FLY
AVIATION

Training aid only, not flight instruction. Review it with your CFI and get their approval before you use it in training or in the airplane. Check every number against the POH and current FAA sources. Last reviewed Nov 7, 2026.

AERODYNAMICS AND AIRCRAFT SYSTEMS

Private pilot checkride · Knowledge test and oral · Our Cherokee as the example

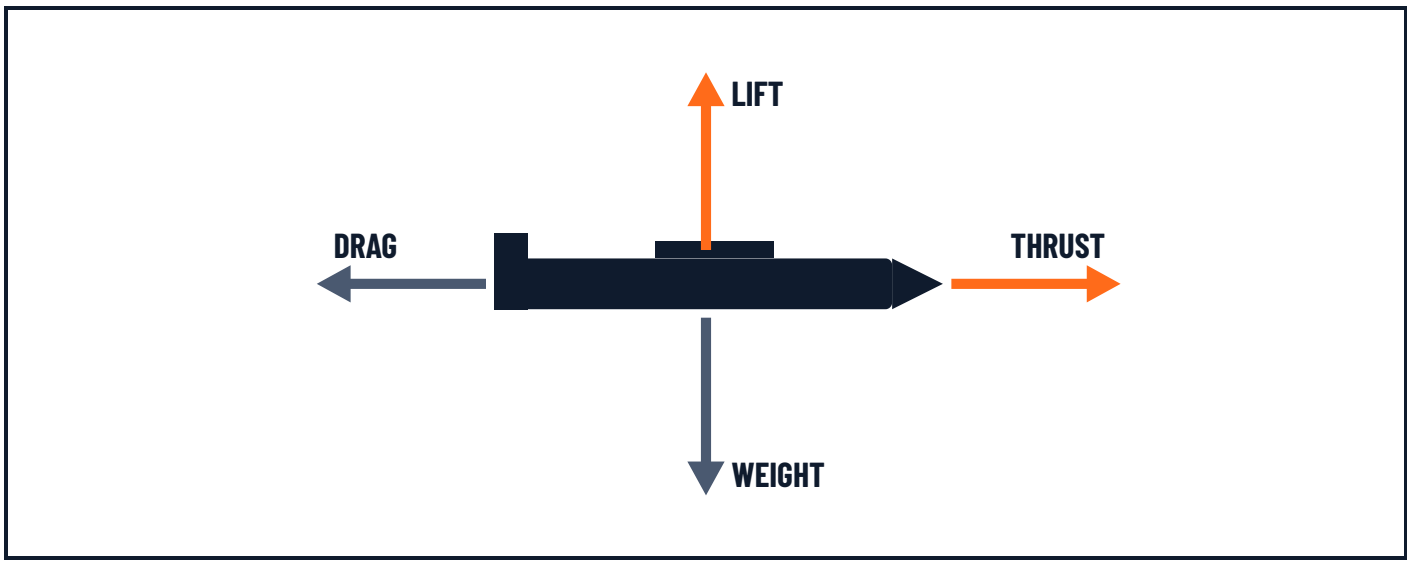
HOW TO USE THIS GUIDE

The knowledge test asks the theory. The oral asks how it applies to the airplane you fly.
This guide does both, with our 1975 Cherokee 140 Cruiser as the running example.

- **Speeds are in mph** from the Cruiser Pilot's Operating Manual (POM 761 555): Vso 55, Vs1 64, Vx 78, Vy 89, best glide 80, Va 129 at 2,150 lb, Vfe 115, Vno 140, Vne 171.
- **Cherokee system details come from the POM and typical 1975 Cruisers.** Airplanes get modified over 50 years. Confirm every system detail against the POH and the airplane itself.
- For how the airplane handles, see the Cherokee 140 Transition Guide. For the flows, see the Cherokee Flow Cards.

THE FOUR FORCES

In steady, unaccelerated flight, lift equals weight and thrust equals drag. Every maneuver is a change in that balance.



Lift

- **The lift equation in words:** lift depends on air density, the square of airspeed, wing area and the coefficient of lift (set mostly by angle of attack and flaps). Double the airspeed and lift goes up four times.
- **Bernoulli:** air speeds up over the curved upper surface, and faster air has lower pressure. Higher pressure underneath pushes the wing up.
- **Newton:** the wing deflects air downward (downwash). The equal and opposite reaction pushes the wing up. Both explanations describe the same thing.
- The pilot controls lift mostly with **angle of attack** (pitch) and **airspeed** (power). Flaps raise the coefficient of lift so the wing can fly slower.

