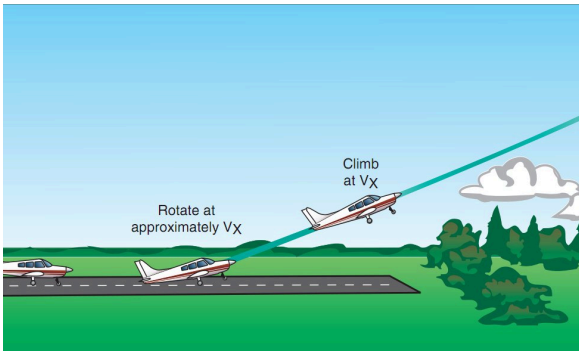
Short-Field Takeoff and Maximum Performance Climb

Objective

To ensure the applicant learns the purpose of and can exhibit a clear understanding of the short-field takeoff maneuver and how to perform the maneuver properly.



Purpose

Short-field takeoff technique emphasizes consideration of the runway environment, weather conditions, and takeoff performance, enabling operating from very small runways. It introduces pilots to maximum-performance takeoffs and climbs.

Schedule

- **Ground Lesson**: 15 minutes
- Initial
  - **Flight 1**: 40 minutes - *Introduction to Maneuver*
  - **Flight 2**: 50 minutes - *Improve Proficiency (Dual)*
- Solo
  - **Flight 3**: 30 minutes - *Improve Proficiency*
- Pre-Checkride
  - **Flight 4**: 20 minutes - *Demonstrate Proficiency*
- **Debrief**: 10 minutes (*per flight*)

Equipment

- Airplane POH and Checklist
- Whiteboard / Markers (optional)
- Model Airplane (optional)

Student Actions

- Ask any questions, receive study material for the next lesson.
- Watch linked video.
- Review listed references.

Instructor Actions

- Deliver the ground lesson (below).
- Demonstrate the maneuver in flight.
- Debrief after each flight.

Completion Standards

- **Ground**: Student can explain the purpose of the maneuver and how to execute it properly.
  - Can explain short-field obstacle avoidance procedures, left turning tendencies, Vx vs Vy, density altitude, calculating airplane takeoff performance.
- **Flight**: Student can perform the maneuver to the applicable ACS standards.
  - Performs a pre-takeoff checklist and configures the airplane correctly.
  - Aligns with the runway centerline, using all available runway, holds brakes while applying full power.
  - After checking engine indications, accelerates and remains on the runway until rotation speed.
  - Climbs out at Vx until clear of obstacles, then accelerates to and climbs at Vy.
  - See expanded Completion Standards below.

References

- MzeroA Flight Training - “Short Field Takeoff and Landing”
    - YouTube - https://www.youtube.com/watch?v=A7dcr12EqwE
- FAA-H-8083-3C (Airplane Flying Handbook) - Chapter 6, Page 1-2 [Prior to Takeoff], Chapter 6, Page 3-6 [Normal Takeoff], Chapter 6, Page 6-10 [Crosswind Takeoff], Chapter 6, Page 10-11 [Ground Effect on Takeoff], Chapter 6, Page 11-12 [Short-Field Takeoff and Maximum Performance Climb], Chapter 6, Page 14 [Rejected Takeoff/Engine Failure]
- FAA-H-8083-25C (Pilot’s Handbook of Aeronautical Knowledge) - Chapter 5, Page 30-33 [Left Turning Tendencies], Chapter 11, Page 7-8 [Rate of Climb, Angle of Climb], Chapter 11, Page 12-16 [Takeoff Performance], Chapter 11, Page 19-28 [Performance Charts]
- FAA-S-ACS-6C (Private Pilot ACS) - Area IV Task E
- FAA-S-ACS-7B (Commercial Pilot ACS) - Area IV Task E
- FAA-S-ACS-25 (CFI ACS) - Area VII Task E

