitude or flight condition that is desired.

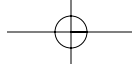
The flight instructor should explain that the controls will have a natural "live pressure" while in flight and that they will remain in neutral position of their own accord, if the airplane is trimmed properly.

With this in mind, the pilot should be cautioned never to think of movement of the controls, but of exerting a force on them against this live pressure or resistance. Movement of the controls should not be emphasized; it is the duration and amount of the force exerted on them that effects the displacement of the control surfaces and maneuvers the airplane.

The amount of force the airflow exerts on a control surface is governed by the airspeed and the degree that the surface is moved out of its neutral or streamlined position. Since the airspeed will not be the same in all maneuvers, the actual amount the control surfaces are moved is of little importance; but it is important that the pilot maneuver the airplane by applying sufficient control *pressure* to obtain a desired result, regardless of how far the control surfaces are actually moved.

The controls should be held lightly, with the fingers, not grabbed and squeezed. Pressure should be exerted on the control yoke with the fingers. A common error in beginning pilots is a tendency to "choke the stick." This tendency should be avoided as it prevents the development of "feel," which is an important part of aircraft control.

The pilot's feet should rest comfortably against the rudder pedals. Both heels should support the weight of the feet on the cockpit floor with the ball of each foot touching the individual rudder pedals. The legs and feet should not be tense; they must be relaxed just as when driving an automobile.



When using the rudder pedals, pressure should be applied smoothly and evenly by pressing with the ball of one foot. Since the rudder pedals are interconnected, and act in opposite directions, when pressure is applied to one pedal, pressure on the other must be relaxed proportionately. When the rudder pedal must be moved significantly, heavy pressure changes should be made by applying the pressure with the ball of the foot while the heels slide along the cockpit floor. Remember, the ball of each foot must rest comfortably on the rudder pedals so that even slight pressure changes can be felt.

In summary, during flight, it is the *pressure* the pilot exerts on the control yoke and rudder pedals that causes the airplane to move about its axes. When a control surface is moved out of its streamlined position (even slightly), the air flowing past it will exert a force against it and will try to return it to its streamlined position. It is this force that the pilot feels as pressure on the control yoke and the rudder pedals.

FEEL OF THE AIRPLANE

The ability to sense a flight condition, without relying on cockpit instrumentation, is often called “feel of the airplane,” but senses in addition to “feel” are involved.

Sounds inherent to flight are an important sense in developing “feel.” The air that rushes past the modern light plane cockpit/cabin is often masked by soundproofing, but it can still be heard. When the level of sound increases, it indicates that airspeed is increasing. Also, the powerplant emits distinctive sound patterns in different conditions of flight. The sound of the engine in cruise flight may be different from that in a climb, and different again from that in a dive. When power is used in fixed-pitch propeller airplanes, the loss of r.p.m. is particularly noticeable. The amount of noise that can be heard will depend on how much the slipstream masks it out. But the relationship between slipstream noise and powerplant noise aids the pilot in estimating not only the present airspeed but the trend of the airspeed.

There are three sources of actual “feel” that are very important to the pilot. One is the pilot’s own body as it responds to forces of acceleration. The “G” loads imposed on the airframe are also felt by the pilot. Centripetal accelerations force the pilot down into the seat or raise the pilot against the seat belt. Radial accelerations, as they produce slips or skids of the airframe, shift the pilot from side to side in the seat. These forces need not be strong, only perceptible by the pilot to be useful. An accomplished pilot who has excellent “feel” for the airplane will be able to detect even the minutest change.

The response of the aileron and rudder controls to the pilot’s touch is another element of “feel,” and is one

that provides direct information concerning airspeed. As previously stated, control surfaces move in the airstream and meet resistance proportional to the speed of the airstream. When the airstream is fast, the controls are stiff and hard to move. When the airstream is slow, the controls move easily, but must be deflected a greater distance. The pressure that must be exerted on the controls to effect a desired result, and the lag between their movement and the response of the airplane, becomes greater as airspeed decreases.

Another type of “feel” comes to the pilot through the airframe. It consists mainly of vibration. An example is the aerodynamic buffeting and shaking that precedes a stall.

Kinesthesia, or the sensing of changes in direction or speed of motion, is one of the most important senses a pilot can develop. When properly developed, kinesthesia can warn the pilot of changes in speed and/or the beginning of a settling or **mushing** of the airplane.

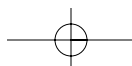
The senses that contribute to “feel” of the airplane are inherent in every person. However, “feel” must be developed. The flight instructor should direct the beginning pilot to be attuned to these senses and teach an awareness of their meaning as it relates to various conditions of flight. To do this effectively, the flight instructor must fully understand the difference between perceiving something and merely noticing it. It is a well established fact that the pilot who develops a “feel” for the airplane early in flight training will have little difficulty with advanced flight maneuvers.

ATTITUDE FLYING

In contact (VFR) flying, flying by attitude means visually establishing the airplane’s attitude with reference to the natural horizon. [Figure 3-1] Attitude is the angular difference measured between an airplane’s axis and the line of the Earth’s horizon. Pitch attitude is the angle formed by the longitudinal axis, and bank attitude is the angle formed by the lateral axis. Rotation about the airplane’s vertical axis (yaw) is termed an attitude relative to the airplane’s flightpath, but not relative to the natural horizon.

In attitude flying, airplane control is composed of four components: pitch control, bank control, power control, and trim.

- Pitch control is the control of the airplane about the lateral axis by using the elevator to raise and lower the nose in relation to the natural horizon.
- Bank control is control of the airplane about the longitudinal axis by use of the ailerons to attain a desired bank angle in relation to the natural horizon.



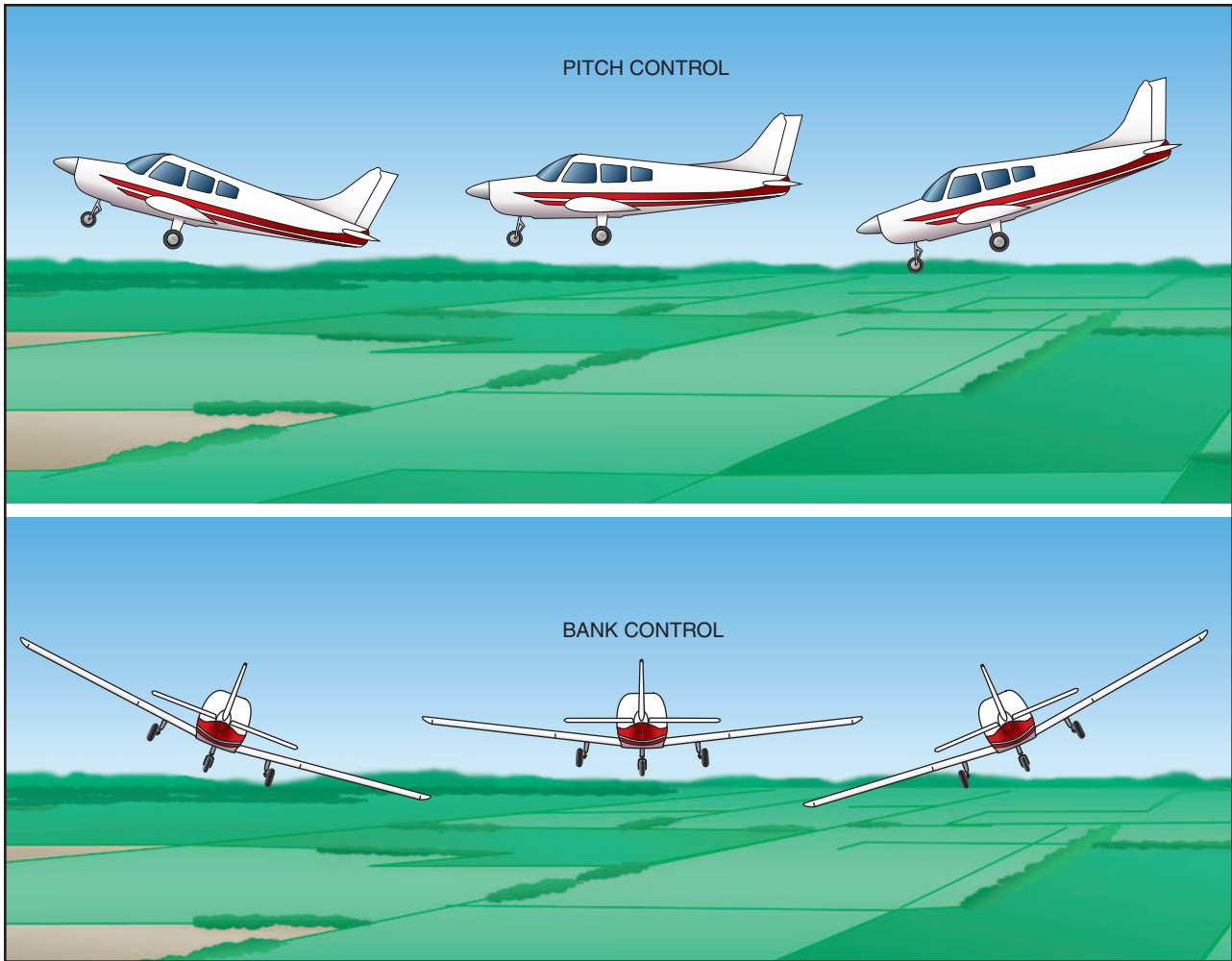
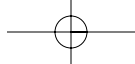


Figure 3-1. Airplane attitude is based on relative positions of the nose and wings on the natural horizon.

