Chapter 5
Takeoffs and Departure Climbs

GENERAL

This chapter discusses takeoffs and departure climbs in tricycle landing gear (nosewheel-type) airplanes under normal conditions, and under conditions which require maximum performance. A thorough knowledge of takeoff principles, both in theory and practice, will often prove of extreme value throughout a pilot's career. It will often prevent an attempted takeoff that would result in an accident, or during an emergency, make possible a takeoff under critical conditions when a pilot with a less well rounded knowledge and technique would fail.

The takeoff, though relatively simple, often presents the most hazards of any part of a flight. The importance of thorough knowledge and faultless technique and judgment cannot be overemphasized.

It must be remembered that the manufacturer's recommended procedures, including airplane configuration and airspeeds, and other information relevant to takeoffs and departure climbs in a specific make and model airplane are contained in the FAA-approved Airplane Flight Manual and/or Pilot's Operating Handbook (AFM/POH) for that airplane. If any of the information in this chapter differs from the airplane manufacturer's recommendations as contained in the AFM/POH, the airplane manufacturer's recommendations take precedence.

TERMS AND DEFINITIONS

Although the takeoff and climb is one continuous maneuver, it will be divided into three separate steps for purposes of explanation: (1) the takeoff roll, (2) the lift-off, and (3) the initial climb after becoming airborne. [Figure 5-1]

- **Takeoff Roll (ground roll)**—the portion of the takeoff procedure during which the airplane is accelerated from a standstill to an airspeed that provides sufficient lift for it to become airborne.
- **Lift-off (rotation)**—the act of becoming airborne as a result of the wings lifting the airplane off the ground or the pilot rotating the nose up, increasing the angle of attack to start a climb.
- **Initial Climb**—begins when the airplane leaves the ground and a pitch attitude has been established to climb away from the takeoff area. Normally, it is considered complete when the airplane has reached a safe maneuvering altitude, or an en route climb has been established.

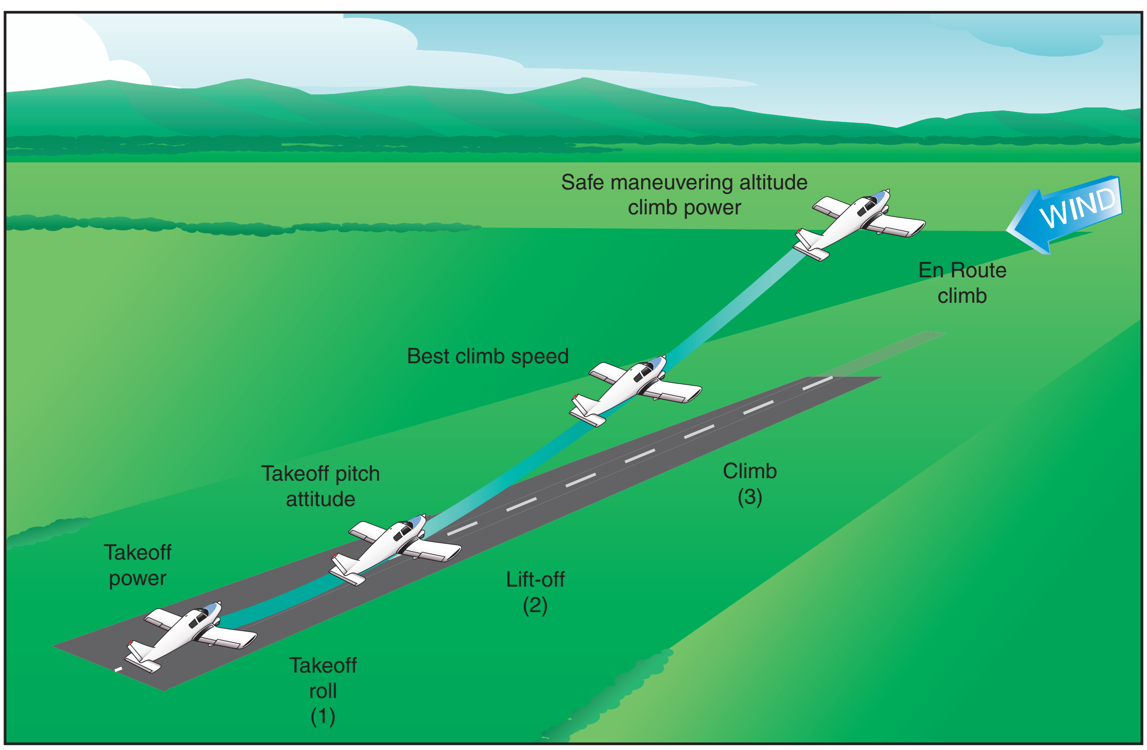

Figure 5-1. Takeoff and climb.

