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.

PERFORMANCE AND WEIGHT AND BALANCE

Private pilot knowledge test · Performance · Weight and balance

HOW TO USE THIS GUIDE

The knowledge test gives you charts and tables and asks you to read them. Real flying asks the same thing of the POH. This guide teaches the method, with worked examples, and uses our Cherokee 140 as the running example.

- **Our Cherokee's numbers** come from the 1975 PA-28-140 Cruiser manual (POM 761 555). **Check every one against the POH in the airplane.**
- **Example numbers** that are not from the POH are marked as examples. They are made up to show the method.
- For the real load sheet, use the Cherokee Weight and Balance calculator. For trip fuel, see the Cross-Country Planning Aid.

Our Cherokee (check the POH)	Value
Max gross weight	2,150 lb (normal category)
Usable fuel	48 gal (50 total)
Takeoff ground roll, 2,150 lb, sea level, standard day	800 ft
Takeoff over a 50 ft obstacle	1,700 ft
Rate of climb at Vy	631 fpm
Landing roll	535 ft
Stations (in aft of datum)	Front seats 85.5 · rear seats 117.0 · fuel 95.0 · baggage 117.0
CG envelope (normal)	Forward 84.0 in at 1,650 lb or less, 85.9 at 1,975 lb, 88.4 at 2,150 lb; aft 95.9 in

ATMOSPHERE AND DENSITY ALTITUDE

The airplane doesn't care how high the field is. It cares how thick the air is. Density altitude is the altitude in the standard atmosphere where the air would be as thin as it is today.

The standard atmosphere (ISA)

- Sea level: **15 °C** and **29.92 inHg**.
- Temperature drops about **2 °C per 1,000 ft**.
- Pressure drops about **1 inHg per 1,000 ft** down low.

Pressure altitude

Pressure altitude = field elevation + (29.92 – altimeter setting) × 1,000.

- Setting below 29.92: pressure altitude is higher than the field.
- Setting above 29.92: pressure altitude is lower than the field.
- In the airplane: set 29.92 in the Kollsman window and read the altimeter.

Density altitude

Density altitude ≈ pressure altitude + 120 × (OAT – ISA temperature).

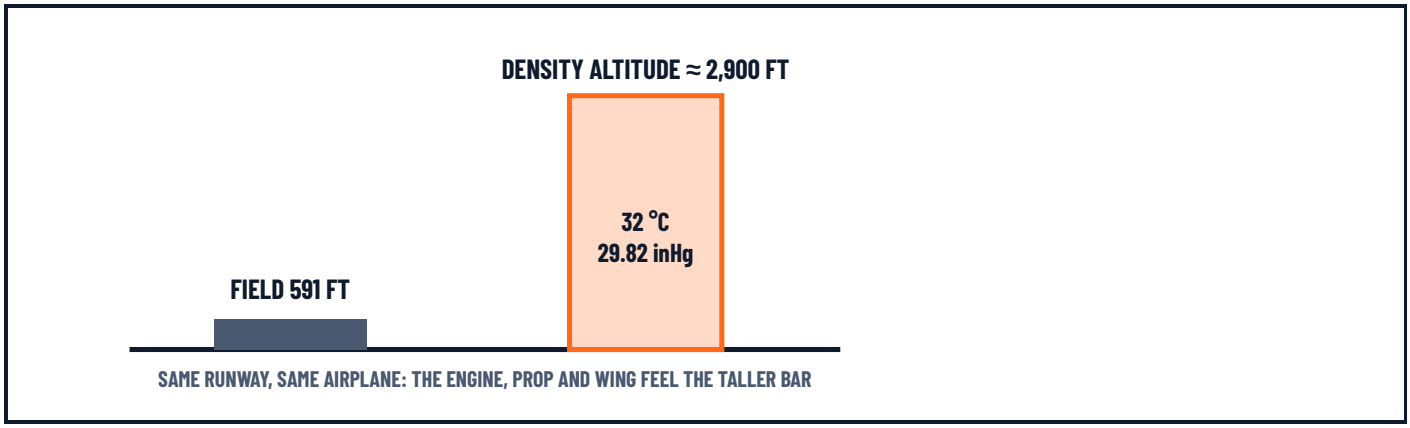
- ISA temperature at an altitude ≈ 15 – 2 × (pressure altitude ÷ 1,000) °C.
- The FAA test usually wants you to use the density altitude chart. The formula gets you close and lets you check your chart answer.
- **Humidity** makes air less dense too. Water vapor is lighter than dry air. The formula and most charts ignore it, so a humid summer day is worse than the number says.