Drag

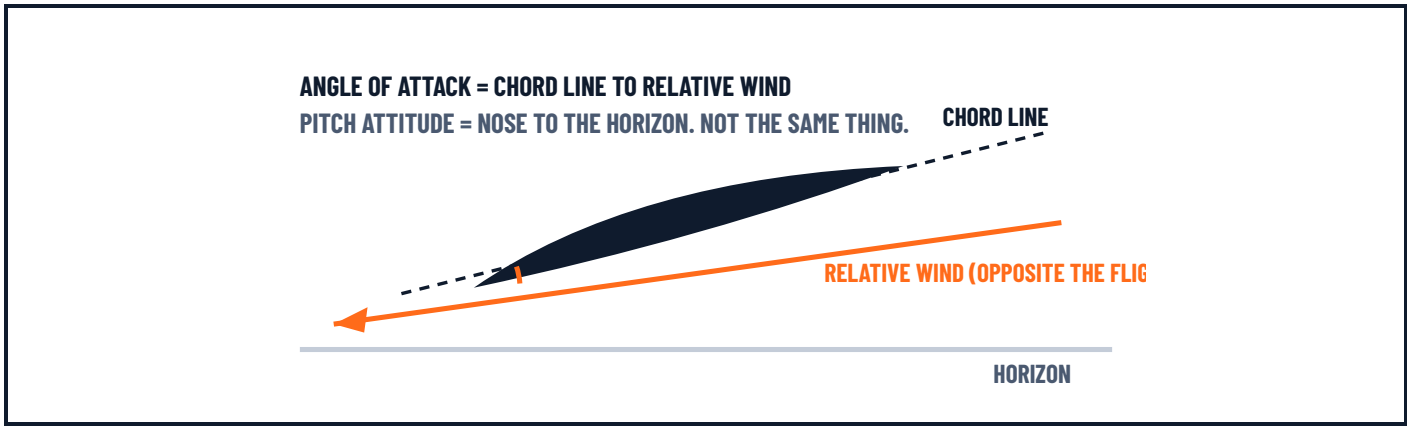
- **Parasite drag** is everything that isn't making lift: form drag (shape), skin friction, and interference drag where parts meet. It rises with the **square of airspeed**.
- **Induced drag** is the price of making lift. Wingtip vortices tilt the lift backward. It is highest at **low airspeed and high angle of attack**, and falls as speed rises.
- **Total drag is lowest where the two curves cross.** That point is L/D max: the most lift for the least drag. It gives the best glide range and roughly the best range. In our Cherokee that is **best glide, 80 mph** at gross.
- Our Cherokee's fixed gear, struts and wheel fairings add parasite drag. Without the wheel fairings, the POM says expect about 3 mph less cruise.

Thrust and weight

- **Thrust** comes from the propeller. With a fixed-pitch prop, more throttle means more RPM and more thrust.
- **Weight** acts at the center of gravity (CG), always straight down toward the center of the earth. Fuel burn reduces it during the flight.

ANGLE OF ATTACK, STALLS AND SPINS

The wing stalls at its critical angle of attack. Airspeed and attitude don't decide it: angle of attack does.



Stalls

- **Angle of attack** is the angle between the wing's chord line and the relative wind. **Pitch attitude** is the angle between the nose and the horizon. In a steep descent you can be nose-low and still stalled.
- Every wing stalls at its **critical angle of attack**, typically 16–20° for a light airplane. Past it, the airflow separates from the top of the wing and lift drops off.
- **You can stall at any airspeed and in any attitude.** Pull hard enough and you reach the critical angle at high speed. That is an accelerated stall.
- **Recovery always starts the same way: reduce the angle of attack.** Forward on the yoke, then full power, wings level, climb.
- Our Cherokee's published stall speeds (at gross, power off): **64 mph flaps up (Vs1), 55 mph full flaps (Vso).** The stall warning light and horn come on about 5–10 mph before the stall.
- The Cherokee's constant-chord "Hershey bar" wing stalls at the root first, so the ailerons keep working into the stall. That makes it gentle and predictable. It does sink fast if you get slow with full flaps and no power.

Load factor raises stall speed

- **Stall speed goes up with the square root of the load factor.** A level 60° bank is 2 g, and the square root of 2 is about 1.41, so stall speed rises about 41%.
- Our Cherokee's flaps-up stall speeds in a level turn, from the POM:

Bank angle	Load factor	Stall speed (mph)
0°	1.0 g	64
20°	1.06 g	66
40°	1.31 g	73
50°	1.56 g	80
60°	2.0 g	91

- This is why a steep, slow turn from base to final is dangerous. Keep pattern turns shallow and the airspeed up.