PRIOR TO TAKEOFF

Before taxiing onto the runway or takeoff area, the pilot should ensure that the engine is operating properly and that all controls, including flaps and trim tabs, are set in accordance with the before takeoff checklist. In addition, the pilot must make certain that the approach and takeoff paths are clear of other aircraft. At uncontrolled airports, pilots should announce their intentions on the common traffic advisory frequency (CTAF) assigned to that airport. When operating from an airport with an operating control tower, pilots must contact the tower operator and receive a takeoff clearance before taxiing onto the active runway.

It is not recommended to take off immediately behind another aircraft, particularly large, heavily loaded transport airplanes, because of the wake turbulence that is generated.

While taxiing onto the runway, the pilot can select ground reference points that are aligned with the runway direction as aids to maintaining directional control during the takeoff. These may be runway centerline markings, runway lighting, distant trees, towers, buildings, or mountain peaks.

NORMAL TAKEOFF

A normal takeoff is one in which the airplane is headed into the wind, or the wind is very light. Also, the takeoff surface is firm and of sufficient length to permit the airplane to gradually accelerate to normal lift-off and climb-out speed, and there are no obstructions along the takeoff path.

There are two reasons for making a takeoff as nearly into the wind as possible. First, the airplane's speed while on the ground is much less than if the takeoff were made downwind, thus reducing wear and stress on the landing gear. Second, a shorter ground roll and therefore much less runway length is required to develop the minimum lift necessary for takeoff and climb. Since the airplane depends on airspeed in order to fly, a headwind provides some of that airspeed, even with the airplane motionless, from the wind flowing over the wings.

TAKEOFF ROLL

After taxiing onto the runway, the airplane should be carefully aligned with the intended takeoff direction, and the nosewheel positioned straight, or centered. After releasing the brakes, the throttle should be advanced smoothly and continuously to takeoff power. An abrupt application of power may cause the airplane to yaw sharply to the left because of the torque effects of the engine and propeller. This will be most apparent in high horsepower engines. As the airplane starts to roll forward, the pilot should assure both feet are on the rudder pedals so that the toes or balls of the feet are on the rudder portions, not on the brake portions. Engine instruments should be monitored during the takeoff roll for any malfunctions.

In nosewheel-type airplanes, pressures on the elevator control are not necessary beyond those needed to steady it. Applying unnecessary pressure will only aggravate the takeoff and prevent the pilot from recognizing when elevator control pressure is actually needed to establish the takeoff attitude.

As speed is gained, the elevator control will tend to assume a neutral position if the airplane is correctly trimmed. At the same time, directional control should be maintained with smooth, prompt, positive rudder corrections throughout the takeoff roll. The effects of engine torque and P-factor at the initial speeds tend to pull the nose to the left. The pilot must use whatever rudder pressure and aileron needed to correct for these effects or for existing wind conditions to keep the nose of the airplane headed straight down the runway. The use of brakes for steering purposes should be avoided, since this will cause slower acceleration of the airplane's speed, lengthen the takeoff distance, and possibly result in severe swerving.

While the speed of the takeoff roll increases, more and more pressure will be felt on the flight controls, particularly the elevators and rudder. If the tail surfaces are affected by the propeller slipstream, they become effective first. As the speed continues to increase, all of the flight controls will gradually become effective enough to maneuver the airplane about its three axes. It is at this point, in the taxi to flight transition, that the airplane is being flown more than taxied. As this occurs, progressively smaller rudder deflections are needed to maintain direction.