Worked example: KONZ on a hot day

KONZ is 591 ft. Altimeter 29.82, temperature 32 °C (90 °F).

1. Pressure altitude = 591 + (29.92 – 29.82) × 1,000 = 591 + 100 = **691 ft**.
2. ISA at 691 ft ≈ 15 – 2 × 0.691 = **13.6 °C**.
3. Density altitude ≈ 691 + 120 × (32 – 13.6) = 691 + 120 × 18.4 = 691 + 2,208 ≈ **2,900 ft**.

On a field that sits under 600 ft, the airplane performs as if it were near 2,900 ft, before you count the humidity.



What high density altitude does

- **Less power.** A normally aspirated engine like our O-320 makes less power in thin air.
- **Less thrust.** The prop has less air to bite.
- **Less lift at a given true airspeed.** The wing needs more true airspeed for the same indicated airspeed.
- **Result:** a longer takeoff roll, a lower climb rate and a faster true airspeed on approach, so a longer landing roll. Indicated airspeeds for rotation, climb and approach stay the same.
- **Lean for best power** before a high-density-altitude takeoff if the POH allows it. Ask your CFI how we do this in our Cherokee.

READING PERFORMANCE CHARTS

The test uses two kinds of charts: tables you read and interpolate, and graphs you trace with a pencil. Work slowly, write each step down and check that the answer makes sense.

Tables and interpolation

When your value falls between two rows, interpolate: find how far between the rows you are, and go that far between the answers.

Example table (made-up numbers to show the method):

Pressure altitude	Ground roll at 2,150 lb, 15 °C
Sea level	800 ft
2,000 ft	960 ft
4,000 ft	1,150 ft

Question: ground roll at a pressure altitude of 1,000 ft?

1. 1,000 ft is halfway between sea level and 2,000 ft.
2. The difference in the answers is 960 − 800 = 160 ft.
3. Halfway is 80 ft. 800 + 80 = **880 ft**.

Question: at 2,500 ft?

1. 2,500 is one quarter of the way from 2,000 to 4,000.
2. Difference: 1,150 − 960 = 190 ft. A quarter is 47.5 ft.
3. 960 + 47.5 ≈ **1,008 ft**.

If a table has two variables (altitude and temperature), interpolate one, then the other. Round only at the end.

Graph charts with reference lines

Takeoff and landing graphs are read left to right through several panels.

1. Start with **temperature** on the bottom. Go up to your **pressure altitude** line.

2. Go straight across to the first **reference line** (the weight panel). Follow the curved guide lines down or up to your **weight**.
3. Go across to the next reference line (the wind panel). Follow the guide lines for your **headwind or tailwind**.
4. Some charts have a last panel for **obstacle height**. Go across and read the answer.
5. Keep your pencil line exactly parallel to the guide lines between reference lines.
6. If your answer goes the wrong way (heavier airplane, shorter roll), you followed a guide line backwards.

Wind corrections

Many tables give a rule in a note. A common style is: **decrease the distance 10% for each 9 kt of headwind** and **increase it 10% for each 2 kt of tailwind**. Use the note on the chart in front of you, not a remembered rule.

- **Example:** table distance 800 ft, 9 kt headwind. 10% of 800 is 80. 800 – 80 = **720 ft**.
- A tailwind costs far more than a headwind saves.

Crosswind and headwind components

The crosswind chart has the wind angle from the runway on curved lines and the wind speed on arcs. Find where they meet, then read straight down for crosswind and straight across for headwind.

Rule of thumb without the chart: crosswind = wind speed × the sine of the angle.

Angle off the runway	Fraction of the wind that is crosswind
10°	about 1/6
20°	about 1/3
30°	1/2
45°	about 3/4 (0.7)
60° or more	nearly all

Example: KONZ Runway 22 (about 220°), wind 270° at 20 kt. The angle is 50°.

- Crosswind = 20 × sin 50° = 20 × 0.77 ≈ **15 kt**.
- Headwind = 20 × cos 50° = 20 × 0.64 ≈ **13 kt**.
- With Runway 17/35 closed, there's no other runway. Check that against your personal crosswind limit.