Ground Lesson Outline

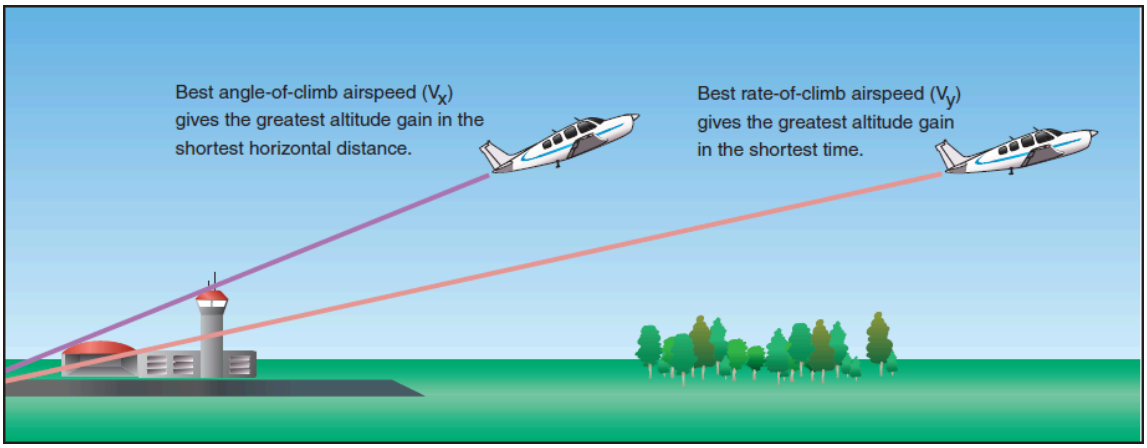
- What are Short-Field Takeoffs?
- Best Angle of Climb (Vx) vs Best Rate of Climb (Vy)
    - Obstacle avoidance
- Left Turning Tendencies
    - P-Factor, Slipstream, Torque, Gyroscopic Precession
- Takeoff Performance
    - Density Altitude
    - Calculating takeoff performance data, Proper aircraft configuration
- Runway Safety
- Safety considerations
    - Use of checklists
    - Visual traffic scanning
    - Runway incursion avoidance
    - Windshear, Tailwinds, Wake Turbulence
    - Runway surface conditions
    - Be ready to abort!
- Maneuver Description - step-by-step
    - Entry position, airspeed, etc.
- Expanded Completion Standards

Common Errors

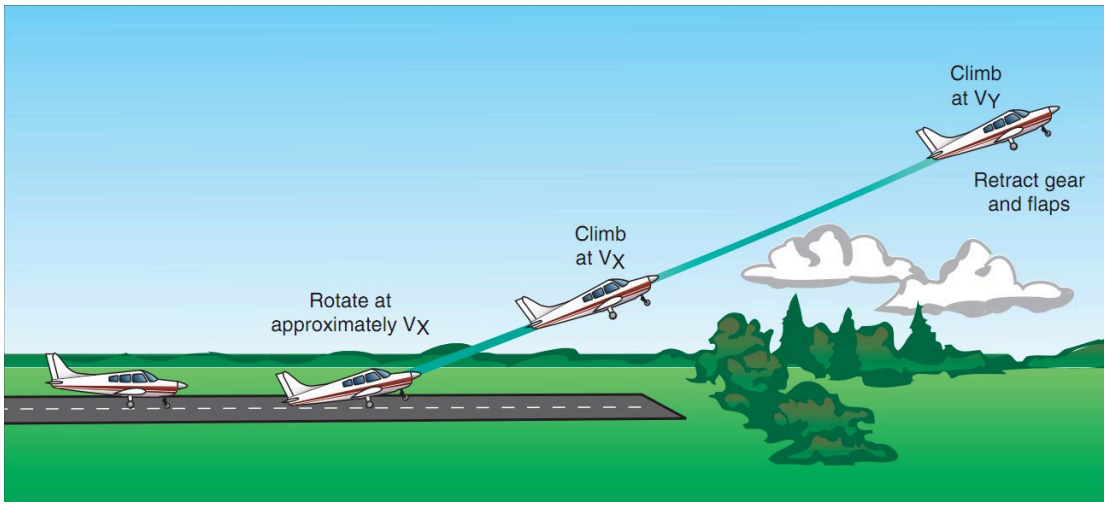
- Improper runway incursion avoidance procedures.
- Improper use of controls during a short-field takeoff.
- **Improper lift-off procedures (lifting off early).**
- **Improper initial climb attitude, power setting, and airspeed (Vx) to clear obstacle.**
- Improper use of checklist.