The feel of resistance to the movement of the controls and the airplane's reaction to such movements are the only real indicators of the degree of control attained. This feel of resistance is not a measure of the airplane's speed, but rather of its controllability. To determine the degree of controllability, the pilot must be conscious of the reaction of the airplane to the control pressures and immediately adjust the pressures as needed to control the airplane. The pilot must wait for the reaction of the airplane to the applied control pressures and attempt to sense the control resistance to pressure rather than attempt to control the airplane by movement of the controls. Balanced control surfaces increase the importance of this point, because they materially reduce the intensity of the resistance offered to pressures exerted by the pilot.

At this stage of training, beginning takeoff practice, a student pilot will normally not have a full appreciation of the variations of control pressures with the speed of the airplane. The student, therefore, may tend to move the controls through wide ranges seeking the pressures that are familiar and expected, and as a consequence over-control the airplane. The situation may be aggravated by the sluggish reaction of the airplane to these movements. The flight instructor should take measures to check these tendencies and stress the importance of the development of feel. The student pilot should be required to feel lightly for resistance and accomplish the desired results by applying pressure against it. This practice will enable the student pilot, as experience is gained, to achieve a sense of the point when sufficient speed has been acquired for the takeoff, instead of merely guessing, fixating on the airspeed indicator, or trying to force performance from the airplane.

LIFT-OFF

Since a good takeoff depends on the proper takeoff attitude, it is important to know how this attitude appears and how it is attained. The ideal takeoff attitude requires only minimum pitch adjustments shortly after the airplane lifts off to attain the speed for the best rate of climb (V_Y). [Figure 5-2] The pitch attitude necessary for the airplane to accelerate to V_Y speed should be demonstrated by the instructor and memorized by the student. Initially, the student pilot may have a tendency to hold excessive back-elevator pressure just after lift-off, resulting in an abrupt pitch-up. The flight instructor should be prepared for this.

Each type of airplane has a best pitch attitude for normal lift-off; however, varying conditions may make a difference in the required takeoff technique. A rough field, a smooth field, a hard surface runway, or a short or soft, muddy field, all call for a slightly different technique, as will smooth air in contrast to a strong, gusty wind. The different techniques for those other-than-normal conditions are discussed later in this chapter.

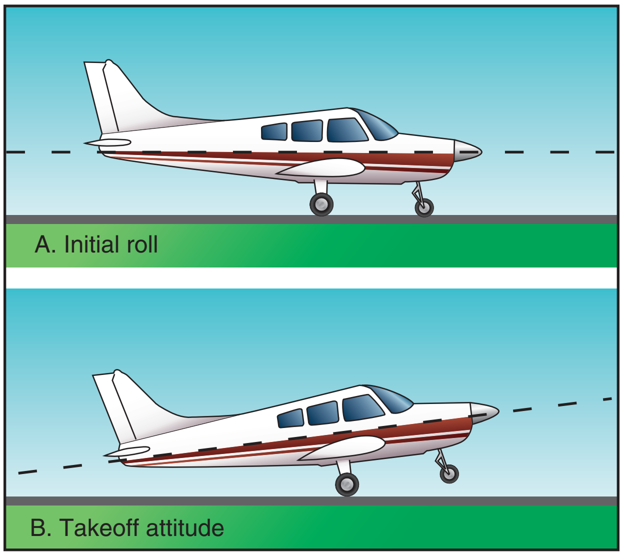

Figure 5-2. Initial roll and takeoff attitude.

When all the flight controls become effective during the takeoff roll in a nosewheel-type airplane, back-elevator pressure should be gradually applied to raise the nosewheel slightly off the runway, thus establishing the takeoff or lift-off attitude. This is often referred to as "rotating." At this point, the position of the nose in relation to the horizon should be noted, then back-elevator pressure applied as necessary to hold this attitude. The wings must be kept level by applying aileron pressure as necessary.

The airplane is allowed to fly off the ground while in the normal takeoff attitude. Forcing it into the air by applying excessive back-elevator pressure would only result in an excessively high pitch attitude and may delay the takeoff. As discussed earlier, excessive and rapid changes in pitch attitude result in proportionate changes in the effects of torque, thus making the airplane more difficult to control.