- Power control is used when the flight situation indicates a need for a change in thrust.
- Trim is used to relieve all possible control pressures held after a desired attitude has been attained.
- The airplane's attitude is established and maintained by positioning the airplane in relation to the natural horizon. At least 90 percent of the pilot's attention should be devoted to this end, along with

The primary rule of attitude flying is:

ATTITUDE + POWER = PERFORMANCE

INTEGRATED FLIGHT INSTRUCTION

When introducing basic flight maneuvers to a beginning pilot, it is recommended that the "Integrated" or "Composite" method of flight instruction be used. This means the use of outside references and flight instruments to establish and maintain desired flight attitudes and airplane performance. [Figure 3-2] When beginning pilots use this technique, they achieve a more precise and competent overall piloting ability. Although this method of airplane control may become second nature with experience, the beginning pilot must make a determined effort to master the technique. The basic elements of which are as follows.

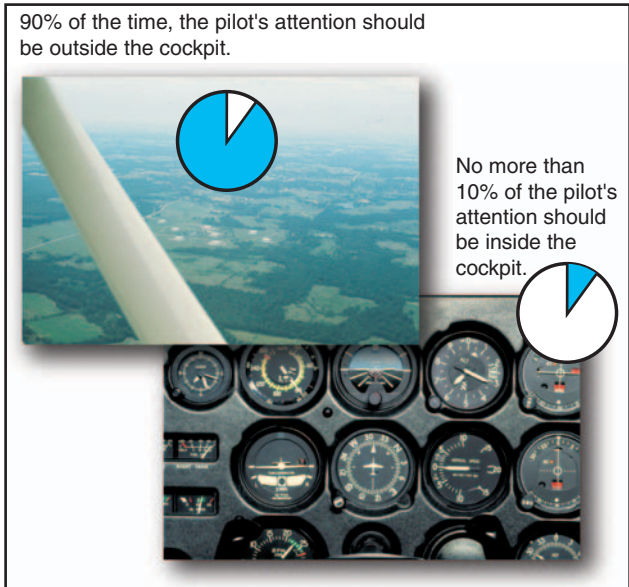
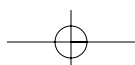
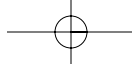


Figure 3-2. Integrated or composite method of flight instruction.





scanning for other airplanes. If, during a recheck of the pitch and/or bank, either or both are found to be other than desired, an immediate correction is made to return the airplane to the proper attitude. Continuous checks and immediate corrections will allow little chance for the airplane to deviate from the desired heading, altitude, and flightpath.

- The airplane's attitude is confirmed by referring to flight instruments, and its performance checked. If airplane performance, as indicated by flight instruments, indicates a need for correction, a specific amount of correction must be determined, then applied with reference to the natural horizon. The airplane's attitude and performance are then rechecked by referring to flight instruments. The pilot then maintains the corrected attitude by reference to the natural horizon.
- The pilot should monitor the airplane's performance by making numerous quick glances at the flight instruments. No more than 10 percent of the pilot's attention should be inside the cockpit. The pilot must develop the skill to instantly focus on the appropriate flight instrument, and then immediately return to outside reference to control the airplane's attitude.

The pilot should become familiar with the relationship between outside references to the natural horizon and the corresponding indications on flight instruments inside the cockpit. For example, a pitch attitude adjustment may require a movement of the pilot's reference point on the airplane of several inches in relation to the natural horizon, but correspond to a small fraction of an inch movement of the reference bar on the airplane's attitude indicator. Similarly, a deviation from desired bank, which is very obvious when referencing the wingtip's position relative to the natural horizon, may be nearly imperceptible on the airplane's attitude indicator to the beginning pilot.

The use of integrated flight instruction does not, and is not intended to prepare pilots for flight in instrument weather conditions. The most common error made by the beginning student is to make pitch or bank corrections while still looking inside the cockpit. Control pressure is applied, but the beginning pilot, not being familiar with the intricacies of flight by references to instruments, including such things as instrument lag and gyroscopic precession, will invariably make excessive attitude corrections and end up "chasing the instruments." Airplane attitude by reference to the natural horizon, however, is immediate in its indications, accurate, and presented many times larger than any instrument could be. Also, the beginning pilot must be made aware that anytime, for whatever reason, airplane attitude by reference to the natural horizon cannot be established and/or maintained, the situation should be considered a bona fide emergency.

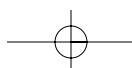
STRAIGHT-AND-LEVEL FLIGHT

It is impossible to emphasize too strongly the necessity for forming correct habits in flying straight and level. All other flight maneuvers are in essence a deviation from this fundamental flight maneuver. Many flight instructors and students are prone to believe that perfection in straight-and-level flight will come of itself, but such is not the case. It is not uncommon to find a pilot whose basic flying ability consistently falls just short of minimum expected standards, and upon analyzing the reasons for the shortcomings to discover that the cause is the inability to fly straight and level properly.

Straight-and-level flight is flight in which a constant heading and altitude are maintained. It is accomplished by making immediate and measured corrections for deviations in direction and altitude from unintentional slight turns, descents, and climbs. *Level flight*, at first, is a matter of consciously fixing the relationship of the position of some portion of the airplane, used as a reference point, with the horizon. In establishing the reference points, the instructor should place the airplane in the desired position and aid the student in selecting reference points. The instructor should be aware that no two pilots see this relationship exactly the same. The references will depend on where the pilot is sitting, the pilot's height (whether short or tall), and the pilot's manner of sitting. It is, therefore, important that during the fixing of this relationship, the pilot sit in a normal manner; otherwise the points will not be the same when the normal position is resumed.

In learning to control the airplane in level flight, it is important that the student be taught to maintain a light grip on the flight controls, and that the control forces desired be exerted lightly and just enough to produce the desired result. The student should learn to associate the apparent movement of the references with the forces which produce it. In this way, the student can develop the ability to regulate the change desired in the airplane's attitude by the amount and direction of forces applied to the controls without the necessity of referring to instrument or outside references for each minor correction.

The pitch attitude for *level flight* (constant altitude) is usually obtained by selecting some portion of the airplane's nose as a reference point, and then keeping that point in a fixed position relative to the horizon. [Figure 3-3] Using the principles of attitude flying, that position should be cross-checked occasionally against the altimeter to determine whether or not the pitch attitude is correct. If altitude is being gained or lost, the pitch attitude should be readjusted in relation to the horizon and then the altimeter rechecked to determine if altitude is now being maintained. The



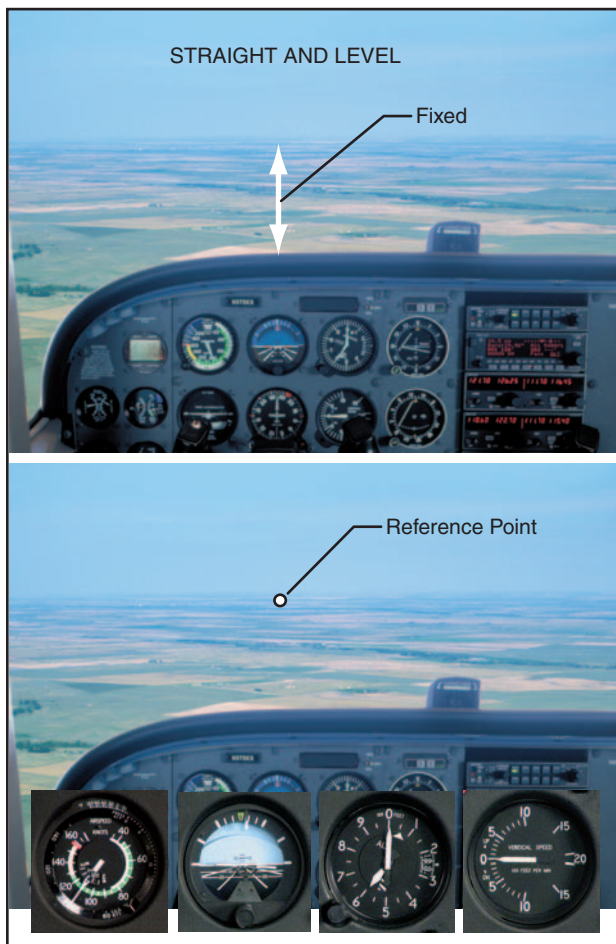
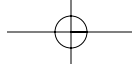


Figure 3-3. Nose reference for straight-and-level flight.

application of forward or back-elevator pressure is used to control this attitude.

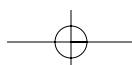
The pitch information obtained from the attitude indicator also will show the position of the nose relative to the horizon and will indicate whether elevator pressure is necessary to change the pitch attitude to return to level flight. However, the primary reference source is the natural horizon.

