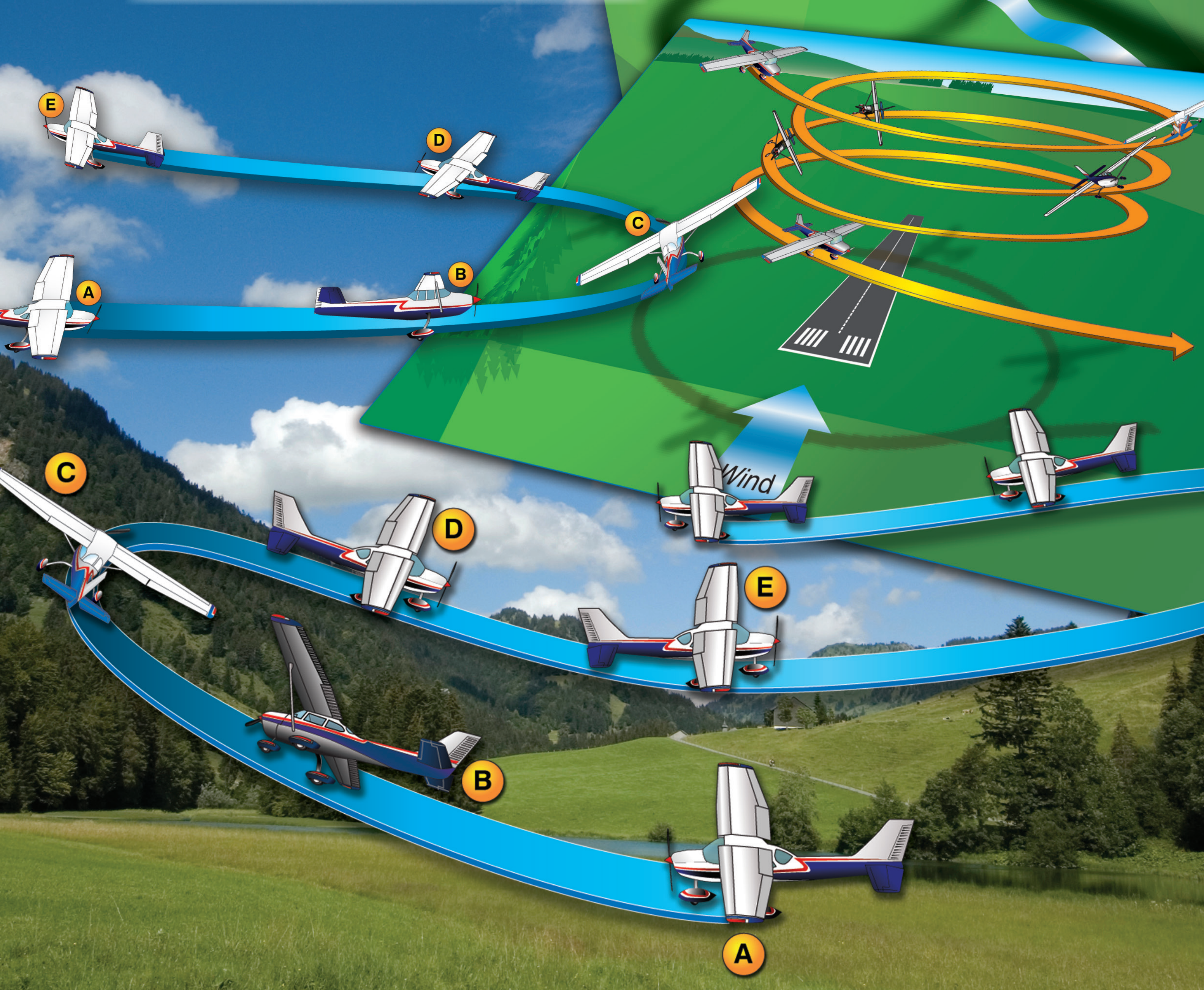
Chapter 9

Performance Maneuvers

Introduction

Flight maneuvers that are initially taught to pilots are designed to be basic and relatively simple: straight-and-level, turns, climbs and descents. However, as a pilot continues through their flight training, additional maneuvers are needed to develop beyond the fundamentals. Performance maneuvers are intended to enhance a pilot's proficiency in flight control application, maneuver planning, situational awareness, and division of attention. To further that intent, performance maneuvers are generally designed so that the application of flight control pressures, attitudes, airspeeds, and orientations are constantly changing throughout the maneuver.



Performance maneuvers also allow for an effective assessment of a pilot's ability to apply the fundamentals; weakness in executing performance maneuvers is likely due to a pilot's lack of understanding or a deficiency of fundamental skills. It is advisable that performance maneuver training should not take place until sufficient competency in the fundamentals is consistently demonstrated by the pilot. Further, initial training for performance maneuvers should always begin with a detailed ground lesson for each maneuver, so that the technicalities are understood prior to flight. In addition, performance maneuver training should be segmented into comprehensible building blocks of instruction so as to allow the pilot an appropriate level of repetition to develop the required skills.