Although the airplane can be forced into the air, this is considered an unsafe practice and should be avoided under normal circumstances. If the airplane is forced to leave the ground by using too much back-elevator pressure before adequate flying speed is attained, the wing's angle of attack may be excessive, causing the airplane to settle back to the runway or even to stall. On the other hand, if sufficient back-elevator pressure is not held to maintain the correct takeoff attitude after becoming airborne, or the nose is allowed to lower excessively, the airplane may also settle back to the runway. This would occur because the angle of attack is decreased and lift diminished to the degree where it will not support the airplane. It is important, then, to hold the correct attitude constant after rotation or lift-off.

As the airplane leaves the ground, the pilot must continue to be concerned with maintaining the wings in a level attitude, as well as holding the proper pitch attitude. Outside visual scan to attain/maintain proper airplane pitch and bank attitude must be intensified at this critical point. The flight controls have not yet become fully effective, and the beginning pilot will often have a tendency to fixate on the airplane's pitch attitude and/or the airspeed indicator and neglect the natural tendency of the airplane to roll just after breaking ground.

During takeoffs in a strong, gusty wind, it is advisable that an extra margin of speed be obtained before the airplane is allowed to leave the ground. A takeoff at the normal takeoff speed may result in a lack of positive control, or a stall, when the airplane encounters a sudden lull in strong, gusty wind, or other turbulent air currents. In this case, the pilot should allow the airplane to stay on the ground longer to attain more speed; then make a smooth, positive rotation to leave the ground.

INITIAL CLIMB

Upon lift-off, the airplane should be flying at approximately the pitch attitude that will allow it to accelerate to V_Y. This is the speed at which the airplane will gain the most altitude in the shortest period of time.

If the airplane has been properly trimmed, some back-elevator pressure may be required to hold this attitude until the proper climb speed is established. On the other hand, relaxation of any back-elevator pressure before this time may result in the airplane settling, even to the extent that it contacts the runway.

The airplane will pick up speed rapidly after it becomes airborne. Once a positive rate of climb is established, the flaps and landing gear can be retracted (if equipped).

It is recommended that takeoff power be maintained until reaching an altitude of at least 500 feet above the surrounding terrain or obstacles. The combination of V_Y and takeoff power assures the maximum altitude gained in a minimum amount of time. This gives the pilot more altitude from which the airplane can be safely maneuvered in case of an engine failure or other emergency.

Since the power on the initial climb is fixed at the takeoff power setting, the airspeed must be controlled by making slight pitch adjustments using the elevators. However, the pilot should not fixate on the airspeed indicator when making these pitch changes, but should, instead, continue to scan outside to adjust the airplane's attitude in relation to the horizon. In accordance with the principles of attitude flying, the pilot should first make the necessary pitch change with reference to the natural horizon and hold the new attitude momentarily, and then glance at the airspeed indicator as a check to see if the new attitude is correct. Due to inertia, the airplane will not accelerate or decelerate immediately as the pitch is changed. It takes a little time for the airspeed to change. If the pitch attitude has been over or under corrected, the airspeed indicator will show a speed that is more or less than that desired. When this occurs, the cross-checking and appropriate pitch-changing process must be repeated until the desired climbing attitude is established.

When the correct pitch attitude has been attained, it should be held constant while cross-checking it against the horizon and other outside visual references. The airspeed indicator should be used only as a check to determine if the attitude is correct.

After the recommended climb airspeed has been established, and a safe maneuvering altitude has been reached, the power should be adjusted to the recommended climb setting and the airplane trimmed to relieve the control pressures. This will make it easier to hold a constant attitude and airspeed.

During initial climb, it is important that the takeoff path remain aligned with the runway to avoid drifting into obstructions, or the path of another aircraft that may be taking off from a parallel runway. Proper scanning techniques are essential to a safe takeoff and climb, not only for maintaining attitude and direction, but also for collision avoidance in the airport area.

When the student pilot nears the solo stage of flight training, it should be explained that the airplane's takeoff performance will be much different when the instructor is out of the airplane. Due to decreased load, the airplane will become airborne sooner and will climb more rapidly. The pitch attitude that the student has learned to associate with initial climb may also differ due to decreased weight, and the flight controls may seem more sensitive. If the situation is unexpected, it may result in increased tension that may remain until after the landing. Frequently, the existence of this tension and the uncertainty that develops due to the perception of an "abnormal" takeoff results in poor performance on the subsequent landing.