Spins

- **A spin is a stall plus yaw.** One wing is more deeply stalled than the other, and the airplane autorotates.
- Uncoordinated flight at low speed is the setup: a skidding turn to final with too much rudder is the classic case.
- **Recovery (PARE):** Power idle, Ailerons neutral, Rudder full opposite the rotation, Elevator (here, the stabilator) forward briskly. Neutralize the rudder when the rotation stops and pull out smoothly.
- **Intentional spins are prohibited in the normal category.** Check the POM for what is allowed in the utility category in our airplane. Private pilots learn spin awareness, not spins.

STABILITY AND CONTROL

A stable airplane tends to return to where it was after a bump. The Cherokee is stable and easy to trim, with a few differences from a high-wing trainer.

The three axes

Axis	Motion	Control	Stability comes from
Longitudinal (nose to tail)	Roll	Ailerons	Dihedral, keel effect
Lateral (wingtip to wingtip)	Pitch	Stabilator (elevator)	CG ahead of the center of lift, balanced by the tail's downforce
Vertical (top to bottom)	Yaw	Rudder	The vertical fin (weathervaning)

- **Longitudinal stability** (pitch) depends on the CG being ahead of the center of lift. The tail pushes down to balance it.
- **Lateral stability** (roll) comes from **dihedral**: the Cherokee's wings angle up from the root. A low-wing airplane needs more dihedral than a high wing, which gets some of its roll stability from the fuselage hanging below it.
- **Directional stability** (yaw) comes from the vertical fin, which weathervanes the nose back into the relative wind.

CG effects

- **Forward CG:** more stable, needs more tail-down force, higher stall speed, slower cruise, harder to flare (you can run out of up-stabilator).
- **Aft CG:** less stable, lighter in pitch, lower stall speed, slightly faster cruise, and harder stall and spin recovery. Beyond the aft limit it may not recover at all.
- Load inside the envelope every time. See Cherokee Weight and Balance.

The stabilator and anti-servo tab

- Instead of a fixed stabilizer with a hinged elevator, the Cherokee's whole horizontal tail moves. That is a **stabilator**. It is powerful, so it is light and sensitive.
- An **anti-servo tab** on the trailing edge moves the **same way** as the stabilator. It adds resistance as you deflect it, so you get a natural feel and don't overcontrol.
- The trim wheel between the seats moves the anti-servo tab to set the neutral point. Trim to take the pressure off the yoke, not to fly the airplane.
- On preflight, the tab should move in the same direction as the stabilator's trailing edge.

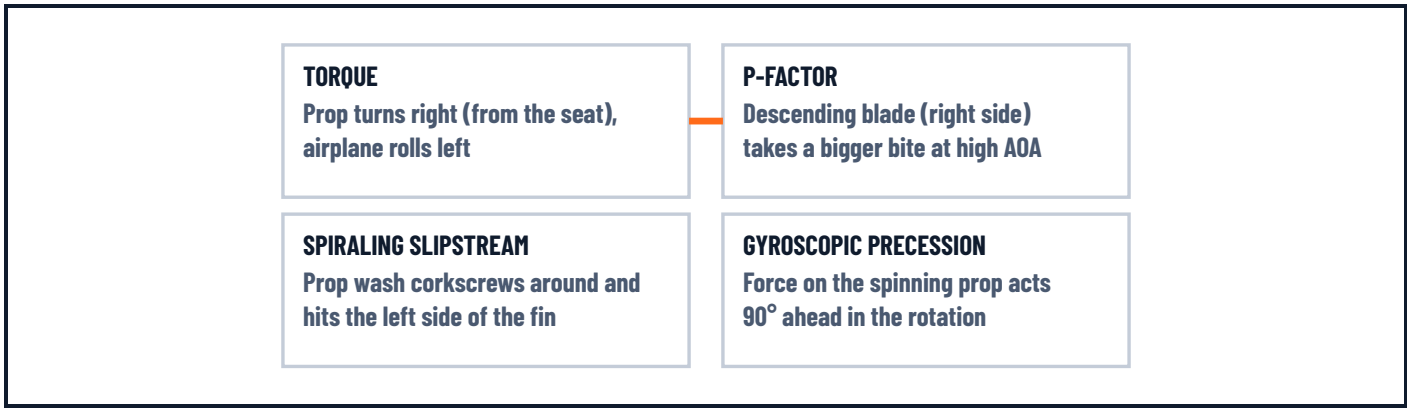
Ground effect

- Within about one wingspan of the ground, the ground blocks the wingtip vortices and downwash. Induced drag drops and lift goes up.
- A **low wing sits closer to the ground**, so the Cherokee feels ground effect strongly. Carry extra speed on landing and it **floats** a long way.
- On takeoff the airplane can lift off in ground effect **before it can climb out of it**. On a soft field that is the technique: lift off, level off in ground effect and accelerate to Vx or Vy. Pull up too early and it settles back.