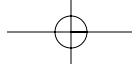
In all normal maneuvers, the term “increase the pitch attitude” implies raising the nose in relation to the horizon; the term “decreasing the pitch attitude” means lowering the nose.

Straight flight (laterally level flight) is accomplished by visually checking the relationship of the airplane’s wingtips with the horizon. Both wingtips should be equidistant above or below the horizon (depending on whether the airplane is a high-wing or low-wing type), and any necessary adjustments should be made with the ailerons, noting the relationship of control pressure and the airplane’s attitude. [Figure 3-4] The student should understand that anytime the wings are banked, even though very slightly, the airplane will turn. The objective of straight-and-level flight is to detect small deviations from laterally level flight as soon as they occur, necessitating only small corrections. Reference to the heading indicator should be made to note any change in direction.



Figure 3-4. Wingtip reference for straight-and-level flight.





Continually observing the wingtips has advantages other than being the only positive check for leveling the wings. It also helps divert the pilot's attention from the airplane's nose, prevents a fixed stare, and automatically expands the pilot's area of vision by increasing the range necessary for the pilot's vision to cover. In practicing straight-and-level-flight, the wingtips can be used not only for establishing the airplane's laterally level attitude or bank, but to a lesser degree, its pitch attitude. This is noted only for assistance in learning straight-and-level flight, and is not a recommended practice in normal operations.

The scope of a student's vision is also very important, for if it is obscured the student will tend to look out to one side continually (usually the left) and consequently lean that way. This not only gives the student a biased angle from which to judge, but also causes the student to exert unconscious pressure on the controls in that direction, which results in dragging a wing.

With the wings approximately level, it is possible to maintain straight flight by simply exerting the necessary forces on the rudder in the desired direction. However, the instructor should point out that the practice of using rudder alone is not correct and may make precise control of the airplane difficult. Straight-and-level flight requires almost no application of control pressures if the airplane is properly trimmed and the air is smooth. For that reason, the student must not form the habit of constantly moving the controls unnecessarily. The student must learn to recognize when corrections are necessary, and then to make a measured response easily and naturally.

To obtain the proper conception of the forces required on the rudder during straight-and-level-flight, the airplane must be held level. One of the most common faults of beginning students is the tendency to concentrate on the nose of the airplane and attempting to hold the wings level by observing the curvature of the nose cowling. With this method, the reference line is very short and the deviation, particularly if very slight, can go unnoticed. Also, a very small deviation from level, by this short reference line, becomes considerable at the wingtips and results in an appreciable dragging of one wing. This attitude requires the use of additional rudder to maintain straight flight, giving a false conception of neutral control forces. The habit of dragging one wing, and compensating with rudder pressure, if allowed to develop is particularly hard to break, and if not corrected will result in considerable difficulty in mastering other flight maneuvers.

For all practical purposes, the airspeed will remain constant in straight-and-level flight with a constant power setting. Practice of intentional airspeed changes, by increasing or decreasing the power, will provide an

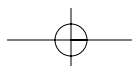
excellent means of developing proficiency in maintaining straight-and-level flight at various speeds. Significant changes in airspeed will, of course, require considerable changes in pitch attitude and pitch trim to maintain altitude. Pronounced changes in pitch attitude and trim will also be necessary as the flaps and landing gear are operated.

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

- Attempting to use improper 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 outside visual reference.
- Attempting to maintain direction using only rudder control.
- Habitually flying with one wing low.
- "Chasing" the flight instruments rather than adhering to the principles of attitude flying.
- Too tight a grip on the flight controls resulting in overcontrol and lack of feel.
- Pushing or pulling on the flight controls rather than exerting pressure against the airstream.
- Improper scanning and/or devoting insufficient time to outside visual reference. (Head in the cockpit.)
- Fixation on the nose (pitch attitude) reference point.
- Unnecessary or inappropriate control inputs.
- 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

The airplane is designed so that the primary flight controls (rudder, aileron, and elevator) are streamlined with the nonmovable airplane surfaces when the airplane is cruising straight-and-level at normal weight and loading. If the airplane is flying out of that basic balanced condition, one or more of the control surfaces is going to have to be held out of its streamlined position by continuous control input. The use of trim tabs relieves the pilot of this requirement. Proper trim technique is a very important and



often overlooked basic flying skill. An improperly trimmed airplane requires constant control pressures, produces pilot tension and fatigue, distracts the pilot from scanning, and contributes to abrupt and erratic airplane attitude control.

Because of their relatively low power and speed, not all light airplanes have a complete set of trim tabs that are adjustable from the cockpit. In airplanes where rudder, aileron, and elevator trim are available, a definite sequence of trim application should be used. Elevator/stabilator should be trimmed first to relieve the need for control pressure to maintain constant airspeed/pitch attitude. Attempts to trim the rudder at varying airspeed are impractical in propeller driven airplanes because of the change in the torque correcting offset of the vertical fin. Once a constant airspeed/pitch attitude has been established, the pilot should hold the wings level with aileron pressure while rudder pressure is trimmed out. Aileron trim should then be adjusted to relieve any lateral control yoke pressure.

A common trim control error is the tendency to overcontrol the airplane with trim adjustments. To avoid this the pilot must learn to establish and hold the airplane in the desired attitude using the primary flight controls. The proper attitude should be established with reference to the horizon and then verified by reference to performance indications on the flight instruments. The pilot should then apply trim in the above sequence to relieve whatever hand and foot pressure had been required. The pilot must avoid using the trim to establish or correct airplane attitude. The airplane attitude must be established and held first, then control pressures trimmed out so that the airplane will maintain the desired attitude in “hands off” flight. Attempting to “fly the airplane with the trim tabs” is a common fault in basic flying technique even among experienced pilots.

A properly trimmed airplane is an indication of good piloting skills. Any control pressures the pilot feels should be a result of deliberate pilot control input during a planned change in airplane attitude, not a result of pressures being applied by the airplane because the pilot is allowing it to assume control.

LEVEL TURNS

A turn is made by banking the wings in the direction of the desired turn. A specific angle of bank is selected by the pilot, control pressures applied to achieve the desired bank angle, and appropriate control pressures exerted to maintain the desired bank angle once it is established. [Figure 3-5]



Figure 3-5. Level turn to the left.

All four primary controls are used in close coordination when making turns. Their functions are as follows.

- The ailerons bank the wings and so determine the rate of turn at any given airspeed.
- The elevator moves the nose of the airplane up or down in relation to the pilot, and perpendicular to the wings. Doing that, it both sets the pitch attitude in the turn and “pulls” the nose of the airplane around the turn.
- The throttle provides thrust which may be used for airspeed to tighten the turn.
- The rudder offsets any yaw effects developed by the other controls. The rudder does not turn the airplane.

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

- Shallow turns are those in which the bank (less than approximately 20°) is so shallow that the inherent lateral stability of the airplane is acting to level the wings unless some aileron is applied to maintain the bank.
- Medium turns are those resulting from a degree of bank (approximately 20° to 45°) at which the airplane remains at a constant bank.

Steep turns are those resulting from a degree of bank (45° or more) at which the “overbanking tendency” of an airplane overcomes stability, and the bank increases unless aileron is applied to prevent it.

Changing the direction of the wing’s lift toward one side or the other causes the airplane to be pulled in that direction. [Figure 3-6] Applying coordinated aileron and rudder to bank the airplane in the direction of the desired turn does this.

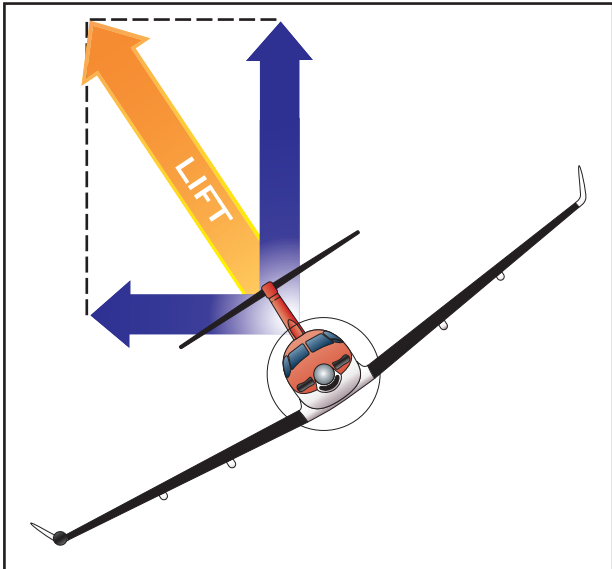


Figure 3-6. Change in lift causes airplane to turn.

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, the lift then becomes the resultant of two components. One, the vertical lift component, continues to act perpendicular to the Earth and opposes gravity. Second, the horizontal lift component (centripetal) acts parallel to the Earth’s surface and opposes inertia (apparent 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 actually turns the airplane—not the rudder. When applying aileron to bank the airplane, the lowered aileron (on the rising wing) produces a greater drag than the raised aileron (on the lowering wing). [Figure 3-7] This increased aileron yaws the airplane toward the rising wing, or opposite to the direction of turn. To counteract this adverse yawing moment, rudder pressure must be applied simultaneously with aileron in the desired direction of turn. This action is required to produce a coordinated turn.