Performance maneuvers, once grasped by the pilot, are very satisfying and rewarding. As the pilot develops skills in executing performance maneuvers, they may likely see an increased smoothness in their flight control application and a higher ability to sense the airplane's attitude and orientation without significant conscious effort.

Steep Turns

Steep turns consist of single to multiple 360° to 720° turns, in either or both directions, using a bank angle between 45° to 60°. The objective of the steep turn is to develop a pilot's skill in flight control smoothness and coordination, an awareness of the airplane's orientation to outside references, division of attention between flight control application, and the constant need to scan for hazards. *[Figure 9-1]*

When steep turns are first demonstrated, the pilot will be in an unfamiliar environment when compared to what was previously experienced in shallow bank angled turns; however, the fundamental concepts of turns remain the same in the execution of steep turns. When performing steep turns, pilots will be exposed to higher load factors, the airplane's inherent overbanking tendency, the loss of vertical component of lift when the wings are steeply banked, the need for substantial pitch control pressures, and the need for additional power to maintain altitude and airspeed during the turn.

As discussed in previous chapters, when an airplane is banked, the total lift is comprised of a vertical component of lift and a horizontal component of lift. In order to not lose altitude, the pilot must increase the wing's angle of attack (AOA) to ensure that the vertical component of lift is sufficient to maintain altitude. In a steep turn, the pilot will need to increase pitch with elevator back pressures that are greater than what has been previously utilized. Total lift must increase substantially to balance the load factor or G-force (G). The load factor is the vector resultant of gravity and centrifugal force. For example, in a level altitude, 45° banked turn, the resulting load factor is 1.4; in a level altitude, 60° banked turn, the resulting load factor is 2.0. To put this in perspective, with a load factor of 2.0, the effective weight of the aircraft will double. Pilots