Ground Lesson Content

- **What are Short Field Takeoffs?** The short-field takeoff is, as the name suggests, all about departing from short fields. The maneuver is effectively a maximum-performance takeoff and climb, and aims to take off in the shortest possible distance and climb away from obstacles as steeply as possible.
- **Best Angle of Climb and Best Rate of Climb** - When performing a maximum-performance climb, there are two important speeds that pilots must memorize for their aircraft:
    - **Vx** - The best *angle* of climb.
    - **Vy** - The best *rate* of climb.
- Climbing at the best *angle* of climb means that the airplane will climb more steeply away from the ground, and is **usually used for avoiding obstacles** which may be present especially near small runways.
- Climbing at the best *rate* of climb is more commonly used, and it means the airplane will climb faster, but at a shallower angle. This is used to gain the most altitude in the shortest amount of time.



- In a short-field takeoff, pilots should first climb at Vx, to avoid obstacles, and then, when clear of obstacles, accelerate to Vy and continue climbing, to maximize performance.



- **Left-Turning Tendencies** - This maneuver also illustrates the strong effects of left-turning tendencies at low airspeeds and high angle of attack. Because full power is applied while the airplane is not moving, after brakes are released, the rudder has limited effectiveness and **significant right rudder pressure may be required to maintain runway centerline**. Likewise, after takeoff and while climbing

at Vx, the airplane will be flying at a high angle of attack and high power setting, exaggerating the torque reaction, spiraling slipstream, and P-Factor, again requiring significant right rudder pressure.

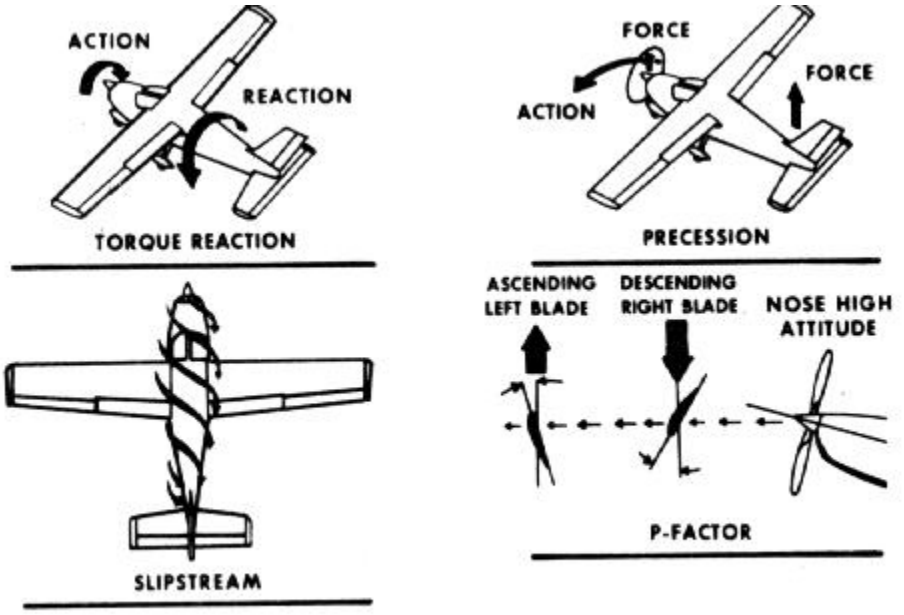


Figure 3–6 Left Turning Tendencies

- **Takeoff Performance** - Determining exactly how much distance will be required for takeoff is crucial to ensure the chosen runway will be long enough to depart safely. An airplane's takeoff performance is highly dependent on several changing factors, such as **weight, wind, and density altitude.** Aircraft performance at heavier weights or higher altitudes is greatly reduced.
    - *Density altitude,* which is a correction for atmospheric conditions, is the altitude that an airplane 'feels'.
    - At higher altitudes or on hot days, the density of the air will be less and therefore the airplane will need to move more air to stay aloft. Because the airspeed indicator is also affected by density altitude, it will show the same values, however the true airspeed will be higher.
    - **The difference between field altitude and the density altitude can be significant!**
        - See the related lesson on Density Altitude.
- The POH for every aircraft will contain performance charts that detail how many feet of takeoff distance is required for various weights, winds, and weather conditions. It also prescribes an airplane configuration that should be used.
    - To use the performance charts, first find the *pressure altitude*, by setting the altimeter to 29.92" or using the conversion. Then, find the cell in the table that matches the airplane gross weight with the pressure altitude and the current temperature. **Make sure to read the notes, in case distances need to be adjusted for wind or other conditions!**
    - It is best to add a 'safety factor' to the performance figures obtained from the POH performance charts. Generally, it is a good idea to overestimate the pressure altitude and temperature for a worst case scenario, and add 20-30% to account for the possibility of imperfect technique.
    - **Don't forget to consider wind!** A tailwind dramatically increases takeoff and landing distances. Likewise, a strong headwind can greatly improve performance.
    - **Pay attention to aircraft configuration** - Some POHs call for flaps, so do not. The performance numbers are only valid for the given configuration!