Common errors in the performance of normal takeoffs and departure climbs are:

- Failure to adequately clear the area prior to taxiing into position on the active runway.
- Abrupt use of the throttle.
- Failure to check engine instruments for signs of malfunction after applying takeoff power.
- Failure to anticipate the airplane's left turning tendency on initial acceleration.
- Overcorrecting for left turning tendency.
- Relying solely on the airspeed indicator rather than developed feel for indications of speed and airplane controllability during acceleration and lift-off.
- Failure to attain proper lift-off attitude.
- Inadequate compensation for torque/P-factor during initial climb resulting in a sideslip.
- Over-control of elevators during initial climb-out.

- Limiting scan to areas directly ahead of the airplane (pitch attitude and direction), resulting in allowing a wing (usually the left) to drop immediately after lift-off.
- Failure to attain/maintain best rate-of-climb airspeed (V_Y).
- Failure to employ the principles of attitude flying during climb-out, resulting in "chasing" the airspeed indicator.

CROSSWIND TAKEOFF

While it is usually preferable to take off directly into the wind whenever possible or practical, there will be many instances when circumstances or judgment will indicate otherwise. Therefore, the pilot must be familiar with the principles and techniques involved in crosswind takeoffs, as well as those for normal takeoffs. A crosswind will affect the airplane during takeoff much as it does in taxiing. With this in mind, it can be seen that the technique for crosswind correction during takeoffs closely parallels the crosswind correction techniques used in taxiing.

TAKEOFF ROLL

The technique used during the initial takeoff roll in a crosswind is generally the same as used in a normal takeoff, except that aileron control must be held INTO the crosswind. This raises the aileron on the upwind wing to impose a downward force on the wing to counteract the lifting force of the crosswind and prevents the wing from rising.

As the airplane is taxied into takeoff position, it is essential that the windsock and other wind direction indicators be checked so that the presence of a crosswind may be recognized and anticipated. If a crosswind is indicated, FULL aileron should be held into the wind as the takeoff roll is started. This control position should be maintained while the airplane is accelerating and until the ailerons start becoming sufficiently effective for maneuvering the airplane about its longitudinal axis.

With the aileron held into the wind, the takeoff path must be held straight with the rudder. [Figure 5-3]

Normally, this will require applying downwind rudder pressure, since on the ground the airplane will tend to **weathervane** into the wind. When takeoff power is applied, torque or P-factor that yaws the airplane to the left may be sufficient to counteract the weathervaning tendency caused by a crosswind from the right. On the other hand, it may also aggravate the tendency to