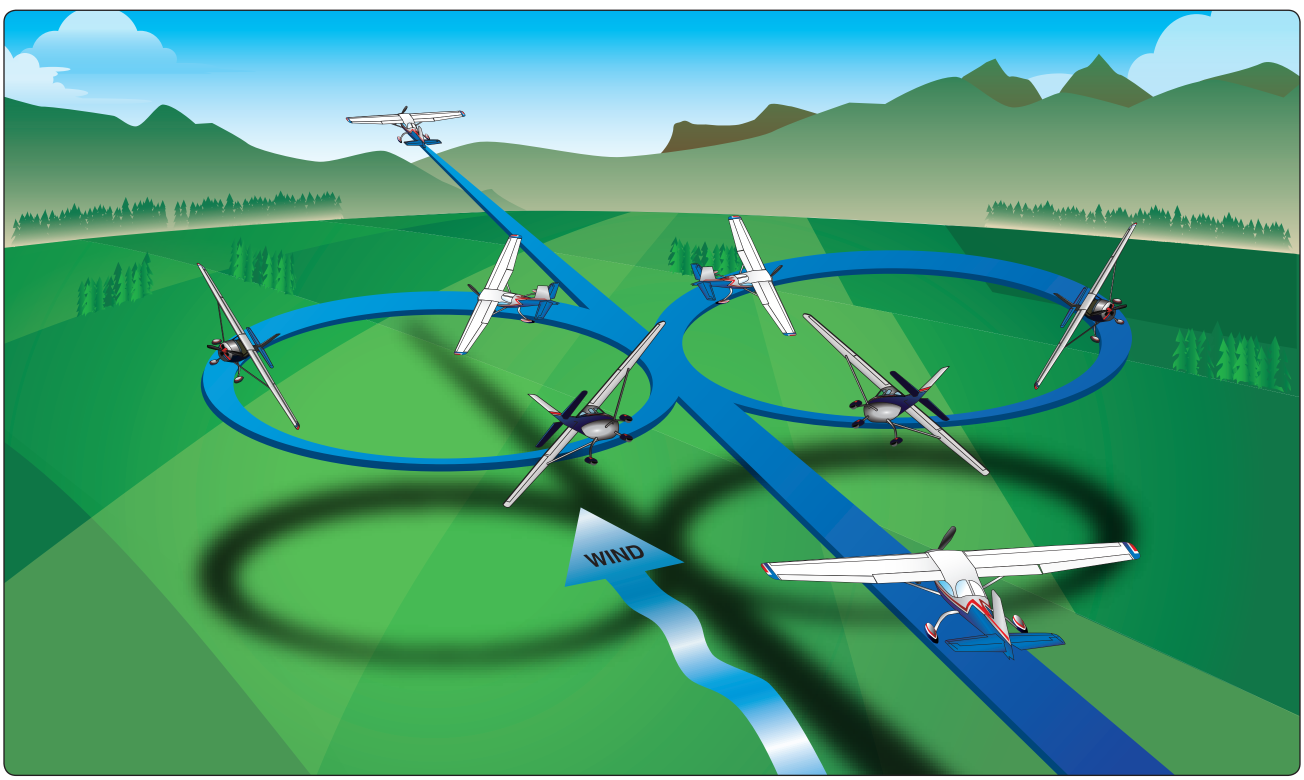


Figure 9-1. *Steep turns.*

should realize load factors increase dramatically beyond 60°. Most general aviation airplanes are designed for a load limit of 3.8Gs. Regardless of the airspeed or what airplane is involved, for a given bank angle in a level altitude turn, the same load factor will always be produced. A light, general aviation airplane in a level altitude, 45° angle of bank turn will experience a load factor of 1.4 just as a large commercial airliner will in the same level altitude, 45° angle of bank turn.

Because of the higher load factors, steep turns should be performed at an airspeed that does not exceed the airplane's design maneuvering speed (V_A) or the manufacturer's recommended speed. Maximum turning performance is accomplished when an airplane has both a fast rate of turn and minimum radius of turn, which is effected by both airspeed and angle of bank. Each airplane's turning performance is limited by structural and aerodynamic design, as well as available power. The airplane's limiting load factor determines the maximum bank angle that can be maintained in level flight without exceeding the airplane's structural limitations or stalling. As the load factor increases, so does the stalling speed. For example, if an airplane stalls in level flight at 50 knots, it will stall at 60 knots in a level altitude, 45° banked turn and at 70 knots in a level altitude, 60° banked turn. Stalling speed increases at the square root of the load factor. As the bank angle increases in level flight, the margin between stalling speed and maneuvering speed decreases—an important concept for a pilot to remain cognizant.

In addition to the increased load factors, the airplane will exhibit what is called "overbanking tendency." Recall from a previous chapter on the discussion of overbanking tendency. In most flight maneuvers, bank angles are shallow enough that the airplane exhibits positive or neutral stability about the longitudinal axis; however, as bank angles steepen, the airplane will exhibit the behavior to continue rolling in the direction of the bank unless deliberate and opposite aileron pressure is held against the bank. Also, pilots should be mindful of the various left turning tendencies, such as P-factor, which requires effective rudder aileron coordination.

Before starting any practice maneuver, the pilot must ensure that the area is clear of air traffic and other hazards. Further, distant references such as a mountain peak or road should be chosen to allow the pilot to assess when to begin rollout from the turn. After establishing the manufacturer's recommended entry speed or the design maneuvering speed, the airplane should be smoothly rolled into the desired bank angle somewhere between 45° to 60°. As the bank angle is being established, generally prior to 30° of bank, elevator back pressure should be smoothly applied to increase the AOA. After the selected bank angle has been reached, the pilot will find that considerable force is required on the elevator control to hold the airplane in level flight—to maintain altitude. Pilots should keep in mind that as the AOA increases, so does drag. Consequently, power must be added to maintain altitude and airspeed.

Steep turns can be conducted more easily by the use of elevator trim and power as the maneuver is entered. In many light general aviation airplanes, as the bank angle transitions from medium to steep, increasing elevator up trim and adding a small increase in engine power minimizes control pressure requirements. Pilots must not forget to remove both the trim and power inputs as the maneuver is completed.

To maintain bank angle, altitude, as well as orientation, requires an awareness of the relative position of the horizon to the nose and the wings. The pilot who references the aircraft's attitude by observing only the nose will have difficulty maintaining altitude. A pilot who observes both the nose and the wings relative to the horizon is likely able to maintain altitude within performance standards. Altitude deviations are primary errors exhibited in the execution of steep turns. If the altitude does increase or decrease, changing elevator back pressure could be used to alter the altitude; however, a more effective method is a slight increase or decrease in bank angle to control small altitude deviations. If altitude is decreasing, reducing the bank angle a few degrees helps recover or stop the altitude loss trend; also, if altitude is increasing, increasing the bank angle a few degrees helps recover or stop the altitude increase trend—all bank angle changes should be accomplished with coordinated use of aileron and rudder.

The rollout from the steep turn should be timed so that the wings reach level flight when the airplane is on heading from which the maneuver was started. A good rule of thumb is to begin the rollout at ½ the number of degrees of bank prior to reaching the terminating heading. For example, if a right steep turn was begun on a heading of 270° and if the bank angle is 60°, the pilot should begin the rollout 30° prior or at a heading of 240°. While the rollout is being made, elevator back pressure, trim, and power should be gradually reduced, as necessary, to maintain the altitude and airspeed.