After the bank has been established in a medium banked turn, all pressure applied to the aileron may be relaxed. The airplane will remain at the selected bank

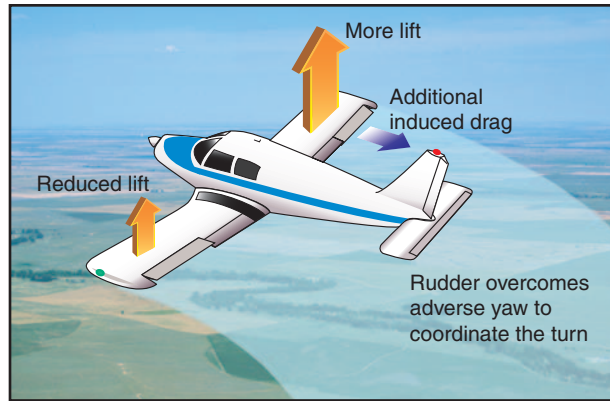


Figure 3-7. Forces during a turn.

with no further tendency to yaw since there is no longer a deflection of the ailerons. As a result, pressure may also be relaxed on the rudder pedals, and the rudder allowed to streamline itself with the direction of the slipstream. Rudder pressure maintained after the turn is established will cause the airplane to skid to the outside of the turn. If a definite effort is made to center the rudder rather than let it streamline itself to the turn, it is probable that some opposite rudder pressure will be exerted inadvertently. This will force the airplane to yaw opposite its turning path, causing the airplane to slip to the inside of the turn. The ball in the turn-and-slip indicator will be displaced off-center whenever the airplane is skidding or slipping sideways. [Figure 3-8] In proper coordinated flight, there is no skidding or slipping. An essential basic airmanship skill is the ability of the pilot to sense or “feel” any uncoordinated condition (slip or skid) without referring to instrument reference. During this stage of training, the flight instructor should stress the development of this ability and insist on its use to attain perfect coordination in all subsequent training.

In all constant altitude, constant airspeed turns, it is necessary to increase the angle of attack of the wing when rolling into the turn by applying up elevator. This is required because part of the vertical lift has been diverted to horizontal lift. Thus, the total lift must be increased to compensate for this loss.

To stop the turn, the wings are returned to level flight by the coordinated use of the ailerons and rudder applied in the opposite direction. 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 true airspeed increases as the angle of bank is increased. On the other hand, when a turn is made at a higher true 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

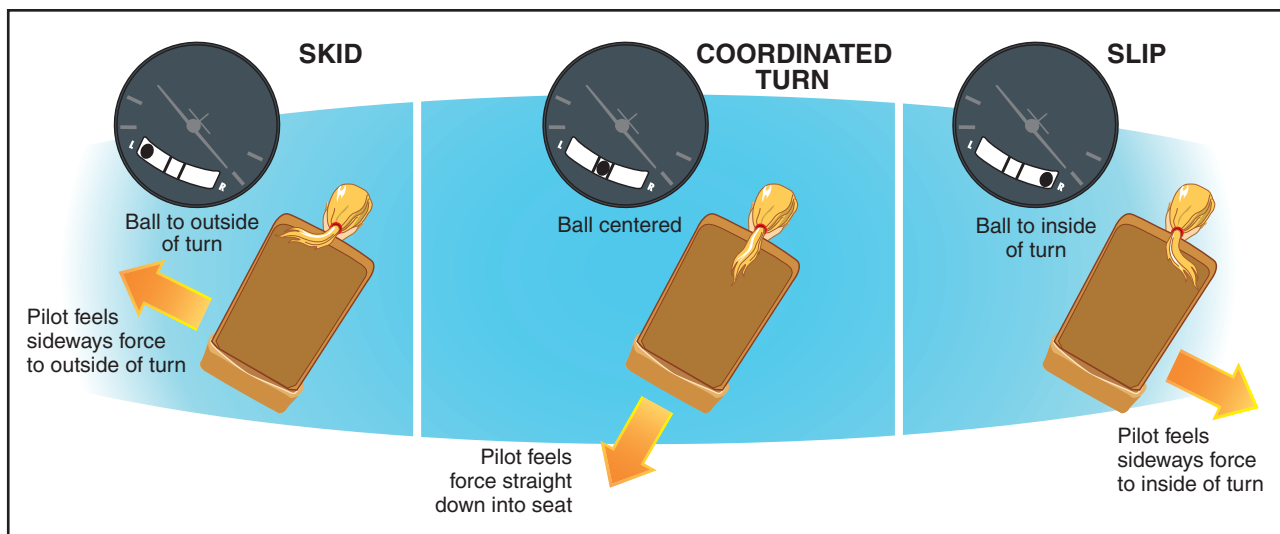


Figure 3-8. Indications of a slip and skid.

to become slower. [Figure 3-9 on next page] Therefore, at a given angle of bank, a higher true airspeed will make the radius of turn larger because the airplane will be turning at a slower rate.

When changing from a shallow bank to a medium bank, the airspeed of the wing on the outside of the turn increases in relation to the inside wing as the radius of turn decreases. The additional lift developed because of this increase in speed of the wing balances the inherent lateral stability of the airplane. At any given airspeed, aileron pressure is not required to maintain the bank. If the bank is allowed to increase from a medium to a steep bank, the radius of turn decreases further. The lift of the outside wing causes the bank to steepen and opposite aileron is necessary to keep the bank constant.

As the radius of the turn becomes smaller, a significant difference develops between the speed of the inside wing and the speed of the outside wing. The wing on the outside of the turn travels a longer circuit than the inside wing, yet both complete their respective circuits in the same length of time. Therefore, the outside wing travels faster 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 the ailerons. [Figure 3-10] Because the outboard wing is developing more lift, it also has more induced drag. This causes a slight slip during steep turns that must be corrected by use of the rudder.

Sometimes during early training in steep turns, the nose may be allowed to get excessively low resulting in a significant loss in altitude. To recover, the pilot should first reduce the angle of bank with coordinated use of the rudder and aileron, then raise the nose of the airplane to level flight with the elevator. If recovery from an excessively nose-low steep bank condition is

attempted by use of the elevator only, it will cause a steepening of the bank and could result in overstressing the airplane. Normally, small corrections for pitch during steep turns are accomplished with the elevator, and the bank is held constant with the ailerons.

To establish the desired angle of bank, the pilot should use outside visual reference points, as well as the bank indicator on the attitude indicator.

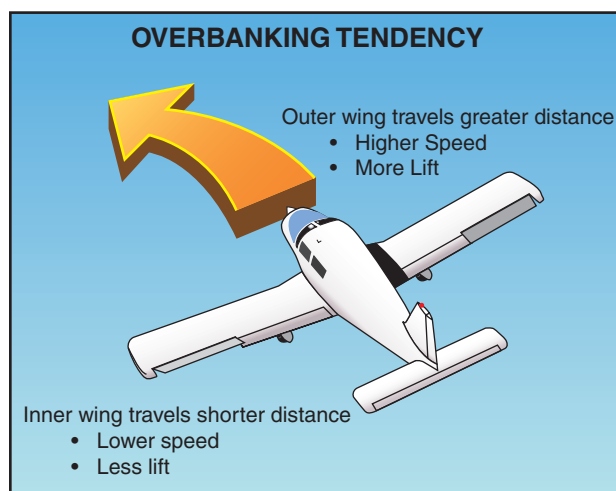


Figure 3-10. Overbanking tendency during a steep turn.

The best outside reference for establishing the degree of bank is the angle formed by the raised wing of low-wing airplanes (the lowered wing of high-wing airplanes) and the horizon, or the angle made by the top of the engine cowling and the horizon. [Figure 3-11 on page 3-11] Since on most light airplanes the engine cowling is fairly flat, its horizontal angle to the horizon will give some indication of the approximate degree of bank. Also, information obtained from the attitude indicator will show the angle of the wing in relation to the horizon. Information from the turn coordinator, however, will not.