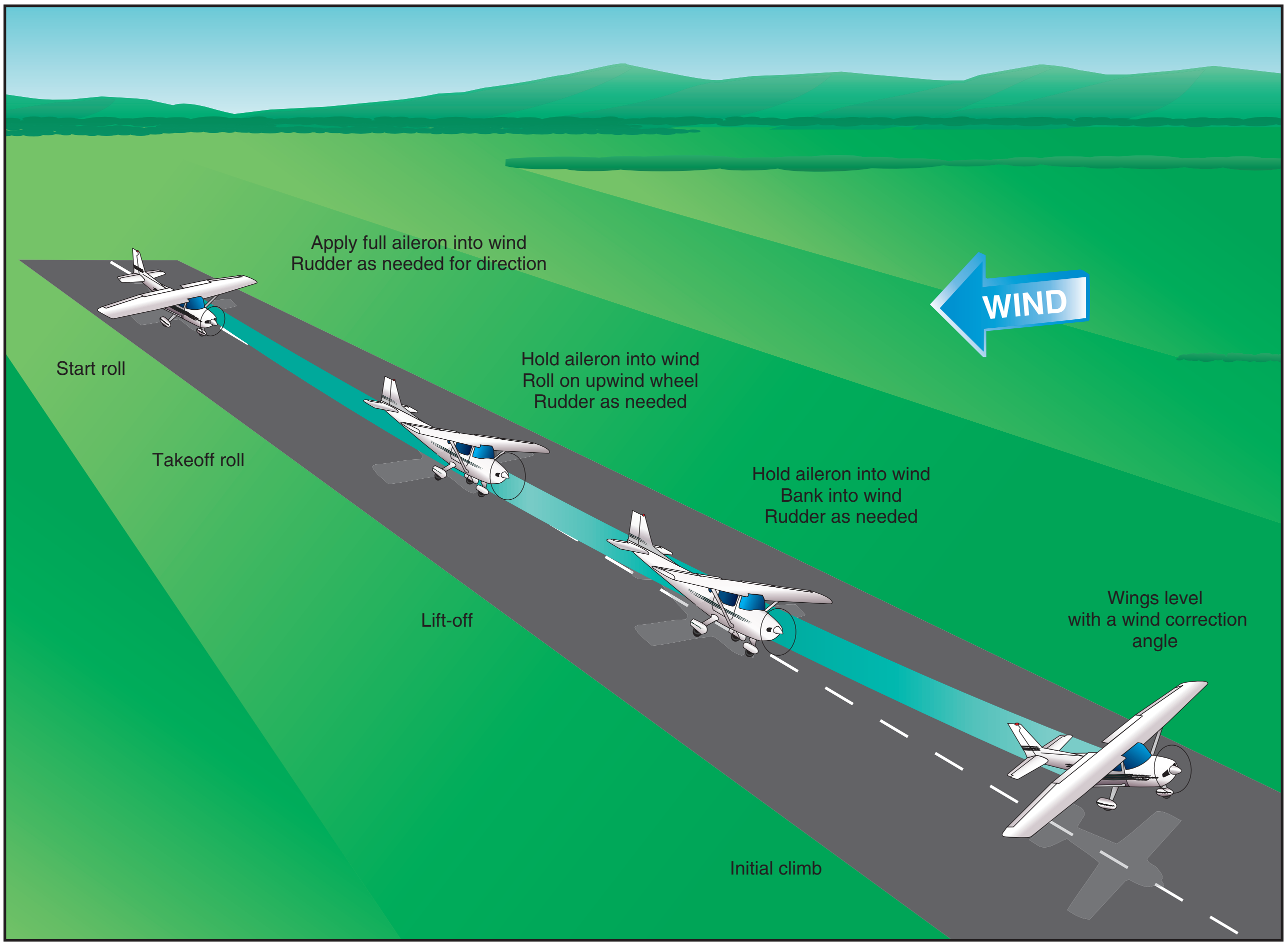

Figure 5-3. Crosswind takeoff roll and initial climb.

swerve left when the wind is from the left. In any case, whatever rudder pressure is required to keep the airplane rolling straight down the runway should be applied.

As the forward speed of the airplane increases and the crosswind becomes more of a relative headwind, the mechanical holding of full aileron into the wind should be reduced. It is when increasing pressure is being felt on the aileron control that the ailerons are becoming more effective. As the aileron's effectiveness increases and the **crosswind component** of the relative wind becomes less effective, it will be necessary to gradually reduce the aileron pressure. The crosswind component effect does not completely vanish, so some aileron pressure will have to be maintained throughout the takeoff roll to keep the crosswind from raising the upwind wing. If the upwind wing rises, thus exposing more surface to the crosswind, a "skipping" action may result. [Figure 5-4]

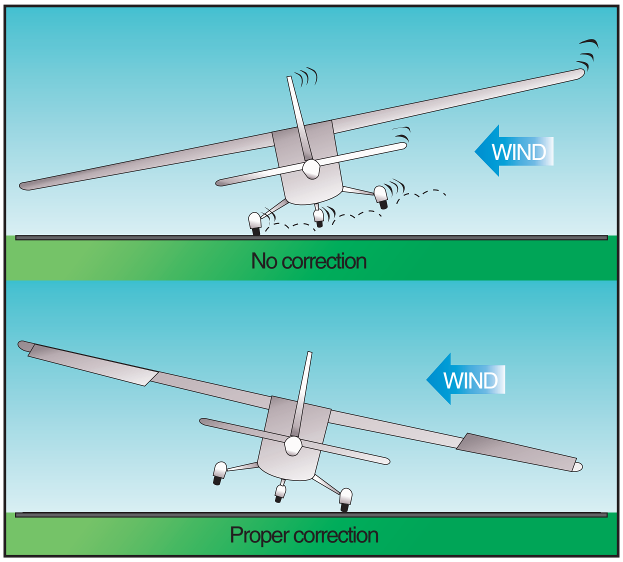

Figure 5-4. Crosswind effect.