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LEFT-TURNING TENDENCIES

At high power and low airspeed, the airplane wants to turn left. Right rudder fixes it. On climbout in the Cherokee you hold right rudder.



- **Torque:** the engine turns the propeller clockwise as seen from the cockpit. By Newton's third law the airplane tries to roll left. Strongest at high power.
- **P-factor (asymmetric thrust):** at high angle of attack the descending blade, on the right, meets the air at a bigger angle and makes more thrust than the ascending blade. The thrust center moves right and the nose yaws left. Strongest at **high power, low speed, high angle of attack**: climbout.
- **Spiraling slipstream:** the prop wash spirals around the fuselage and strikes the left side of the vertical fin, yawing the nose left.
- **Gyroscopic precession:** a force on the spinning prop disc acts 90° later in the direction of rotation. It matters most when the nose pitches suddenly, as when a **tailwheel** airplane raises its tail on takeoff. In a tricycle-gear Cherokee it is minor.
- **What you do:** right rudder whenever power is high and speed is low. Keep the ball centered.

LOAD FACTOR AND MANEUVERING SPEED

Load factor is the lift divided by the weight, in g. Turns, pull-ups and gusts raise it. The structure has limits, and so does the stall speed.

- **Level turn load factor:** 30° bank is 1.15 g, 45° is 1.41 g, 60° is 2 g. Past 60° it climbs very fast.
- **Limit load factors** (the most the structure is designed to take without damage):

Category	Positive	Negative
Normal	+3.8 g	−1.52 g
Utility	+4.4 g	−1.76 g

- **Maneuvering speed (Va)** is the speed at or below which a full, abrupt control input (or a big gust) stalls the wing before it can overstress the structure. Our Cherokee's Va is **129 mph at 2,150 lb**.
- **Va gets lower as the airplane gets lighter.** A lighter airplane reaches the stalling angle of attack at a higher g, so the wing can make more g before it stalls. Rule of thumb: Va drops by about half the percentage of weight reduction.

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- **In turbulence:** slow to Va or a little below. Stay out of the yellow arc (above 140 mph, Vno) unless the air is smooth.
- **Va is not full protection.** Full deflection in more than one axis, or alternating inputs, can still overload the structure below Va.

DENSITY ALTITUDE AND PERFORMANCE

High, hot and humid air is thin. The wing makes less lift, the engine makes less power and the propeller makes less thrust.

- **Density altitude** is pressure altitude corrected for non-standard temperature. Hot days make it much higher than the field elevation.
- A 150 hp fixed-pitch airplane feels it fast: longer takeoff roll, slower climb, higher true airspeed for the same indicated airspeed on approach (so a longer landing).
- The POM's performance charts use density altitude and weight. Add a safety margin to book numbers: they were set by a test pilot in a new airplane.
- **Humidity** lowers air density too. It isn't in the charts, so add more margin on muggy summer days.
- Formulas and a worked example are in the Cross-Country Planning Aid. Weight is the other half of performance: see Cherokee Weight and Balance.

THE ENGINE

Our Cherokee has a Lycoming O-320-E3D: four cylinders, horizontally opposed, air-cooled, carbureted, 150 hp at 2,700 RPM, driving a fixed-pitch Sensenich propeller.

The four-stroke cycle

1. **Intake:** the piston moves down and pulls in the fuel-air mixture.
2. **Compression:** the piston moves up and squeezes the mixture.
3. **Power:** the spark plugs fire, the mixture burns, and the expanding gas pushes the piston down.
4. **Exhaust:** the piston moves up and pushes the burned gas out.
5. Memory aid: **suck, squeeze, bang, blow.**

Ignition: magnetos

- Two **magnetos** make their own electricity from engine rotation. They don't need the battery or alternator. Each fires one of the two spark plugs in every cylinder.
- Two independent systems give redundancy and burn the mixture more completely.
- **Run-up mag check:** each mag alone should drop RPM a little, within the POM limits (Cherokee: 175 RPM max drop, 50 RPM max difference at 2,000 RPM). **No drop at all** may mean a mag isn't grounding.
- **Hot mag / broken P-lead:** the P-lead grounds a magneto when it's switched off. If it breaks, that mag stays "hot" with the key off, and the propeller can start the engine if someone moves it. **Always treat a propeller as live.** Before shutdown, a quick dead-cut check (key briefly to OFF at idle) shows whether the mags ground. Do it only if your CFI teaches it.