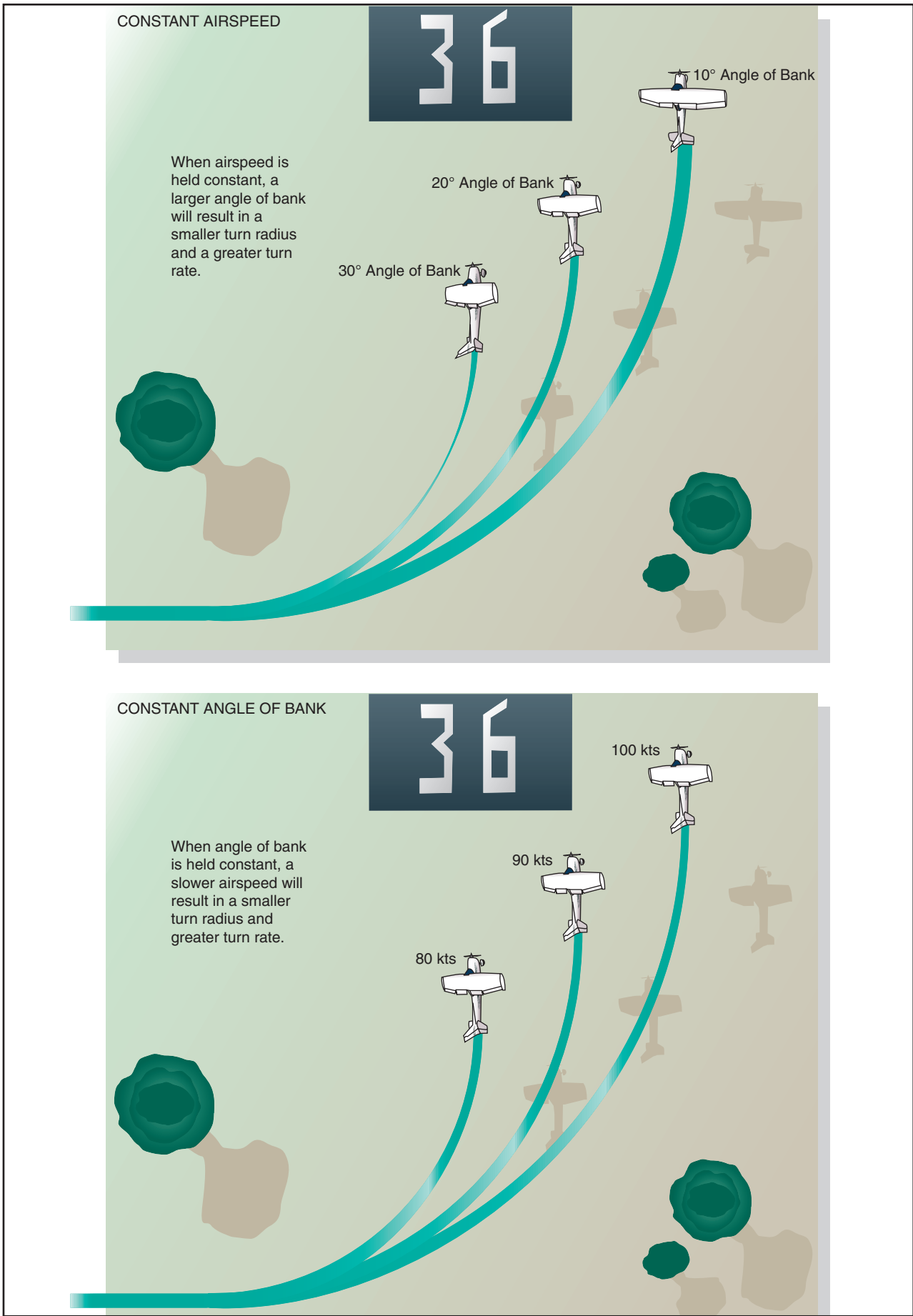
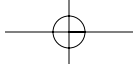


Figure 3-9. Angle of bank and airspeed regulate rate and radius of turn.

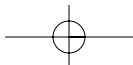




Figure 3-11. Visual reference for angle of bank.

The pilot's posture while seated in the airplane is very important, particularly during turns. It will affect the interpretation of outside visual references. At the beginning, the student may lean away from the turn in an attempt to remain upright in relation to the ground rather than ride with the airplane. This should be corrected immediately if the student is to properly learn to use visual references. [Figure 3-12]

Parallax error is common among students and experienced pilots. This error is a characteristic of airplanes that have side-by-side seats because the pilot is seated to one side of the longitudinal axis about which the airplane rolls. This makes the nose *appear* to rise when making a left turn and to descend when making right turns. [Figure 3-13]

Beginning students should not use large aileron and rudder applications because this produces a rapid roll rate and allows little time for corrections before the desired bank is reached. Slower (small control displacement) roll rates provide more time to make necessary pitch and bank corrections. As soon as the airplane rolls from the wings-level attitude, the nose should also start to move along the horizon, increasing its rate of travel proportionately as the bank is increased.

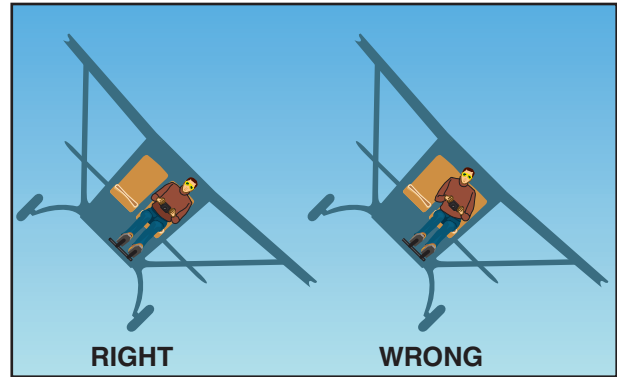


Figure 3-12. Right and wrong posture while seated in the airplane.

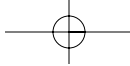
The following variations provide excellent guides.

- If the nose starts to move before the bank starts, 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 up elevator is being applied.

As the desired angle of bank is established, aileron and rudder pressures should be relaxed. This will stop the bank from increasing because the aileron and rudder control surfaces will be neutral in their streamlined position. The up-elevator pressure should not be relaxed, but should be held constant to maintain a constant altitude. Throughout the turn, the pilot should cross-check the airspeed indicator, and if the airspeed has decreased more than 5 knots, additional power should be used. The cross-check should also include outside references, altimeter, and vertical speed indicator (VSI), which can help determine whether or not the pitch attitude is correct. If gaining or losing altitude, the pitch attitude should be adjusted in relation to the horizon, and then the altimeter and VSI rechecked to determine if altitude is being maintained.



Figure 3-13. Parallax view.



During all turns, the ailerons, rudder, and elevator are used to correct minor variations in pitch and bank just as they are in straight-and-level flight.

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.

Since the airplane will continue turning as long as there is any bank, the rollout must be started before reaching the desired heading. The amount of lead required to roll out on the desired heading will depend on the degree of bank used in the turn. Normally, the lead is one-half the degrees of bank. For example, if the bank is 30°, lead the rollout by 15°. As the wings become level, the control pressures should be smoothly relaxed so that the controls are neutralized as the airplane returns to straight-and-level flight. As the rollout is being completed, attention should be given to outside visual references, as well as the attitude and heading indicators to determine that the wings are being leveled and the turn stopped.

Instruction in level turns should begin with medium turns, so that the student has an opportunity to grasp the fundamentals of turning flight without having to deal with overbanking tendency, or the inherent stability of the airplane attempting to level the wings. The instructor should not ask the student to roll the airplane from bank to bank, but to change its attitude from level to bank, bank to level, and so on with a slight pause at the termination of each phase. This pause allows the airplane to free itself from the effects of any misuse of the controls and assures a correct start for the next turn. During these exercises, the idea of control forces, rather than movement, should be emphasized by pointing out the resistance of the controls to varying forces applied to them. The beginning student should be encouraged to use the rudder freely. Skidding in this phase indicates positive control use, and may be easily corrected later. The use of too little rudder, or rudder use in the wrong direction at this stage of training, on the other hand, indicates a lack of proper conception of coordination.

In practicing turns, the action of the airplane's nose will show any error in coordination of the controls. Often, during the entry or recovery from a bank, the nose will describe a vertical arc above or below the horizon, and then remain in proper position after the bank is established. This is the result of lack of timing and coordination of forces on the elevator and rudder controls during the entry and recovery. It indicates that the student has a knowledge of correct turns, but that entry and recovery techniques are in error.

3-12

Because the elevator and ailerons are on one control, and pressures on both are executed simultaneously, the beginning pilot is often apt to continue pressure on one of these unintentionally when force on the other only is intended. This is particularly true in left-hand turns, because the position of the hands makes correct movements slightly awkward at first. This is sometimes responsible for the habit of climbing slightly in right-hand turns and diving slightly in left-hand turns. This results from many factors, including the unequal rudder pressures required to the right and to the left when turning, due to the torque effect.

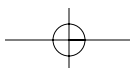
The tendency to climb in right-hand turns and descend in left-hand turns is also prevalent in airplanes having side-by-side cockpit seating. In this case, it is due to the pilot's being seated to one side of the longitudinal axis about which the airplane rolls. This makes the nose appear to rise during a correctly executed left turn and to descend during a correctly executed right turn. An attempt to keep the nose on the same apparent level will cause climbing in right turns and diving in left turns.

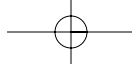
Excellent coordination and timing of all the controls in turning requires much practice. It is essential that this coordination be developed, because it is the very basis of this fundamental flight maneuver.

If the body is properly relaxed, it will act as a pendulum and may be swayed by any force acting on it. During a skid, it will be swayed away from the turn, and during a slip, toward the inside of the turn. The same effects will be noted in tendencies to slide on the seat. As the "feel" of flying develops, the properly directed student will become highly sensitive to this last tendency and will be able to detect the presence of, or even the approach of, a slip or skid long before any other indication is present.