Common errors when performing steep turns are:

- Not clearing the area
- Inadequate pitch control on entry or rollout
- Gaining altitude or losing altitude
- Failure to maintain constant bank angle
- Poor flight control coordination
- Ineffective use of trim

- Ineffective use of power
- Inadequate airspeed control
- Becoming disoriented
- Performing by reference to the flight instrument rather than visual references
- Failure to scan for other traffic during the maneuver
- Attempts to start recovery prematurely
- Failure to stop the turn on designated heading

Steep Spiral

The objective of the steep spiral is to provide a flight maneuver for rapidly dissipating substantial amounts of altitude while remaining over a selected spot. This maneuver is especially effective for emergency descents or landings. A steep spiral is a gliding turn where the pilot maintains a constant radius around a surface-based reference point while rapidly descending—similar to the turns around a point maneuver. Sufficient altitude must be gained prior to practicing the maneuver so that at least three 360° turns are completed. *[Figure 9-2]* The maneuver should not be allowed to continue below 1,500 feet above ground level (AGL) unless an actual emergency exists.

The steep spiral is initiated by properly clearing the airspace for air traffic and hazards. In general, the throttle is closed to idle, carburetor heat is applied if equipped, and gliding speed is established. Once the proper airspeed is attained, the pitch should be lowered and the airplane rolled to the desired bank angle as the reference point is reached. The steepest bank should not exceed 60°. The gliding spiral should be a turn of constant radius while maintaining the airplane's position to the reference. This can only be accomplished by proper correction for wind drift by steepening the bank on downwind headings and shallowing the bank on upwind headings, just as in the maneuver, turns around a point. During the steep spiral, the pilot must continually correct for any changes in wind direction and velocity to maintain a constant radius.

Operating the engine at idle speed for any prolonged period during the glide may result in excessive engine cooling, spark plug fouling, or carburetor ice. To assist in avoiding these issues, the throttle should be periodically advanced to normal cruise power and sustained for a few seconds. If equipped, monitoring cylinder head temperatures provides a pilot with additional information on engine cooling. When advancing the throttle, the pitch attitude must be adjusted to maintain a constant airspeed and, preferably, this should be done when headed into the wind.

Maintaining a constant airspeed throughout the maneuver is an important skill for a pilot to develop. This is necessary because the airspeed tends to fluctuate as the bank angle is changed throughout the maneuver. The pilot should anticipate pitch corrections as the bank angle is varied throughout the