TAKEOFF AND LANDING DISTANCE FACTORS

The POH numbers assume a new airplane, a test pilot, a dry paved runway and exact technique. Real numbers are longer.

Factor	Effect
Higher weight	Longer takeoff and landing. Higher takeoff speed needed and more inertia to stop
Higher density altitude	Longer takeoff and landing; lower climb rate
Headwind	Shorter. Lower groundspeed at liftoff and touchdown
Tailwind	Much longer. Avoid it
Uphill slope	Longer takeoff, shorter landing
Downhill slope	Shorter takeoff, longer landing
Grass, gravel or soft surface	Longer takeoff. Dry grass adds a lot; wet or long grass adds more
Wet or icy pavement	Longer landing, poor braking
Wrong speed on final	Every 10% too fast adds about 20% to the landing distance

- **Our habit:** add **at least 50%** to the book takeoff and landing distances, more for grass, wet runways or a hot day.
- **Example in our Cherokee:** book takeoff over a 50 ft obstacle is 1,700 ft at 2,150 lb, sea level, standard day. With the 50% margin, plan on about **2,550 ft** before density altitude. KONZ Runway 4/22 is 4,846 ft, but Runway 22's threshold is displaced 428 ft, which matters for landing distance, not takeoff.

CLIMB, CRUISE AND RANGE

Climb and cruise charts answer two questions: how fast can I climb, and how far can I go.

Climb speeds

- **Vx** (best angle) gives the most altitude per distance. Use it to clear obstacles. Our Cherokee: **78 mph**.
- **Vy** (best rate) gives the most altitude per minute. Our Cherokee: **89 mph**, about 631 fpm at gross, sea level.
- As altitude rises, **Vx (indicated) increases slightly and Vy (indicated) decreases.** They meet at the **absolute ceiling**, where the airplane can't climb at all.
- **Service ceiling** is where the best climb rate drops to 100 fpm. Our Cherokee's book figure is about 10,950 ft.

Cruise tables

A cruise table lists, for a pressure altitude and temperature, the RPM, percent power, true airspeed and fuel flow.

1. Find your pressure altitude row and temperature column.

2. Read the RPM for the power you want (for example 65% or 75%).
3. Read the true airspeed and fuel flow. Interpolate if needed.
4. At the same percent power, **true airspeed goes up as you climb**, because the air is thinner.

Endurance versus range

- **Maximum endurance:** the longest time aloft. The lowest fuel flow that keeps you flying, slower than best glide speed.
- **Maximum range:** the farthest distance. Near the speed for best lift-to-drag ratio, adjusted for wind. Slow down a bit in a tailwind and speed up a bit in a headwind.
- **Fuel:** 100LL weighs **6 lb per gallon**. Our 48 usable gallons weigh 288 lb. Plan the trip and the reserve in the Cross-Country Planning Aid.

WEIGHT AND BALANCE FUNDAMENTALS

Weight and balance is arithmetic. If you set it up neatly, it is hard to get wrong.

Terms

Term	Meaning
Datum	The reference point all arms are measured from. Our Cherokee's datum is 78.4 in ahead of the wing leading edge
Arm (station)	Distance from the datum, in inches. Aft of the datum is positive
Moment	Weight × arm, in pound-inches
Moment index	Moment ÷ 1,000 (or ÷ 100). Keeps the numbers small. Check which the chart uses
CG	Total moment ÷ total weight
Basic empty weight	The airplane, unusable fuel and full oil (modern standard). Older records may use "licensed empty weight", which leaves out most of the oil. Check the record
Useful load	Max gross weight minus basic empty weight: people, bags and usable fuel
Payload	People and bags only, after fuel
Standard weights	Avgas 6 lb/gal, oil 7.5 lb/gal (about 1.9 lb per quart), water 8.35 lb/gal