Common errors in the performance of level turns are:

- Failure to adequately clear the area before beginning the turn.
- Attempting to execute the turn solely by instrument reference.
- Attempting to sit up straight, in relation to the ground, during a turn, rather than riding with the airplane.
- Insufficient feel for the airplane as evidenced by the inability to detect slips/skids without reference to flight instruments.
- Attempting to maintain a constant bank angle by referencing the "cant" of the airplane's nose.





- Fixating on the nose reference while excluding wingtip reference.
- “Ground shyness”—making “flat turns” (skidding) while operating at low altitudes in a conscious or subconscious effort to avoid banking close to the ground.
- Holding rudder in the turn.
- Gaining proficiency in turns in only one direction (usually the left).
- Failure to coordinate the use of throttle with other controls.
- Altitude gain/loss during the turn.

CLIMBS AND CLIMBING TURNS

When an airplane enters a climb, it changes its flightpath from level flight to an inclined plane or climb attitude. In a climb, weight no longer acts in a direction perpendicular to the flightpath. It acts in a rearward direction. This causes an increase in total drag requiring an increase in thrust (power) to balance the forces. An airplane can only sustain a climb angle when there is sufficient thrust to offset increased drag; therefore, climb is limited by the thrust available.

Like other maneuvers, climbs should be performed using outside visual references and flight instruments. It is important that the pilot know the engine power settings and pitch attitudes that will produce the following conditions of climb.

NORMAL CLIMB—Normal climb is performed at an airspeed recommended by the airplane manufacturer. Normal climb speed is generally somewhat higher than the airplane’s best rate of climb. The additional airspeed provides better engine cooling, easier control, and better visibility over the nose. Normal

climb is sometimes referred to as “cruise climb.” Complex or high performance airplanes may have a specified cruise climb in addition to normal climb.

BEST RATE OF CLIMB—Best rate of climb (V_Y) is performed at an airspeed where the most excess *power* is available over that required for level flight. This condition of climb will produce the most gain in altitude in the least amount of time (maximum rate of climb in feet per minute). The best rate of climb made at full allowable power is a maximum climb. It must be fully understood that attempts to obtain more climb performance than the airplane is capable of by increasing pitch attitude will result in a *decrease* in the rate of altitude gain.

BEST ANGLE OF CLIMB—Best angle of climb (V_X) is performed at an airspeed that will produce the most altitude gain in a given *distance*. Best angle-of-climb airspeed (V_X) is considerably lower than best rate of climb (V_Y), and is the airspeed where the most excess *thrust* is available over that required for level flight. The best angle of climb will result in a steeper climb *path*, although the airplane will take longer to reach the same altitude than it would at best rate of climb. The best angle of climb, therefore, is used in clearing obstacles after takeoff. [Figure 3-14]

It should be noted that, as altitude increases, the speed for best angle of climb increases, and the speed for best rate of climb decreases. The point at which these two speeds meet is the absolute ceiling of the airplane. [Figure 3-15 on next page]

A straight climb is entered by gently increasing pitch attitude to a predetermined level using back-elevator pressure, and simultaneously increasing engine power to the climb power setting. Due to an increase in downwash over the horizontal stabilizer as power is applied, the airplane’s nose will tend to immediately begin to rise of its own accord to an attitude higher than

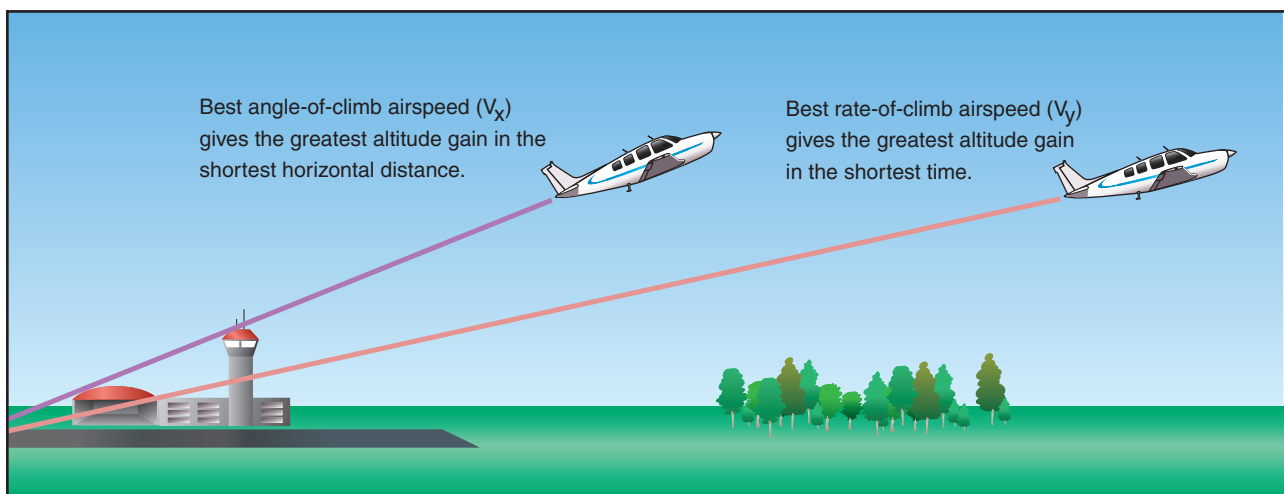
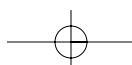


Figure 3-14. Best angle of climb vs. best rate of climb.



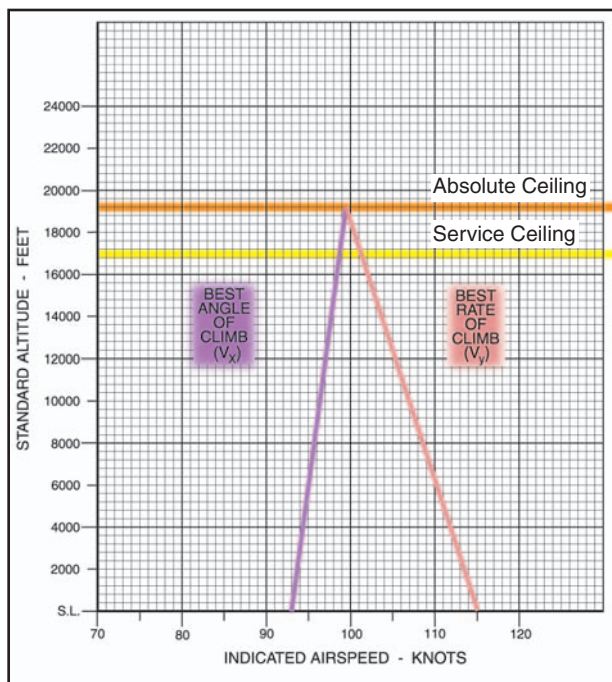


Figure 3-15. Absolute ceiling.

that at which it would stabilize. The pilot must be prepared for this.

As a climb is started, the airspeed will gradually diminish. This reduction in airspeed is gradual because of the initial momentum of the airplane. The thrust required to maintain straight-and-level flight at a given airspeed is not sufficient to maintain the same airspeed in a climb. Climbing flight requires more power than flying level because of the increased drag caused by gravity acting rearward. Therefore, power must be advanced to a higher power setting to offset the increased drag.

The propeller effects at climb power are a primary factor. This is because airspeed is significantly slower than at cruising speed, and the airplane's angle of attack is significantly greater. Under these conditions, torque and asymmetrical loading of the propeller will cause the airplane to roll and yaw to the left. To counteract this, the right rudder must be used.

During the early practice of climbs and climbing turns, this may make coordination of the controls seem awkward (left climbing turn holding right rudder), but after a little practice this correction for propeller effects will become instinctive.

Trim is also a very important consideration during a climb. After the climb has been established, the airplane should be trimmed to relieve all pressures from the flight controls. If changes are made in the pitch attitude, power, or airspeed, the airplane should be retrimmed in order to relieve control pressures.

When performing a climb, the power should be advanced to the climb power recommended by the manufacturer. If the airplane is equipped with a controllable-pitch propeller, it will have not only an engine tachometer, but also a manifold pressure gauge. Normally, the flaps and landing gear (if retractable) should be in the retracted position to reduce drag.

As the airplane gains altitude during a climb, the manifold pressure gauge (if equipped) will indicate a loss in manifold pressure (power). This is because the same volume of air going into the engine's induction system gradually decreases in density as altitude increases. When the volume of air in the manifold decreases, it causes a loss of power. This will occur at the rate of approximately 1-inch of manifold pressure for each 1,000-foot gain in altitude. During prolonged climbs, the throttle must be continually advanced, if constant power is to be maintained.

To enter the climb, simultaneously advance the throttle and apply back-elevator pressure to raise the nose of the airplane to the proper position in relation to the horizon. As power is increased, the airplane's nose will rise due to increased download on the stabilizer. This is caused by increased slipstream. As the pitch attitude increases and the airspeed decreases, progressively more right rudder must be applied to compensate for propeller effects and to hold a constant heading.