Mixture and the carburetor

- The **mixture** control sets the fuel-to-air ratio. Air gets thinner as you climb, so the mixture gets too rich unless you **lean** it.
- To lean in cruise: pull the mixture until the engine roughens, then enrich until smooth. Full rich for takeoff and landing at our low-elevation fields.
- Too rich: rough running, fouled plugs, wasted fuel. Too lean: overheating and detonation.
- The **float-type carburetor** meters fuel through a venturi. Fuel evaporation and the venturi's pressure drop can cool the air by up to about 70 °F.
- **Carburetor icing** can form at outside temperatures from about **20 °F to 70 °F** in high humidity, even in clear air, and is most likely at **low power**. First sign with a fixed-pitch prop: a **slow loss of RPM**, then roughness.
- **Carb heat** routes unfiltered, heated air to the carburetor. Applying it causes a small RPM drop (less dense air). If ice was there, RPM drops, roughens, then rises as the ice melts.

Abnormal combustion

	Detonation	Preignition
What it is	The mixture explodes instead of burning evenly	The mixture ignites before the spark plug fires
Causes	Too-low fuel grade, too lean, high power with high cylinder temps, overheating	Hot spots in the cylinder: carbon deposits, a glowing plug
What you notice	Rising temperatures, roughness, loss of power (often not heard)	Roughness, power loss, high temperatures
What you do	Enrich the mixture, reduce power, lower the nose for cooling air	Enrich, reduce power, land

Fuel grades and oil

- **100LL is blue.** Jet A is clear or straw-colored and smells like kerosene. Jet A in a piston engine causes detonation and engine failure. Check the color in every sump sample.
- Never use a lower grade than the engine is approved for. A higher approved grade is acceptable in a pinch.
- **The oil system** lubricates, cools, seals and cleans. Check the oil before every flight (Cherokee: 8 quarts maximum). Low oil pressure with rising temperature means land soon.
- Engine temperature is mostly cooled by air through the cowling. The Cherokee has **no cowl flaps**: on long climbs, use a cruise climb (100 mph) for more cooling air.

The fixed-pitch propeller

- The blade angle can't change, so **RPM is your power gauge.** Throttle up, RPM up.
- The propeller is a compromise between climb and cruise. In a dive, RPM can rise past the redline (2,700): reduce throttle.
- Full-throttle **static RPM** on the ground should be in the POM range (2,275–2,425). Lower than that means a sick engine or a bad tachometer. Abort the takeoff.