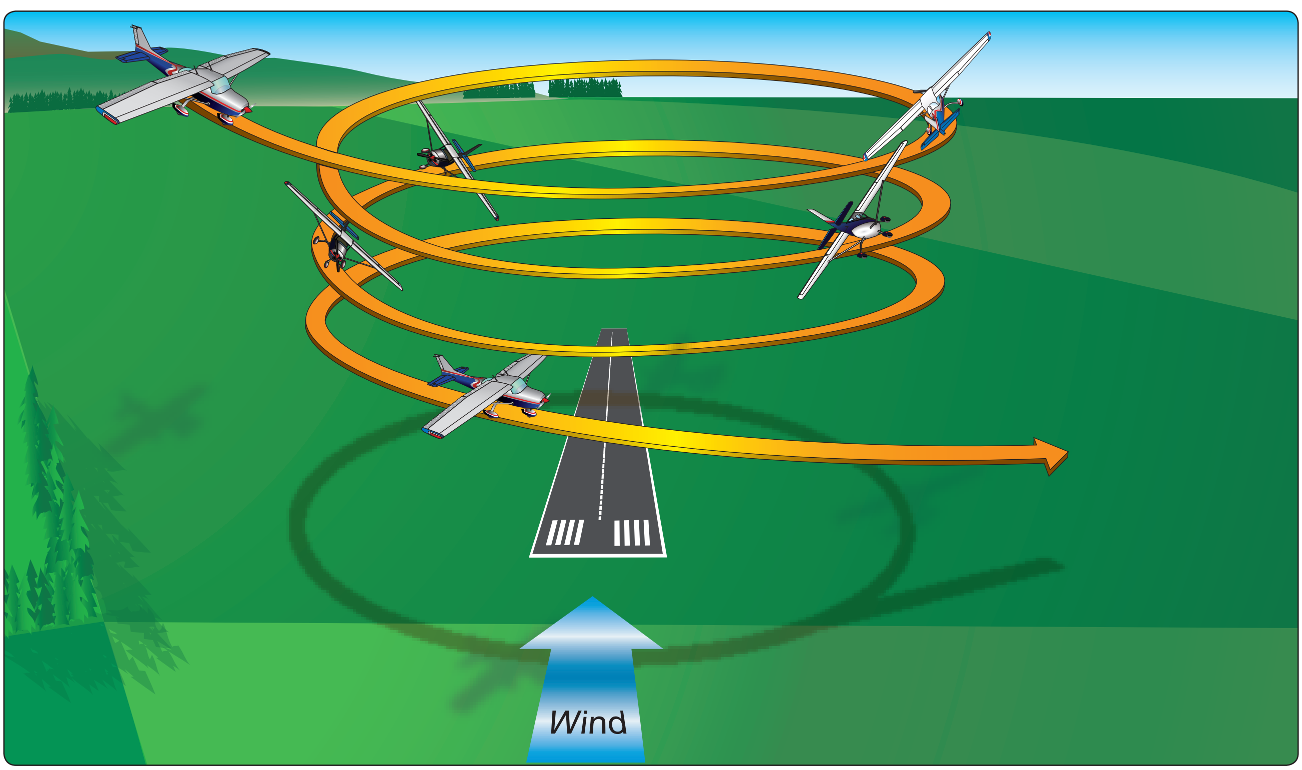


Figure 9-2. *Steep spiral.*

maneuver. During practice of the maneuver, the pilot should execute three turns and roll out toward a definite object or on a specific heading. During rollout, the smooth and accurate application of the flight controls allow the airplane to recover to a wing's level glide with no change in airspeed. Recovering to normal cruise flight would proceed after the establishment of a wing's level glide.

Common errors when performing steep spirals are:

- Not clearing the area
- Inadequate pitch control on entry or rollout
- Gaining altitude
- Not correcting the bank angle to compensate for wind
- Poor flight control coordination
- Ineffective use of trim
- Inadequate airspeed control
- Becoming disoriented
- Performing by reference to the flight instrument rather than visual references
- Not scanning for other traffic during the maneuver
- Not completing the turn on designated heading or reference

Chandelle

A chandelle is a maximum performance, 180° climbing turn that begins from approximately straight-and-level flight and concludes with the airplane in a wings-level, nose-high attitude just above stall speed. *[Figure 9-3]* The goal is to gain the most altitude possible for a given bank angle and power setting; however, the standard used to judge the maneuver is not the amount of altitude gained, but by the pilot's proficiency as it pertains to maximizing climb performance for the power and bank selected, as well as the skill demonstrated.

A chandelle is best described in two specific phases: the first 90° of turn and the second 90° of turn. The first 90° of turn is described as constant bank and changing pitch; and the second 90° as constant pitch and changing bank. During the first 90°, the pilot will set the bank angle, increase power and pitch at a rate so that maximum pitch-up is set at the completion of the first 90°. If the pitch is not correct, the airplane's airspeed is either above stall speed or the airplane may aerodynamically stall prior to the completion of the maneuver. Starting at the 90° point, the pilot begins a slow and coordinated constant rate rollout so as to have the wings level when the airplane is at the 180° point while maintaining the constant pitch attitude set in the first 90°. If the rate of rollout is too rapid or sluggish, the airplane either does not