After the climb is established, back-elevator pressure must be maintained to keep the pitch attitude constant. As the airspeed decreases, the elevators will try to return to their neutral or streamlined position, and the airplane's nose will tend to lower. Nose-up elevator trim should be used to compensate for this so that the pitch attitude can be maintained without holding back-elevator pressure. Throughout the climb, since the power is fixed at the climb power setting, the airspeed is controlled by the use of elevator.

A cross-check of the airspeed indicator, attitude indicator, and the position of the airplane's nose in relation to the horizon will determine if the pitch attitude is correct. At the same time, a constant heading should be held with the wings level if a straight climb is being performed, or a constant angle of bank and rate of turn if a climbing turn is being performed. [Figure 3-16]

To return to straight-and-level flight from a climb, it is necessary to initiate the level-off at approximately 10 percent of the rate of climb. For example, if the airplane is climbing at 500 feet per minute (f.p.m.), leveling off should start 50 feet below the desired altitude. The nose must be lowered gradually because a loss of altitude will result if the pitch attitude is changed to the level flight position without allowing the airspeed to increase proportionately.



Figure 3-16. Climb indications.

After the airplane is established in level flight at a constant altitude, climb power should be retained temporarily so that the airplane will accelerate to the cruise airspeed more rapidly. When the speed reaches the desired cruise speed, the throttle setting and the propeller control (if equipped) should be set to the cruise power setting and the airplane trimmed. After allowing time for engine temperatures to stabilize, adjust the mixture control as required.

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 will climb at a slightly shallower climb angle because some of the lift is being used to turn the airplane.
- Attention should be diverted from fixation on the airplane's nose and divided equally among inside and outside references.

There are two ways to establish a climbing turn. Either establish a straight climb and then turn, or enter the climb and turn simultaneously. Climbing turns should be used when climbing to the local practice area. Climbing turns allow better visual scanning, and it is easier for other pilots to see a turning aircraft.

In any turn, the loss of vertical lift and increased induced drag, due to increased angle of attack,

becomes greater as the angle of bank is increased. So shallow turns should be used to maintain an efficient rate of climb.

All the factors that affect the airplane during level (constant altitude) turns will affect it during climbing turns or any other training maneuver. It will be noted that because of the low airspeed, aileron drag (adverse yaw) will have a more prominent effect than it did in straight-and-level flight and more rudder pressure will have to be blended with aileron pressure to keep the airplane in coordinated flight during changes in bank angle. Additional elevator back pressure and trim will also have to be used to compensate for centrifugal force, for the loss of vertical lift, and to keep pitch attitude constant.

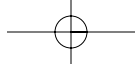
During climbing turns, as in any turn, the loss of vertical lift and induced drag due to increased angle of attack becomes greater as the angle of bank is increased, so shallow turns should be used to maintain an efficient rate of climb. If a medium or steep banked turn is used, climb performance will be degraded.

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

- Attempting to establish climb pitch attitude by referencing the airspeed indicator, resulting in "chasing" the airspeed.
- Applying elevator pressure too aggressively, resulting in an excessive climb angle.
- Applying elevator pressure too aggressively during level-off resulting in negative "G" forces.
- Inadequate or inappropriate rudder pressure during climbing turns.
- Allowing the airplane to yaw in straight climbs, usually due to inadequate right rudder pressure.
- Fixation on the nose during straight climbs, resulting in climbing with one wing low.
- Failure to initiate a climbing turn properly with use of rudder and elevators, resulting in little turn, but rather a climb with one wing low.
- Improper coordination resulting in a slip which counteracts the effect of the 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.

DESCENTS AND DESCENDING TURNS

When an airplane enters a descent, it changes its flight-path from level to an inclined plane. It is important that



the pilot know the power settings and pitch attitudes that will produce the following conditions of descent.

PARTIAL POWER DESCENT—The normal method of losing altitude is to descend with partial power. This is often termed “cruise” or “enroute” descent. The airspeed and power setting recommended by the airplane manufacturer for prolonged descent should be used. The target descent rate should be 400–500 f.p.m. The airspeed may vary from cruise airspeed to that used on the downwind leg of the landing pattern. But the wide range of possible airspeeds should not be interpreted to permit erratic pitch changes. The desired airspeed, pitch attitude, and power combination should be preselected and kept constant.

DESCENT AT MINIMUM SAFE AIRSPEED—A minimum safe airspeed descent is a nose-high, power assisted descent condition principally used for clearing obstacles during a landing approach to a short runway. The airspeed used for this descent condition is recommended by the airplane manufacturer and normally is 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.

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.

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.

Because the application of controls is somewhat different in glides than in power-on descents, gliding maneuvers require the perfection of a technique somewhat different from that required for ordinary power-on maneuvers. This control difference is caused primarily by two factors—the absence of the usual propeller slipstream, and the difference in the relative effectiveness of the various control surfaces at slow speeds.

The glide ratio of an airplane is the distance the airplane will, with power off, travel forward in relation to the altitude it loses. For instance, if an airplane travels 10,000 feet forward while descending 1,000 feet, its glide ratio is said to be 10 to 1.

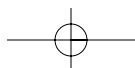
The glide ratio is affected by all four fundamental forces that act on an airplane (weight, lift, drag, and thrust). If all factors affecting the airplane are constant, the glide ratio will be constant. Although the effect of wind will not be covered in this section, it is a very prominent force acting on the gliding distance of the airplane in relationship to its movement over the ground. With a tailwind, the airplane will glide farther because of the higher groundspeed. Conversely, with a headwind the airplane will not glide as far because of the slower groundspeed.

Variations in weight do not affect the glide angle provided the pilot uses the correct airspeed. Since it is the lift over drag (L/D) ratio that determines the distance the airplane can glide, weight will not affect the distance. The glide ratio is based only on the relationship of the aerodynamic forces acting on the airplane. The only effect weight has is to vary the time the airplane will glide. The heavier the airplane the higher the airspeed must be 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 will arrive at the same touchdown point in a shorter time. Both airplanes will cover the same distance, only the lighter airplane will take a longer time.

Under various flight conditions, the drag factor may change through the operation of the landing gear and/or flaps. When the landing gear or the flaps are extended, drag increases and the airspeed will decrease unless the pitch attitude is lowered. As the pitch is lowered, the glidepath steepens and reduces the distance traveled. With the power off, a windmilling propeller also creates considerable drag, thereby retarding the airplane’s forward movement.

Although the propeller thrust of the airplane is normally dependent on the power output of the engine, the throttle is in the closed position during a glide so the thrust is constant. Since power is not used during a glide or power-off approach, the pitch attitude must be adjusted as necessary to maintain a constant airspeed.

The best speed for the glide is one at which the airplane will travel the greatest forward distance for a given loss of altitude in still air. This *best glide speed* corresponds to an angle of attack resulting in the least drag on the airplane and giving the best lift-to-drag ratio (L/D_{MAX}). [Figure 3-17]



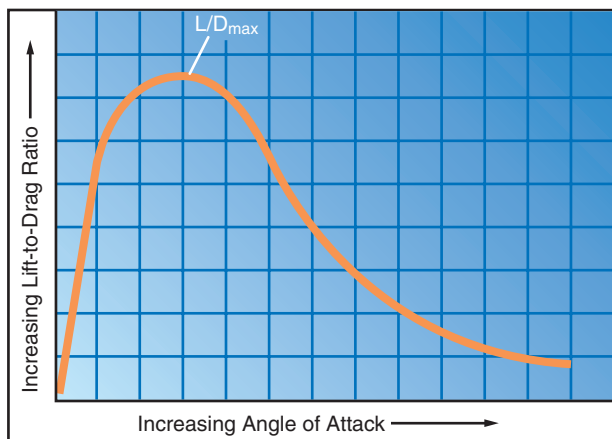


Figure 3-17. L/D_{MAX} .

Any change in the gliding airspeed will result in a proportionate change in glide ratio. Any speed, other than the best glide speed, results in more drag. Therefore, as the glide airspeed is reduced or increased from the optimum or best glide speed, the glide ratio is also changed. When descending at a speed below the best glide speed, induced drag increases. When descending at a speed above best glide speed, parasite drag increases. In either case, the rate of descent will increase. [Figure 3-18]

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. Attempts to stretch a glide will invariably result in an increase in the rate and angle of descent and may precipitate an inadvertent stall.

To enter a glide, the pilot should close the throttle and advance the propeller (if so equipped) to low pitch (high r.p.m.). A constant altitude should be held with back pressure on the elevator control until the airspeed decreases to the recommended glide speed. Due to a decrease in downwash over the horizontal stabilizer as power is reduced, the airplane’s nose will tend to immediately begin to lower of its own accord to an atti-

tude lower than that at which it would stabilize. The pilot must be prepared for this. To keep pitch attitude constant after a power change, the pilot must counteract the immediate trim change. If the pitch attitude is allowed to decrease during glide entry, excess speed will be carried into the glide and retard 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 in so-called clean airplanes as they are very slow to lose their speed and any slight deviation of the nose downwards results in an immediate increase in airspeed. Once the airspeed has dissipated to normal or best glide speed, the pitch attitude should be allowed to decrease to maintain that speed. This should be done with reference to the horizon. When the speed has stabilized, the airplane should be retrimmed for “hands off” flight.