TAKEOFF DISTANCE

SHORT FIELD

CONDITIONS:
Flaps 10°
Full Throttle Prior to Brake Release
Paved, Level, Dry Runway
Zero Wind

NOTES:
1. Short field technique as specified in Section 4.
2. Prior to takeoff from fields above 3000 feet elevation, the mixture should be leaned to give maximum RPM in a full throttle, static runup.
3. Decrease distances 10% for each 9 knots headwind. For operation with tailwinds up to 10 knots, increase distances by 10% for each 2 knots.
4. For operation on a dry, grass runway, increase distances by 15% of the "ground roll" figure.

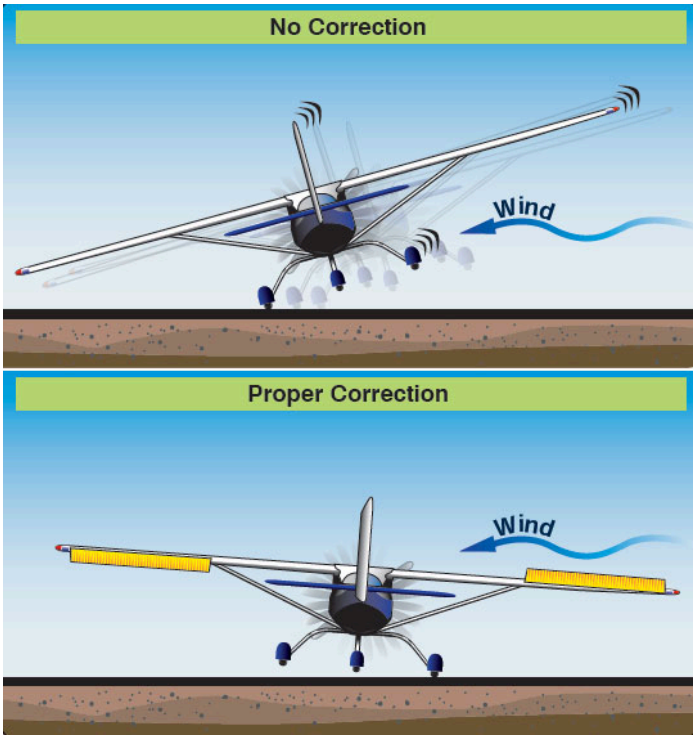
WEIGHT LBS	TAKEOFF SPEED KIAS		PRESS ALT FT	0°C		10°C		20°C		30°C		40°C	
	LIFT OFF	AT 50 FT		GRND ROLL	TOTAL TO CLEAR 50 FT OBS	GRND ROLL	TOTAL TO CLEAR 50 FT OBS	GRND ROLL	TOTAL TO CLEAR 50 FT OBS	GRND ROLL	TOTAL TO CLEAR 50 FT OBS	GRND ROLL	TOTAL TO CLEAR 50 FT OBS
1670	50	54	S.L.	640	1190	695	1290	755	1390	810	1495	875	1605
			1000	705	1310	765	1420	825	1530	890	1645	960	1770
			2000	775	1445	840	1565	910	1690	980	1820	1055	1960
			3000	855	1600	925	1730	1000	1870	1080	2020	1165	2185
			4000	940	1775	1020	1920	1100	2080	1190	2250	1285	2440
			5000	1040	1970	1125	2140	1215	2320	1315	2525	1420	2750
			6000	1145	2200	1245	2395	1345	2610	1455	2855	1570	3125
			7000	1270	2470	1375	2705	1490	2960	1615	3255	1745	3590
			8000	1405	2800	1525	3080	1655	3395	1795	3765	1940	4195