This is usually indicated by a series of very small bounces, caused by the airplane attempting to fly and then settling back onto the runway. During these bounces, the crosswind also tends to move the airplane sideways, and these bounces will develop into side-skipping. This side-skipping imposes severe side stresses on the landing gear and could result in structural failure.

It is important, during a crosswind takeoff roll, to hold sufficient aileron into the wind not only to keep the upwind wing from rising but to hold that wing down so that the airplane will, immediately after lift-off, be **sideslipping** into the wind enough to counteract drift.

LIFT-OFF

As the nosewheel is being raised off the runway, the holding of aileron control into the wind may result in the downwind wing rising and the downwind main wheel lifting off the runway first, with the remainder of the takeoff roll being made on that one main wheel. This is acceptable and is preferable to side-skipping.

If a significant crosswind exists, the main wheels should be held on the ground slightly longer than in a normal takeoff so that a smooth but very definite lift-off can be made. This procedure will allow the airplane to leave the ground under more positive control so that it will definitely remain airborne while the proper amount of wind correction is being established. More importantly, this procedure will avoid imposing excessive side-loads on the landing gear and prevent possible damage that would result from the airplane settling back to the runway while drifting.

As both main wheels leave the runway and ground friction no longer resists drifting, the airplane will be slowly carried sideways with the wind unless adequate drift correction is maintained by the pilot. Therefore, it is important to establish and maintain the proper amount of crosswind correction prior to lift-off by applying aileron pressure toward the wind to keep the upwind wing from rising and applying rudder pressure as needed to prevent weathervaning.

INITIAL CLIMB

If proper crosswind correction is being applied, as soon as the airplane is airborne, it will be sideslipping into the wind sufficiently to counteract the drifting effect of the wind. [Figure 5-5] This sideslipping should be continued until the airplane has a positive rate of climb. At that time, the airplane should be turned into the wind to establish just enough wind correction angle to counteract the wind and then the wings rolled level. Firm and aggressive use of the rudders will be required to keep the airplane headed straight down the runway. The climb with a wind correction angle should be continued to follow a ground track aligned with the runway direction. However, because the force of a crosswind may vary markedly within a few hundred feet of the ground, frequent checks of actual ground track should be made, and the wind correction adjusted as necessary. The remainder of the climb technique is the same used for normal takeoffs and climbs.

Common errors in the performance of crosswind takeoffs are:

- Failure to adequately clear the area prior to taxiing onto the active runway.
- Using less than full aileron pressure into the wind initially on the takeoff roll.
- Mechanical use of aileron control rather than sensing the need for varying aileron control input through feel for the airplane.

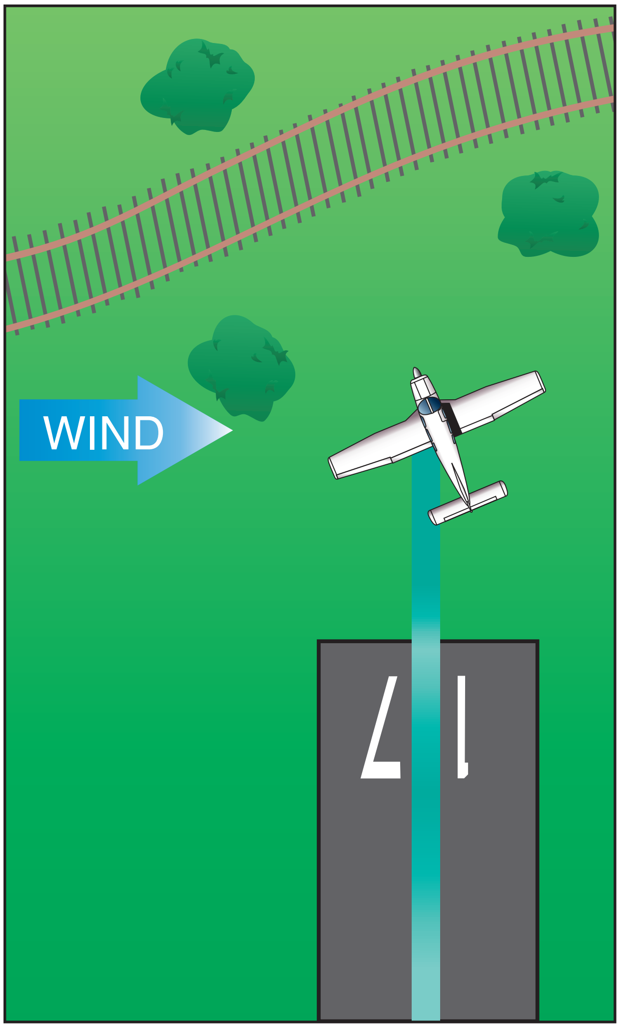

Figure 5-5. Crosswind climb flightpath.