The method

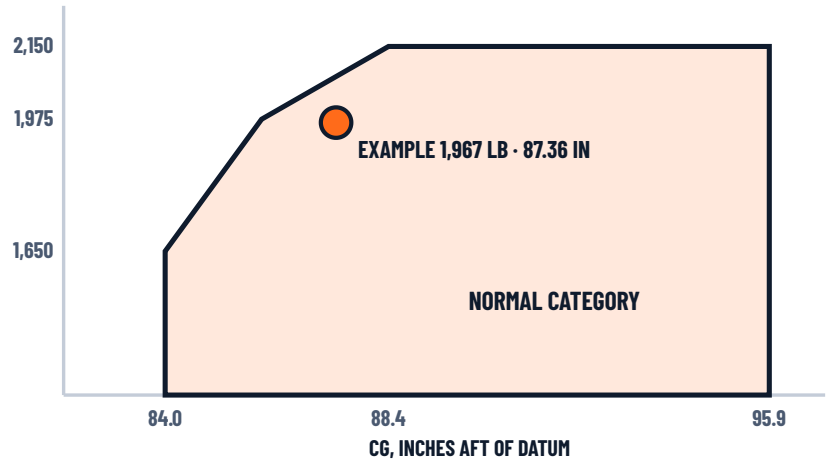
1. List every item: empty airplane, front seats, rear seats, baggage, fuel.
2. Write each weight and arm. Multiply for the moment.
3. Add the weights. Add the moments.
4. Divide total moment by total weight for the CG.
5. Check total weight against max gross and the CG against the envelope at that weight.
6. Do it again for landing, with the fuel you'll burn removed.

Worked load sheet

Our Cherokee's empty weight from the 2006 record is 1,391 lb. **The 86.2 in empty CG arm below is a made-up example**; use the arm on the airplane's current record.

Item	Weight (lb)	Arm (in)	Moment (lb-in)
Basic empty weight (example arm)	1,391	86.2	119,904
Pilot and front passenger	340	85.5	29,070
Rear seats	0	117.0	0
Baggage	20	117.0	2,340
Fuel, 36 gal × 6	216	95.0	20,520
Takeoff total	1,967	| 171,834	

- CG = 171,834 ÷ 1,967 = **87.36 in.**
- **Forward limit at 1,967 lb:** between 84.0 at 1,650 and 85.9 at 1,975. 1,967 is 317 lb above 1,650, out of 325 lb, so the limit is 84.0 + (317 ÷ 325) × 1.9 ≈ **85.85 in.**
- **Aft limit:** 95.9 in. 87.36 is inside. 1,967 lb is 183 lb under max gross. **Within limits.**
- **Moment index** (÷1,000) for the takeoff total: 171.8.



The Cherokee Weight and Balance calculator does this math and plots both points for you.

WEIGHT SHIFT AND WEIGHT CHANGE PROBLEMS

The test likes two kinds of problem: moving weight that's already aboard, and adding or removing weight.

Shifting weight

Weight to move = total weight × CG change ÷ distance moved.

- The total weight doesn't change. Only the CG moves.
- **Example:** the airplane weighs 2,000 lb with the CG at 96.4 in, aft of the 95.9 in limit. You want 95.4 in, a change of 1.0 in. Move bags from the baggage area (117.0 in) to the front seats (85.5 in), a distance of 31.5 in.
- Weight to move = 2,000 × 1.0 ÷ 31.5 ≈ **63.5 lb**.
- Check: 63.5 lb × 31.5 in = 2,000 lb-in less moment. 2,000 lb-in ÷ 2,000 lb = 1.0 in further forward.

Adding or removing weight

The safest method is to redo the moments.

- **Add example:** 1,900 lb at 88.0 in (moment 167,200). Add 20 lb of baggage at 117.0 in (moment 2,340).
- New weight = 1,920 lb. New moment = 169,540. New CG = 169,540 ÷ 1,920 ≈ **88.30 in**.
- **Remove example (fuel burn):** from the load sheet above, burn 9 gal (54 lb at 95.0 in, moment 5,130).
- Landing weight = 1,967 – 54 = 1,913 lb. Landing moment = 171,834 – 5,130 = 166,704. CG = 166,704 ÷ 1,913 ≈ **87.14 in**.
- Weight added aft of the CG moves the CG aft. Weight removed aft of the CG moves it forward.

EFFECTS OF CG ON FLIGHT

Being inside the envelope matters for control, not just paperwork.

Forward CG	Aft CG
More stable, harder to rotate and flare	Less stable, light and twitchy in pitch
Higher stall speed: the tail pushes down harder, so the wing carries more load	Lower stall speed, but stall and spin recovery get harder or impossible past the aft limit
Slower cruise, more fuel burned	Slightly faster cruise
May run out of up elevator in the flare	May run out of down elevator for stall recovery

- In our Cherokee, two adults up front with a little fuel is near the forward side at light weights. Rear passengers and bags move it aft quickly, because they sit 31.5 in behind the front seats.
- **Over max gross** is never acceptable, even inside the CG range: longer takeoff, weaker climb and lower structural margins.