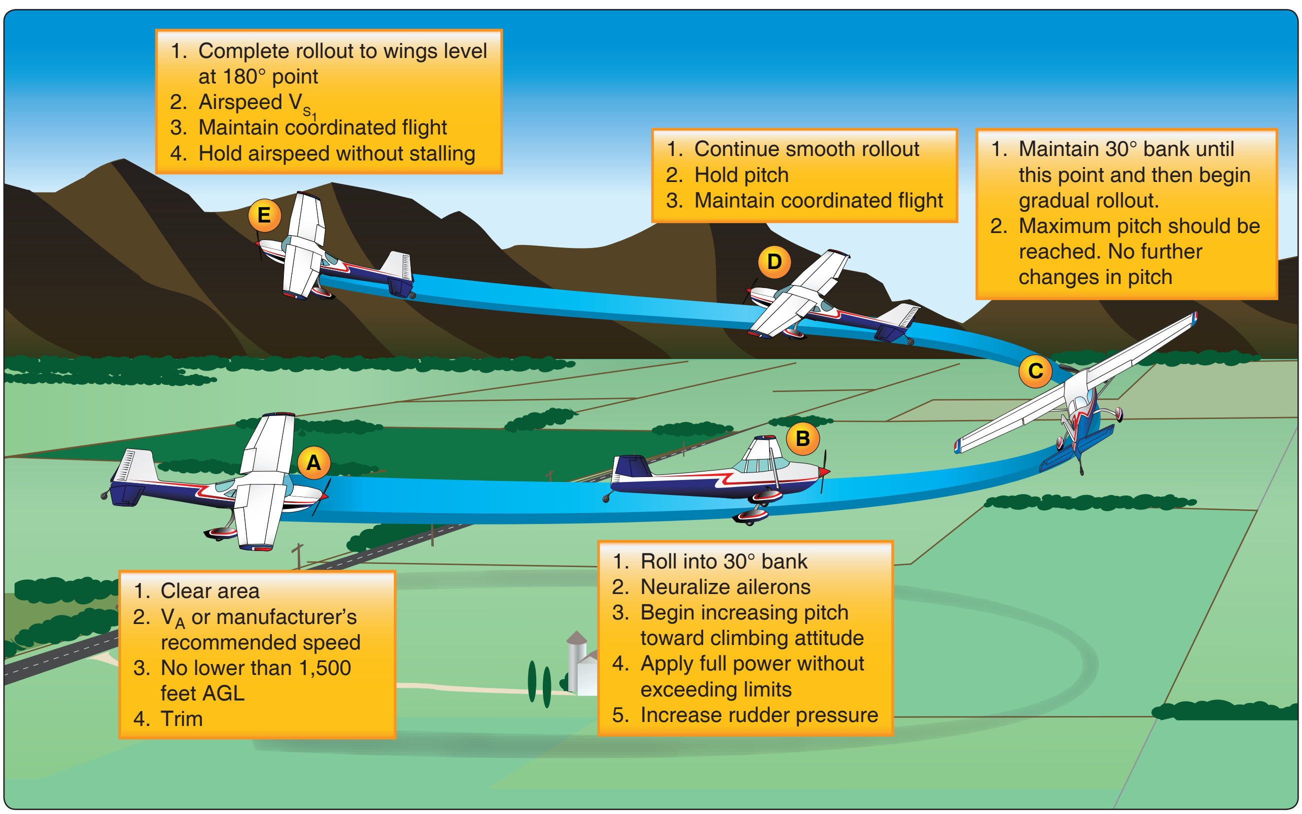


Figure 9-3. *Chandelle.*

complete or exceeds the 180° turn as the wings come level to the horizon.

Prior to starting the chandelle, the flaps and landing gear (if retractable) should be in the UP position. The chandelle is initiated by properly clearing the airspace for air traffic and hazards. The maneuver should be entered from straight-and-level flight or a shallow dive at an airspeed recommended by the manufacturer—in most cases this is the airplane's design maneuvering speed (V_A). *[Figure 9-3A]* After the appropriate entry airspeed has been established, the chandelle is started by smoothly entering a coordinated turn to the desired angle of bank; once the bank angle is established, which is generally 30°, a climbing turn should be started by smoothly applying elevator back pressure at a constant rate while simultaneously increasing engine power to the recommended setting. In airplanes with a fixed-pitch propeller, the throttle should be set so as to not exceed rotations per minute (rpm) limitations; in airplanes with constant-speed propellers, power may be set at the normal cruise or climb setting as appropriate. *[Figure 9-3B]*

Since the airspeed is constantly decreasing throughout the chandelle, the effects of left turning tendencies, such as P-factor, becomes more apparent. As airspeed decreases, right-rudder pressure is progressively increased to ensure that the airplane remains in coordinated flight. The pilot should maintain coordinated flight by sensing slipping or skidding pressures applied to the controls and by quick glances to the ball in the turn-and-slip or turn coordinator.

At the 90° point, the pilot should begin to smoothly roll out of the bank at a constant rate while maintaining the pitch attitude set in the first 90°. While the angle of bank is fixed during the first 90°, recall that as airspeed decreases, the overbanking tendency increases. *[Figure 9-3C]* As a result, proper use of the ailerons allows the bank to remain at a fixed angle until rollout is begun at the start of the final 90°. As the rollout continues, the vertical component of lift increases; therefore, a slight release of elevator back pressure is required to keep the pitch attitude from increasing.

When the airspeed is slowest, near the completion of the chandelle, right rudder pressure is significant, especially when rolling out from a left chandelle due to left adverse yaw and left turning tendencies, such as P-factor. *[Figure 9-3D]* When rolling out from a right chandelle, the yawing moment is to the right, which partially cancels some of the left turning tendency's effect. Depending on the airplane, either very little left rudder or a reduction in right rudder pressure is required during the rollout from a right chandelle. At the completion of 180° of turn, the wings should be leveled to the horizon, the airspeed should be just above stall speed, and the airplane's pitch high attitude should be held momentarily. *[Figure 9-3E]* Once demonstrated that the airplane is in controlled flight, the pitch attitude may be reduced and the airplane returned to straight-and-level cruise flight.