- **Runway Safety** - All takeoffs generally start with the airplane crossing over a *hold short* line, which is the line that indicates where the runway area begins. Hold short lines should be taken very seriously!
    - Before crossing a hold short line:
        - At a towered airport, the pilot must have received a taxi, runway crossing, or takeoff clearance for the runway they are about to enter.
        - At a non-towered airport, the pilot has communicated their intentions over the radio (Common Traffic Advisory Frequency--CTAF), and has visually verified that there is no traffic on final approach for the runway, or on the runway itself, which would conflict.
- **Safety Considerations**
    - As with any takeoff, the **use of checklists is important**. Before entering the runway area, the before takeoff checklist must be completed.
    - **Short-field takeoffs require special caution to be exercised for obstacles on or near the field!** Powerlines, tall trees, or other obstacles may be quite close to the runway environment! These obstacles may be difficult to see in a nose-high attitude after takeoff, so a thorough takeoff briefing which highlights these hazards should be conducted before every takeoff.
    - It is crucial to not become so focused on performing the maneuver that an unsafe situation is created. Maintain situational awareness, make appropriate radio calls, and ensure that takeoff clearance is obtained before entering any runways, if at a controlled field. **Vigilance must be maintained to avoid taxiing onto any intersecting runways beyond other hold short lines.** At uncontrolled fields, clearly communicate your taxi and takeoff intentions on the radio. Remember that uncontrolled fields often have no-radio (NORDO) pattern traffic, so **always visually verify the runway and final approach path is clear!**
    - If the airplane is not accelerating as expected and the takeoff is in doubt, **abort!**
    - **Windshear, Tailwinds, Wake Turbulence** - During takeoffs and landings, we are operating near the ground at low speed. Pilots should exercise caution if there are indications of windshear, pay attention to situations where wake turbulence will be a factor. Additionally, taking off or landing with a tailwind creates a much higher ground speed, lengthening the ground roll, and increasing the danger.

- **Runway Surface Conditions** - If the runway is wet or icy, it can be quite slippery, particularly in the touchdown zone where many preceding aircraft have deposited rubber. Exercise caution in these situations!

Maneuver Description

- **Selecting a Suitable Runway** - Select a runway that will allow takeoff into the wind, or with a manageable crosswind.
- **Checklists** - Pilots must perform a before-takeoff checklist before beginning the maneuver, and thoroughly brief any hazards that may be present on departure.
- **Before Takeoff** - Configure the airplane for short-field takeoff (per the POH), usually requiring flaps.
- **Entering the Runway** - Taxi into the runway, using all available takeoff area (possibly requiring back-taxiing) and line up with the centerline and come to a stop. Apply full power while holding stationary with brakes, and verify the engine indications.
- **Takeoff Roll and Liftoff** - Allow the airplane to accelerate but **do not allow the airplane to lift off before rotation speed**. Be prepared to counteract the significant amount of left-turning tendencies with right rudder during takeoff roll. Positive aircraft control must be maintained at all times! **Apply *and hold* proper crosswind corrections to avoid sidewards drifting.**



- **Climbout** - Once the airplane has accelerated to Vx, climb at Vx until any obstacles are cleared. After all obstacles are cleared, reduce pitch, retract flaps, and accelerate to Vy. Make sure to fly coordinated. **More right rudder!**
- **This is a visual maneuver!** Eyes should remain outside the cockpit as much as possible to scan for traffic and ensure proper tracking of the centerline. *Monitoring for other traffic is especially critical when performing this maneuver at uncontrolled airfields.*

Expanded Completion Standards

- The pilot can explain the purpose of the short-field takeoff maneuver and how the various factors affect the performance of the maneuver.
- The pilot can perform the maneuver to the following standards:
    - Pilot configures the airplane properly for takeoff, performs a pre-takeoff checklist, ensures that takeoff clearance is obtained (at a towered airport) or that the runway and final approach path is clear (at a non-towered airport), and makes the appropriate radio calls.
    - Pilot taxis onto the runway, using all available runway (back-taxiing if necessary), and aligns with the centerline.
    - Pilot holds the airplane stationary with brakes while applying full power.
    - Pilot verifies proper engine indications before releasing brakes and remains on the ground until rotation speed.
    - Pilot accelerates to and climbs out at Vx until clear of obstacles.
    - After clear of obstacles, pilot properly reconfigures airplane and accelerates to Vy.
    - Pilot divides attention between accurate, *coordinated airplane control* and outside visual references.