- Premature lift-off resulting in side-skipping.
- Excessive aileron input in the latter stage of the takeoff roll resulting in a steep bank into the wind at lift-off.
- Inadequate drift correction after lift-off.

GROUND EFFECT ON TAKEOFF

Ground effect is a condition of improved performance encountered when the airplane is operating very close to the ground. Ground effect can be detected and measured up to an altitude equal to one wingspan above the surface. [Figure 5-6] However, ground effect is most significant when the airplane (especially a low-wing airplane) is maintaining a constant attitude at low airspeed at low altitude (for example, during takeoff when the airplane lifts off and accelerates to climb speed, and during the landing flare before touchdown).

When the wing is under the influence of ground effect, there is a reduction in upwash, downwash, and wingtip vortices. As a result of the reduced wingtip vortices, induced drag is reduced. When the wing is at a height equal to one-fourth the span, the reduction in induced drag is about 25 percent, and when the wing is at a height equal to one-tenth the span, the reduction in induced drag is about 50 percent. At high speeds where parasite drag dominates, induced drag is a small part of the total drag. Consequently, the effects of ground effect are of greater concern during takeoff and landing.

On takeoff, the takeoff roll, lift-off, and the beginning of the initial climb are accomplished in the ground effect area. The ground effect causes local increases in static pressure, which cause the airspeed indicator and altimeter to indicate slightly less than they should, and usually results in the vertical speed indicator indicating a descent. As the airplane lifts off and climbs out of the ground effect area, however, the following will occur.

- The airplane will require an increase in angle of attack to maintain the same lift coefficient.
- The airplane will experience an increase in induced drag and thrust required.
- The airplane will experience a pitch-up tendency and will require less elevator travel because of an increase in downwash at the horizontal tail.

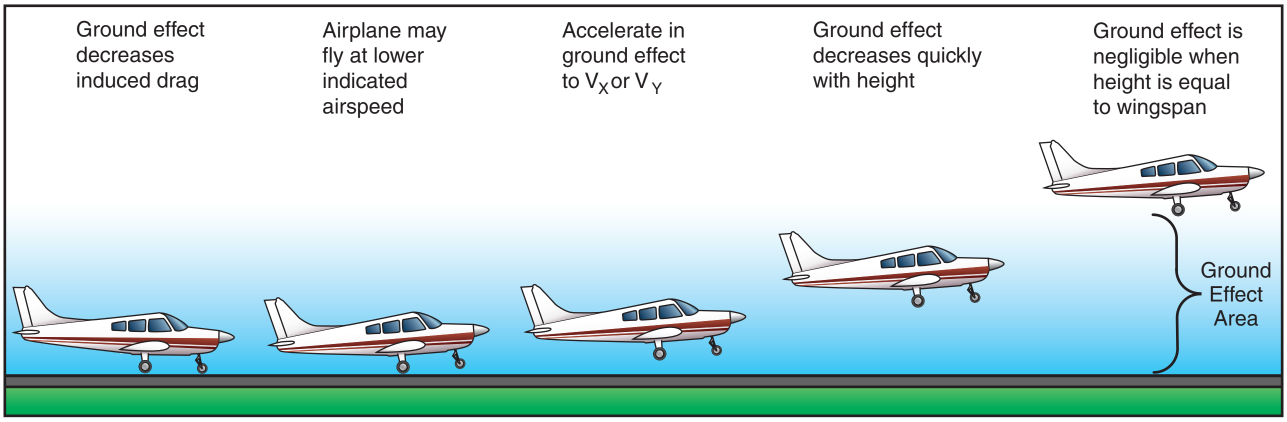

Figure 5-6. Takeoff in ground effect area.