Common errors when performing chandelles are:

- Not clearing the area
- Initial bank is too shallow resulting in a stall
- Initial bank is too steep resulting in failure to gain maximum performance
- Allowing the bank angle to increase after initial establishment
- Not starting the recovery at the 90° point in the turn
- Allowing the pitch attitude to increase as the bank is rolled out during the second 90° of turn
- Leveling the wings prior to the 180° point being reached
- Pitch attitude is low on recovery resulting in airspeed well above stall speed
- Application of flight control pressures is not smooth
- Poor flight control coordination
- Stalling at any point during the maneuver
- Execution of a steep turn instead of a climbing maneuver
- Not scanning for other traffic during the maneuver
- Performing by reference to the flight instrument rather than visual references

Lazy Eight

The lazy eight is a maneuver that is designed to develop the proper coordination of the flight controls across a wide range of airspeeds and attitudes. It is the only standard flight training maneuver that, at no time, flight control pressures are constant. In an attempt to simplify the discussion about this maneuver, the lazy eight can be loosely described by the ground reference maneuver, S-turns across the road. Recall that S-turns across the road are made of opposing 180° turns. For example, first a 180° turn to the right, followed immediately by a 180° turn to the left. The lazy eight adds both a climb and descent to each 180° segment. The first 90° is a climb; the second 90° is a descent. *[Figure 9-4]*

To aid in the performance of the lazy eight's symmetrical climbing/descending turns, prominent reference points must be selected on the natural horizon. The reference points selected should be at 45°, 90°, and 135° from the direction in which the maneuver is started for each 180° turn. With the general concept of climbing and descending turns grasped, specifics of the lazy eight can then be discussed.