When the approximate gliding pitch attitude is established, the airspeed indicator should be checked. If the airspeed is higher than the recommended speed, the pitch attitude is too low, and if the airspeed is less than recommended, the pitch attitude is too high; therefore, the pitch attitude should be readjusted accordingly referencing the horizon. After the adjustment has been made, the airplane should be retrimmed so that it will maintain this attitude without the need to hold pressure on the elevator control. *The principles of attitude flying require that the proper flight attitude be established using outside visual references first, then using the flight instruments as a secondary check.* It is a good practice to always retrim the airplane after each pitch adjustment.

A stabilized power-off descent at the best glide speed is often referred to as a *normal* glide. The flight instructor should demonstrate a normal glide, and direct the student pilot to memorize the airplane’s angle and speed by visually checking the airplane’s attitude with reference to the horizon, and noting the pitch of the sound made by the air passing over the structure, the pressure on the controls, and the feel of

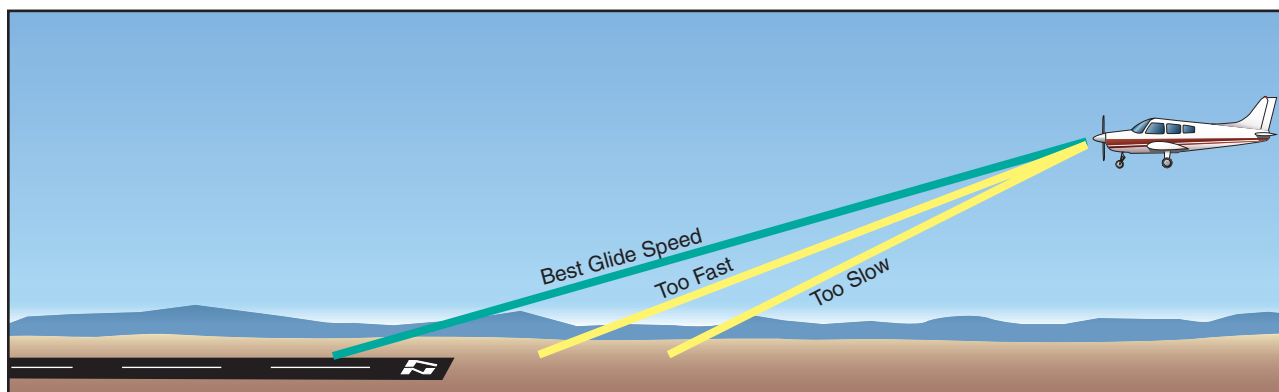
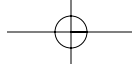


Figure 3-18. Best glide speed provides the greatest forward distance for a given loss of altitude.



the airplane. Due to lack of experience, the beginning student may be unable to recognize slight variations of speed and angle of bank immediately by vision or by the pressure required on the controls. Hearing will probably be the indicator that will be the most easily used at first. The instructor should, therefore, be certain that the student understands that an increase in the pitch of sound denotes increasing speed, while a decrease in pitch denotes less speed. When such an indication is received, the student should consciously apply the other two means of perception so as to establish the proper relationship. The student pilot must use all three elements consciously until they become habits, and must be alert when attention is diverted from the attitude of the airplane and be responsive to any warning given by a variation in the feel of the airplane or controls, or by a change in the pitch of the sound.

After a good comprehension of the normal glide is attained, the student pilot should be instructed in the differences in the results of normal and “abnormal” glides. Abnormal glides being those conducted at speeds other than the normal best glide speed. Pilots who do not acquire an understanding and appreciation of these differences will experience difficulties with accuracy landings, which are comparatively simple if the fundamentals of the glide are thoroughly understood.

Too fast a glide during the approach for landing invariably results in floating over the ground for varying distances, or even overshooting, while too slow a glide causes undershooting, flat approaches, and hard touchdowns. A pilot without the ability to recognize a normal glide will not be able to judge where the airplane will go, or can be made to go, in an emergency. Whereas, in a normal glide, the flight-path may be sighted to the spot on the ground on which the airplane will land. This cannot be done in any abnormal glide.

GLIDING TURNS—The action of the control system is somewhat different in a glide than with power, making gliding maneuvers stand in a class by themselves and require the perfection of a technique different from that required for ordinary power maneuvers. The control difference is caused mainly by two factors—the absence of the usual slipstream, and the difference or relative effectiveness of the various control surfaces at various speeds and particularly at reduced speed. The latter factor has its effect exaggerated by the first, and makes the task of coordination even more difficult for the inexperienced pilot. These principles should be thoroughly explained in order that the student may be alert to the necessary differences in coordination.

After a feel for the airplane and control touch have been developed, the necessary compensation will be

automatic; but while any mechanical tendency exists, the student will have difficulty executing gliding turns, particularly when making a practical application of them in attempting accuracy landings.

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

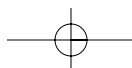
- Decrease in effective lift due to the direction of the lifting force being at an angle to the pull of gravity.
- The use of the rudder acting as it does in the entry to a power turn.
- The normal stability and inherent characteristics of the airplane to nose down with the power off.

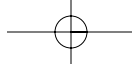
These three factors make it necessary to use more back pressure on the elevator than is required for a straight glide or a power turn and, therefore, have a greater effect on the relationship of control coordination.

When recovery is being made from a gliding turn, the force on the elevator control which was applied during the turn must be decreased or the nose will come up too high and considerable speed will be lost. This error will require considerable attention and conscious control adjustment before the normal glide can again be resumed.

In order to maintain the most efficient or normal glide in a turn, more altitude must be sacrificed than in a straight glide since this is the only way speed can be maintained without power. Turning in a glide decreases the performance of the airplane to an even greater extent than a normal turn with power.

Still another factor is the difference in rudder action in turns with and without power. In power turns it is required that the desired recovery point be anticipated in the use of controls and that considerably more pressure than usual be exerted on the rudder. In the recovery from a gliding turn, the same rudder action takes place but without as much pressure being necessary. The actual displacement of the rudder is approximately the same, but it seems to be less in a glide because the resistance to pressure is so much less due to the absence of the propeller slipstream. This often results in a much greater application of rudder through a greater range than is realized, resulting in an abrupt stoppage of the turn when the rudder is applied for recovery. This factor is particularly important during landing practice since the student almost invariably recovers from the last turn too soon and may enter a cross-control condition trying to correct the landing with the rudder alone. This results in landing from a skid that is too easily mistaken for drift.





There is another danger in excessive rudder use during gliding turns. As the airplane skids, the bank will increase. This often alarms the beginning pilot when it occurs close to the ground, and the pilot may respond by applying aileron pressure toward the outside of the turn to stop the bank. At the same time, the rudder forces the nose down and the pilot may apply back-elevator pressure to hold it up. If allowed to progress, this situation may result in a fully developed cross-control condition. A stall in this situation will almost certainly result in a spin.

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 the pilot's control technique. With too little lead, there will be a tendency to descend below the selected altitude. For example, assuming a 500-foot per minute rate of descent, the altitude must be led by 100 – 150 feet to level off at an airspeed higher than the glide speed. At the lead point, power should be increased to the appropriate level flight cruise setting so the desired airspeed will be attained at the desired altitude. The nose tends to rise as both airspeed and downwash on the tail section increase. The pilot must be prepared for this and smoothly control the pitch attitude to attain level flight attitude so that the level-off is completed at the desired altitude.

Particular attention should be paid to the action of the airplane's nose when recovering (and entering) gliding turns. The nose must not be allowed to describe an arc with relation to the horizon, and particularly it must not be allowed to come up during recovery from turns, which require a constant variation of the relative pressures on the different controls.

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

- Failure to adequately clear the area.
- Inadequate back-elevator control during glide entry resulting in too steep a 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 action as opposed 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 glides.
- “Ground shyness”—resulting in cross-controlling during gliding turns near the ground.
- Failure to maintain constant bank angle during gliding turns.

PITCH AND POWER

No discussion of climbs and descents would be complete without touching on the question of what controls altitude and what controls airspeed. The pilot must understand the effects of both power and elevator control, working together, during different conditions of flight. The closest one can come to a formula for determining airspeed/altitude control that is valid under all circumstances is a basic principle of attitude flying which states:

“At any pitch attitude, the amount of power used will determine whether the airplane will climb, descend, or remain level at that attitude.”

Through a wide range of nose-low attitudes, a descent is the only possible condition of flight. The addition of power at these attitudes will only result in a greater rate of descent at a faster airspeed.

Through a range of attitudes from very slightly nose-low to about 30° nose-up, a typical light airplane can be made to climb, descend, or maintain altitude depending on the power used. In about the lower third of this range, the airplane will descend at idle power without stalling. As pitch attitude is increased, however, engine power will be required to prevent a stall. Even more power will be required to maintain altitude, and even more for a climb. At a pitch attitude approaching 30° nose-up, all available power will provide only enough thrust to maintain altitude. A slight increase in the steepness of climb or a slight decrease in power will produce a descent. From that point, the least inducement will result in a stall.