USING OUR CALCULATOR

The Cherokee Weight and Balance calculator is set up with our Cherokee's stations and envelope.

- Enter the basic empty weight and CG arm from the current weight and balance record. It leaves the arm blank on purpose.
- Enter people, bags, fuel at takeoff and fuel burned.

- It shows takeoff and landing CG, flags anything over gross or outside the envelope, and plots both points.
- Use the numbers in this guide to check it by hand at least once.

SELF-CHECK

Tap a question to see the answer. Work the math on paper first.

– Field elevation 1,000 ft, altimeter 30.12. What is the pressure altitude?

1,000 + (29.92 – 30.12) × 1,000 = 1,000 – 200 = 800 ft.

– Pressure altitude 2,000 ft, OAT 25 °C. Estimate the density altitude.

ISA at 2,000 ft is 15 – 4 = 11 °C. DA ≈ 2,000 + 120 × (25 – 11) = 2,000 + 1,680 = 3,680 ft.

– Does humidity raise or lower density altitude?

It raises it. Moist air is less dense than dry air, so performance is worse than the dry formula shows.

– High density altitude: what happens to indicated rotation speed, true airspeed and takeoff roll?

Indicated rotation speed stays the same. True airspeed at that indicated speed is higher, so groundspeed at liftoff is higher and the takeoff roll is longer. Climb rate is lower.

– A table gives a landing roll of 535 ft at sea level and 615 ft at 2,000 ft. What is it at 1,000 ft?

Halfway between: 535 + (615 – 535) ÷ 2 = 535 + 40 = 575 ft.

– Book takeoff distance is 1,700 ft. The note says decrease 10% for each 9 kt of headwind. What is it with an 18 kt headwind?

18 kt is two steps of 9 kt, so 20%. 20% of 1,700 is 340. 1,700 – 340 = 1,360 ft.

– Wind is 30° off the runway at 20 kt. What is the crosswind component?

Sine of 30° is 0.5. 20 × 0.5 = 10 kt.

– How do Vx and Vy change as you climb, and where do they meet?

Vx increases slightly and Vy decreases. They meet at the absolute ceiling.

– What is the difference between maximum endurance and maximum range?

Endurance is the most time aloft, at the lowest fuel flow. Range is the most distance, near the best lift-to-drag speed, adjusted for wind.

– How much do 48 gallons of 100LL weigh?

48 × 6 = 288 lb.

– **Empty airplane 1,500 lb at 85.0 in, front seats 300 lb at 85.5 in, fuel 200 lb at 95.0 in. What is the CG?**

Moments: 127,500 + 25,650 + 19,000 = 172,150 lb-in. Weight: 2,000 lb. CG = 172,150 ÷ 2,000 ≈ 86.08 in.

– **The airplane weighs 2,100 lb. You need the CG 0.5 in further forward. How much baggage must move from 117.0 in to the front seats at 85.5 in?**

Distance moved: 117.0 – 85.5 = 31.5 in. Weight = 2,100 × 0.5 ÷ 31.5 ≈ 33.3 lb.

– **What is the moment index of 1,391 lb at 86.2 in, using a reduction factor of 1,000?**

1,391 × 86.2 = 119,904 lb-in. ÷ 1,000 = 119.9.

– **Name two effects of a forward CG.**

Higher stall speed and harder rotation and flare. It also cruises slower and burns more fuel, and is more stable.

– **Why add a margin to the book takeoff and landing distances?**

The book assumes a new airplane, a test pilot, a dry paved runway and perfect technique. Our habit is at least 50% more, and more on grass, wet runways or hot days.

SOURCES

- Pilot's Handbook of Aeronautical Knowledge (FAA-H-8083-25), chapter 10 (Weight and Balance) and chapter 11 (Aircraft Performance).
- Aircraft Weight and Balance Handbook (FAA-H-8083-1).
- FAA Airman Knowledge Testing Supplement for Sport Pilot, Recreational Pilot and Private Pilot (the chart figures the test uses).
- Piper PA-28-140 Cherokee Cruiser Pilot's Operating Manual 761 555: performance figures, stations and the CG envelope.
- The POH and the weight and balance record in the airplane are the authority. Check every number in this guide against them.

Training aid only, not flight instruction. The POH in the airplane and its placards win: check every number against them, and fly with your CFI.