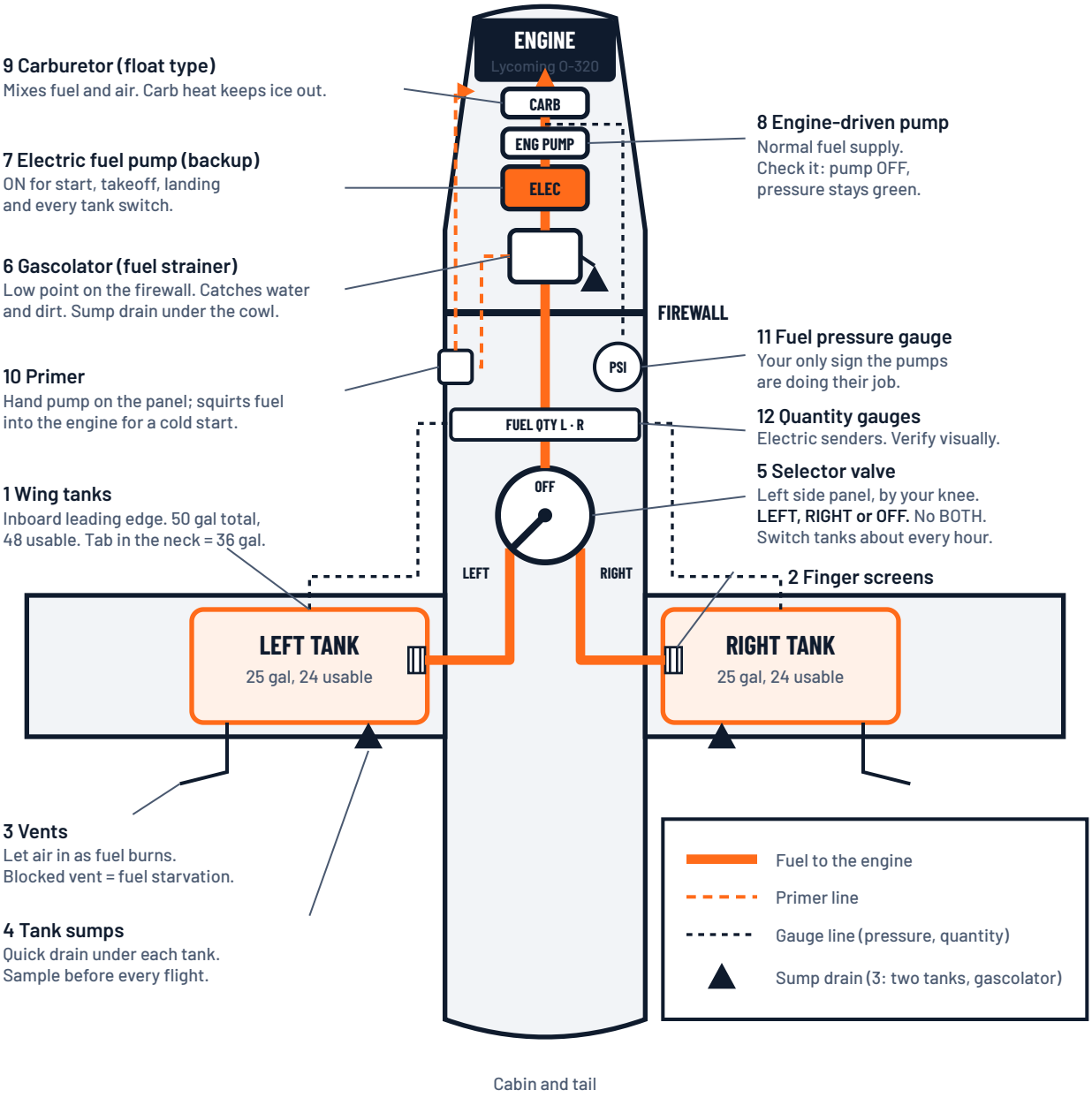
FUEL SYSTEM

The Cherokee's fuel system is where a 172 pilot most needs new habits. Two wing tanks feed one at a time through a selector, with two fuel pumps.

- **Two 25-gallon tanks**, one in each wing's inboard leading edge, 50 gallons total and 48 usable.
- **Selector: LEFT, RIGHT or OFF.** There is no BOTH. You manage one tank at a time and switch about every hour.
- **Fuel pumps:** an **engine-driven pump** feeds the engine normally. An **electric boost pump** is the backup. Turn it **on for takeoff, landing and every tank switch**, and watch fuel pressure when you turn it off.
- **Fuel is pumped, not gravity-fed.** A low wing puts the tanks below the engine, so without a working pump the engine starves.
- **Gascolator:** a filter bowl at the low point of the system, on the firewall, that collects water and sediment. Sump it with each tank selected in turn.
- **Sumps:** three points on a typical Cherokee 140: each tank drain and the gascolator. Look for blue fuel with no water or debris.
- **Vents:** each tank is vented so air replaces the fuel as it burns. A blocked vent can starve the engine. Check the vents on preflight.
- **Unporting:** in a long slip or skid with a partly empty tank, fuel can slosh away from the outlet and the engine can stumble. Avoid long slips on a low tank.

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Fuel system diagram



Schematic, not to scale, drawn from the usual PA-28-140 layout. Check the order of the pumps and where the primer and pressure gauge connect against the fuel system diagram in our POM.

ELECTRICAL SYSTEM

The electrical system runs the starter, radios, lights, electric fuel pump, fuel gauges and stall warning. The engine does not need it: the magnetos keep the engine running.

- A typical Cruiser has a **14-volt** system with an engine-driven **alternator** and a 12-volt **battery**. Confirm against the POH and the airplane.