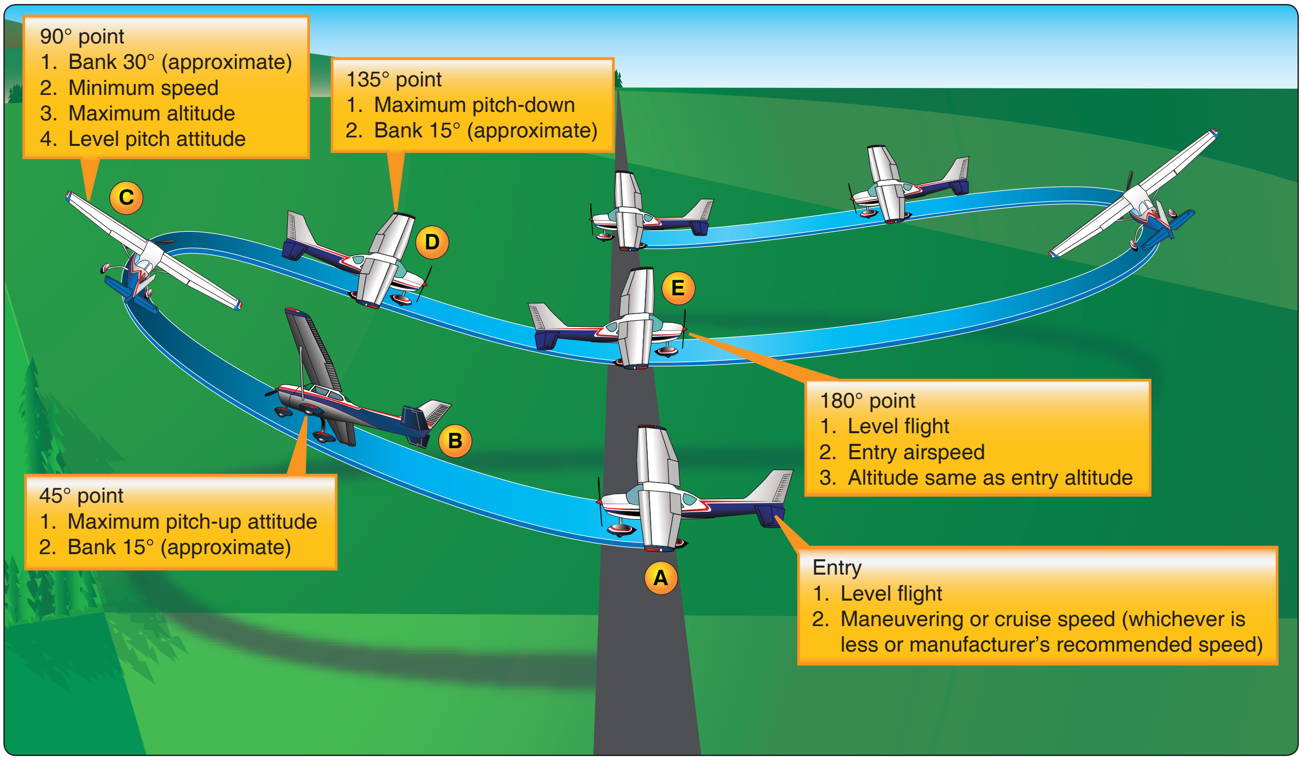


Figure 9-4. *Lazy eight.*

Shown in *Figure 9-4A*, from level flight a gradual climbing turn is begun in the direction of the 45° reference point; the climbing turn should be planned and controlled so that the maximum pitch-up attitude is reached at the 45° point with an approximate bank angle of 15°. *[Figure 9-4B]* As the pitch attitude is raised, the airspeed decreases, which causes the rate of turn to increase. As such, the lazy eight must begin with a slow rate of roll as the combination of increasing pitch and increasing bank may cause the rate of turn to be so rapid that the 45° reference point will be reached before the highest pitch attitude is attained. At the 45° reference point, the pitch attitude should be at the maximum pitch-up selected for the maneuver while the bank angle is slowly increasing. Beyond the 45° reference point, the pitch-up attitude should begin to decrease slowly toward the horizon until the 90° reference point is reached where the pitch attitude should be momentarily level.

The lazy eight requires substantial skill in coordinating the aileron and rudder; therefore, some discussion about coordination is warranted. As pilots understand, the purpose of the rudder is to maintain coordination; slipping or skidding is to be avoided. Pilots should remember that since the airspeed is still decreasing as the airplane is climbing; additional right rudder pressure must be applied to counteract left turning tendencies, such as P-factor. As the airspeed decreases, right rudder pressure must be gradually applied to counteract yaw at the apex of the lazy eight in both the right and left turns; however, additional right rudder pressure is required when turning or rolling out to the right than left because left adverse yaw augments with the left yawing P-factor in an attempt to yaw the nose to the left. Correction is needed to prevent these additive left yawing moments from decreasing a right turn's rate. In contrast, in left climbing turns or rolling to the left, the left yawing P-factor tends to cancel the effects of adverse yaw to the right; consequently, less right rudder pressure is required. These concepts can be difficult to remember; however, to simplify, rolling right at low airspeeds and high-power settings requires substantial right rudder pressures.

At the lazy eight's 90° reference point, the bank angle should also have reached its maximum angle of approximately 30°. *[Figure 9-4C]* The airspeed should be at its minimum, just about 5 to 10 knots above stall speed, with the airplane's pitch attitude passing through level flight. Coordinated flight at this point requires that, in some flight conditions, a slight amount of opposite aileron pressure may be required to prevent the wings from overbanking while maintaining rudder pressure to cancel the effects of left turning tendencies.

The pilot should not hesitate at the 90° point but should continue to maneuver the airplane into a descending turn. The rollout from the bank should proceed slowly while the airplane's pitch attitude is allowed to decrease. When the airplane has turned 135°, the airplane should be in its lowest pitch attitude. *[Figure 9-4D]* Pilots should remember that the airplane's airspeed is increasing as the airplane's pitch attitude decreases; therefore, to maintain proper coordination will require a decrease in right rudder pressure. As the airplane approaches the 180° point, it is necessary to progressively relax rudder and aileron pressure while simultaneously raising pitch and roll to level flight. As the rollout is being accomplished, the pilot should note the amount of turn remaining and adjust the rate of rollout and pitch change so that the wings and nose are level at the original airspeed just as the 180° point is reached.

Upon arriving at 180° point, a climbing turn should be started immediately in the opposite direction toward the preselected reference points to complete the second half of the lazy eight in the same manner as the first half. *[Figure 9-4E]*

Power should be set so as not to enter the maneuver at an airspeed that would exceed manufacturer's recommendations, which is generally no greater than V_A. Power and bank angle have significant effect on the altitude gained or lost; if excess power is used for a given bank angle, altitude is gained at the completion of the maneuver; however, if insufficient power is used for a given bank angle, altitude is lost.

Common errors when performing lazy eights are:

- Not clearing the area
- Maneuver is not symmetrical across each 180°
- Inadequate or improper selection or use of 45°, 90°, 135° references
- Ineffective planning
- Gain or loss of altitude at each 180° point
- Poor control at the top of each climb segment resulting in the pitch rapidly falling through the horizon
- Airspeed or bank angle standards not met
- Control roughness
- Poor flight control coordination
- Stalling at any point during the maneuver
- Execution of a steep turn instead of a climbing maneuver
- Not scanning for other traffic during the maneuver
- Performing by reference to the flight instrument rather than visual references

Chapter Summary

Performance maneuvers are used to develop a pilot's skills in coordinating the flight control's use and effect while enhancing the pilot's ability to divide attention across the various demands of flight. Performance maneuvers are also designed to further develop a pilot's application and correlation of the fundamentals of flight and integrate developing skills into advanced maneuvers. Developing highly-honed skills in performance maneuvers allows the pilot to effectively progress toward the mastery of flight. Mastery is developed as the mechanics of flight become a subconscious, rather than a conscious, application of the flight controls to maneuver the airplane in attitude, orientation, and position.