- **Master switch:** turns on the battery and alternator field. Some airplanes have a split master (BAT and ALT halves); others a single switch. Check how ours is set up.
- **Ammeter or load meter:** shows whether the alternator is charging. A discharge or zero reading in flight means the alternator isn't charging and you're on the battery.
- **Annunciator lights:** the 1975 Cruiser has ALT, OIL and VAC lights with a press-to-test.
- **Circuit breakers** protect each circuit. If one pops, wait a few minutes and reset it **once**. If it pops again, leave it.
- **Overvoltage relay:** trips the alternator off if voltage gets too high.
- **If the electrical system fails:** the engine keeps running on the magnetos. You lose radios, transponder, electric fuel pump, lights, the stall-warning light, the fuel gauges, and (typically) the turn coordinator. Shed load early to make the battery last, and land at the nearest suitable airport.

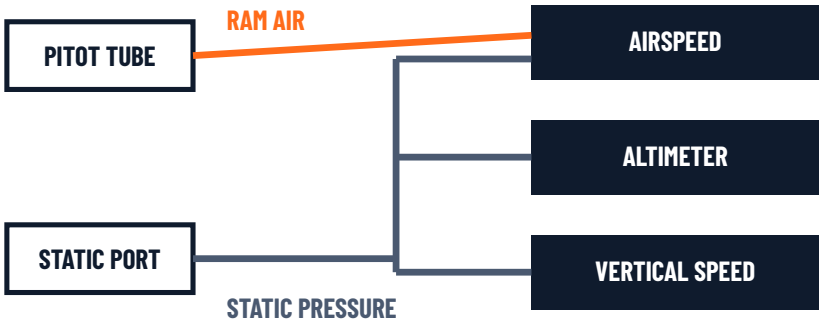
VACUUM SYSTEM AND GYRO INSTRUMENTS

An engine-driven vacuum pump spins the attitude and heading indicators. The turn coordinator is typically electric, so a single failure doesn't take all three.

- **Vacuum:** normal is 5.0 ± 0.1 in. Hg at 2,000 RPM in our Cherokee. The VAC light below about 1,000 RPM is normal.
- **Attitude indicator:** a gyro spinning in the horizontal plane shows pitch and bank. It uses **rigidity in space**.
- **Heading indicator:** a gyro spinning in the vertical plane. It doesn't sense north. Friction makes it **precess** (drift), so **reset it to the magnetic compass about every 15 minutes**, in straight and level, unaccelerated flight.
- **Turn coordinator:** shows rate of roll and rate of turn; the ball shows coordination. Typically electric, as a backup to the vacuum instruments.
- **Vacuum failure signs:** low suction, the VAC light, the attitude indicator slowly tipping or the heading indicator spinning. **Cover the failed instruments** and fly by the turn coordinator, compass, airspeed and altimeter (and a backup attitude source if you have one).

PITOT-STATIC INSTRUMENTS

The airspeed indicator, altimeter and vertical speed indicator all use static (outside) pressure. Only the airspeed indicator also uses the pitot tube.



- **Airspeed indicator:** compares pitot (ram) pressure with static pressure.
- **Altimeter:** an aneroid wafer expands and contracts with static pressure. Set it to the local altimeter setting (Kollsman window).
- **Vertical speed indicator:** compares current static pressure with pressure trapped behind a calibrated leak. It shows trend immediately and rate after a 6–9 second lag.
- On our Cherokee the **pitot tube is under the left wing**. The static port is on the fuselage. Cover off and holes clear on preflight.

Blockages

Blocked	Airspeed	Altimeter	VSI
Pitot tube only (drain hole open)	Drops to zero	Normal	Normal
Pitot tube and drain hole	Acts like an altimeter: reads high in a climb, low in a descent	Normal	Normal
Static port	Reads low in a climb, high in a descent	Frozen at the altitude where it blocked	Stuck at zero

- **Pitot heat** prevents icing in the tube, if installed. Our flying is VFR, out of visible moisture.
- **Alternate static source**, if installed: it draws from inside the cabin, where pressure is a little lower. Altimeter and airspeed read slightly high, and the VSI may jump briefly. If none is installed, breaking the VSI glass is the textbook last resort. Check what our airplane has.

Altimeter errors

- **"High to low, look out below."** Flying from high pressure to low pressure without resetting, the altimeter reads higher than you are. About 10 ft per 0.01 inHg.
- **Hot to cold, look out below** too. In air colder than standard, you are lower than the altimeter shows.
- **Types of altitude:** indicated (what it shows), pressure (set to 29.92), density (pressure altitude corrected for temperature), true (above sea level), absolute (above the ground).

MAGNETIC COMPASS ERRORS

The compass is the only direction instrument that needs no power. It has errors you must know for the test and use when the heading indicator fails.

- **Variation:** the difference between true north and magnetic north. Read it from the isogonic lines on the sectional (about 7° W at KONZ). "East is least, west is best."
- **Deviation:** error from the airplane's own magnetic fields: radios, wiring, engine. Read the **compass correction card** near the compass.
- **Magnetic dip** causes two errors in the Northern Hemisphere:
  - **Northerly turning error (UNOS: Undershoot North, Overshoot South).** Turning from a northerly heading, the compass first lags or swings the wrong way. Roll out before north and after south.
  - **Acceleration error (ANDS: Accelerate North, Decelerate South).** On an east or west heading, accelerating swings the compass toward north and decelerating toward south.
- **Oscillation:** the card swings in turbulence. Read the average.
- Read the compass only in **straight, level, unaccelerated flight**.

LANDING GEAR AND BRAKES

The Cherokee has fixed tricycle gear: two mains and a steerable nosewheel. Simple and tough, with a few differences from a 172.

- **Oleo struts** (air and oil) cushion all three wheels. On preflight, typical extension is about 4.5 in. on the mains and 3.25 in. on the nose. Check for leaks.
- **Nosewheel steering** is linked to the rudder pedals. A shimmy damper stops the nosewheel from oscillating.
- **Brakes:** hydraulic disc brakes on the mains. Use the **toe brakes** for differential braking in tight turns. A **hand brake lever** applies both brakes and sets the parking brake.
- Keep your feet low on the pedals for steering and slide them up only when you want brakes. Riding the brakes on taxi wears them out and overheats them.

SELF-CHECK

Tap a question to see the answer. Then find it in the section above.

What four things does lift depend on?

Air density, the square of airspeed, wing area, and the coefficient of lift, which the pilot controls mostly with angle of attack and flaps.

Which kind of drag increases as airspeed decreases?

Induced drag. Parasite drag increases with airspeed.

– What is L/D max and what speed is it in our Cherokee?

The angle of attack with the least total drag for the lift made. It gives the best glide, 80 mph at gross in the Cruiser.

– Can a wing stall at high airspeed?

Yes. A wing stalls when it exceeds its critical angle of attack, at any airspeed or attitude. An abrupt pull at high speed causes an accelerated stall.

– What is our Cherokee's stall speed in a level 60° bank, flaps up?

About 91 mph, compared with 64 mph wings level. A 60° bank is 2 g, and stall speed rises with the square root of load factor (about 41%).

– What does an aft CG do to stability and stall recovery?

It makes the airplane less stable in pitch and makes stall and spin recovery harder. Past the aft limit, recovery may not be possible.

– Which way does the anti-servo tab move, and why?

The same way as the stabilator's trailing edge. It adds control force so the powerful stabilator doesn't feel too light.

– Name the four left-turning tendencies.

Torque, P-factor, spiraling slipstream and gyroscopic precession. Right rudder corrects them.

– Why does maneuvering speed go down when the airplane is lighter?

A lighter airplane needs less angle of attack for the same lift, so a full control input produces more g before the wing stalls. To stay within the load limit, it has to fly slower.

– What is the first sign of carburetor ice in a fixed-pitch airplane?

A gradual loss of RPM, then roughness. Apply full carb heat and expect it to run rougher before it improves.

– What is the difference between detonation and preignition?

Detonation is the mixture exploding instead of burning evenly, often from a lean mixture or high temperatures. Preignition is the mixture igniting before the spark, from a hot spot.

– What does a broken P-lead mean?

That magneto can't be grounded, so it stays "hot" with the key off. The engine can fire if someone moves the propeller.

– Why is the Cherokee's electric fuel pump on for takeoff and landing?

The tanks are below the engine, so fuel must be pumped. The electric pump backs up the engine-driven pump during the phases where an engine failure is most dangerous, and during tank switches.

– The static port is blocked in a climb. What do the instruments show?

The altimeter freezes, the VSI reads zero, and the airspeed indicator reads lower than actual in the climb (higher in a descent).

– Turning north from a southerly heading in the Northern Hemisphere, when do you roll out on the compass?

Before reaching north on the compass (Undershoot North). Turning south, roll out after south (Overshoot South).

SOURCES

- FAA Pilot's Handbook of Aeronautical Knowledge (FAA-H-8083-25), chapters 4–8: aerodynamics, flight controls, aircraft systems and flight instruments.
- FAA Airplane Flying Handbook (FAA-H-8083-3).
- Piper PA-28-140 Cherokee Cruiser Pilot's Operating Manual 761 555: speeds, limits, systems and procedures.
- Confirm every Cherokee-specific system detail against the POH and the airplane itself. Our airplane may have been modified since it left the factory.

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