Private, Commercial & Sport Pilot Training Manual

A study guide for pilots and flight instructors

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Introduction: This manual was created as a guide to both instructor and student for flight training in single engine aircraft for private and commercial licenses. Private Pilot Flight training is divided into three phases:

1) Pre solo training- all training required to solo the aircraft
2) Post Solo training- training that leads up to cross-country solo flight
3) Check Ride Prep: review of previous stages of flight training to meet Airmen Certification Standards.

Phases of Training. Each phase of training has a specific syllabus with reference to specific GROUND and FLIGHT training lesson plans. Each referenced lesson plan may be found in the index and appropriate index tab. Each lesson often requires the use of more than one lesson plan (ground and flight). Flight and ground lessons may be arranged to meet student and instructor's needs and current flight conditions. Additionally, each lesson will review important concepts of previous lessons. Specifically emphasizing Aeronautic Decision Making.

Check lists. Each phase of training has a corresponding check list that the instructor should sign off as each goal is achieved documenting the training. This also gives the student pilot an understanding of how far they have progressed through each phase of training.

Instructor responsibility: Review the phases of training, syllabi, and check lists with the student. Assigns students appropriate flight and ground lessons that correspond to the syllabus. Lesson plans should be assigned in advance of the intended lesson to give the student sufficient study time to prepare for the anticipated ground or flight lesson. Provides ground training and flight training appropriate to each phase of training. Provides appropriate endorsements and documentation of training.

Special note to instructor: Documentation of ground training is REQUIRED and may be REQUIRED to be presented at time of check ride. Signing each component of this syllabus in the students' copy can be used as a log to verify training for check rides and legal considerations. Additionally, maintain continuity of training between transitioning instructors and demonstrate positive progress to the students and customers we serve, it is highly recommended that you sign off the training accomplishments listed in the "**Training Requirements and Endorsements**" section listed in the table of contents.

Student Responsibility: Becomes familiar with the training manual, phases of training, lesson plans and check lists. Prepare for each ground and flight lesson with reference to appropriate lesson plans and reference books and materials.

Airman Certification Standards. Is the FAA document that integrates Aeronautical knowledge, flight skills and Aeronautical Decision-Making standards that are required to pass the knowledge test and the practical test. It is available on the FAA website or for purchase at your flight school. *This should be required reading as it outlines the MINIMUM requirements and areas that will be tested to obtain a pilot certificate.* Essentially, it is a list of the questions and maneuvers that will be on the "final exam." Should be used as a syllabus and guide to ensure completion of the knowledge and skill to pass the check ride. It is recommended that this booklet is referenced early in-flight training.

Reference materials: Appropriate reference materials should be used for study to augment the lesson plans and generally, at a minimum, should include:

FAA-H-8083-3C Airplane Flying Handbook, 2021

FAA-H-8083-25C Pilot's Handbook of Aeronautical Knowledge, 2023

Aircraft Information Manual (specific to the aircraft you will be training in)

Federal Aviation Regulations/Aeronautical Information Manual "FAR/AIM"

Airman Certification Standards- Private/Commercial -required reading!

Your flight instructor may recommend additional resources. These are also available on the FAA web site or for purchase at your school. FAR/AIM iPad or phone App from ASA highly recommended.

Airman Knowledge test: is a required multiple choice computer exam to take the check ride for your private pilot certificate. In addition to the ground lessons provided by your flight instructor, you may also enroll in a formal ground school course at the flight school or computerized courses are available (King Schools and Sporty's are popular). I personally like Rod Machado's Private Pilot Ground school online course available at

https://rodmachado.com/products/rod-machados-40-hour-private-pilot-elearning-ground-school

It is recommended that you take advantage of practice test questions which are available via Sporty's, KING Schools, Rod Machados course and ASA. The written test prep questions are available in the actual E courses or as a separate APP for iPad and iPhone for reasonable costs and are quite effective study tools to pass the written FAA multiple choice test. Please consult your flight instructor for further guidance on these learning tools. *NOTE: The computer and web-based courses prepare you for passing the written test ONLY. It does not prepare you for the oral (ground) portion of the practical test with an FAA Designated Pilot Examiner. Most pilots need about 4 hours of study for every hour of flight time.*

Training Course Outline (Syllabus)

Training Requirements and Endorsements

Fundamentals of Flight

Stalls and Spins

Take-Offs and Landings

Ground Reference Maneuvers

Performance Maneuvers

Under the Hood- Flight by Reference to Instruments

Emergency Procedures

Ground Lessons

Pre-Solo Training Syllabus

Lesson 1: Four Fundamentals

Time: 1 hour Ground, 2 hours Flight

Flight Lessons: Pre-flight, Taxi, Normal Take-off and landing
Straight and level flight, turns, climbs, descents
Ground Lesson: Aeronautic Decision Making. Aerodynamics

Instructor Reviews:
Introduces Aeronautical Decision Making (ADM) intro, PAVE, IMSAFE
Preflight inspections
Gathering and checking Wx
Taxi/ground ops/wind correction
Four fundamentals of flight, drag, ground effect, axes of aircraft
Parking/securing aircraft

Read: Airplane Flying Handbook: 1-9 to 1-16, Chapt 2 and 3.
Pilots Handbook of Aeronautical Knowledge: Chapter 2-4 to 2-9, 17-1 to 17-10, 4-1 to 4-3, 4-5 to 4-8, chapter 6.
Ground and flight Lessons handouts

Lesson 2: Aircraft Systems and Pre Flight

Time: 1 hour ground, Flight Time as needed

Flight Lessons: as needed

Ground Lesson: Aircraft Systems, Fuel, Electrical systems and Propeller

Instructor Reviews:
ADM, PAVE, IMSAFE, Hazardous Attitudes
Aircraft Systems and Preflight in detail
Gathering and checking Wx

Read: *Pilots Handbook of Aeronautical Knowledge*: Chapt 5-22 to 5-33, Chap 7-1 to 7-5, 7-8 to 7-11, 7-15 to 7-18, 7-25 to 7-28, 7-30.
Pilot Operating Handbook- Preflight check list, Airplane and Systems Description

Initial Solo Requirements for Student Pilots (Private, Sport, Recreational)

61.83 The student must be 16, receive and log flight training for the following maneuvers and procedures, have medical, state/gov ID and Student Pilot certificate.

Before Any flight training begins, verify US Citizenship or approval from TSA for foreign nationals (https://www.fts.tsa.dhs.gov/home) Flight Training Security Program and document with TSA endorsement in logbook. (See AOPA training module)

Training 61.87(c)

Completion Date and CFI Int.

__________ (1) Proper flight preparation procedures, including preflight. planning and preparation, powerplant operation, aircraft systems.

__________ (2) Taxiing or surface operations, including runups.

__________ (3) Takeoffs and landings, including normal and crosswind.

__________ (4) Straight and level flight, and turns in both directions.

__________ (5) Climbs and climbing turns.

__________ (6) Airport traffic patterns, entry and departure procedures.

__________ (7) Collision, windshear, and wake turbulence avoidance.

__________ (8) Descents, Descending turns, high and low drag configurations.

__________ (9) Flight at various airspeeds from cruise to slow flight.

__________ (10) Stall entries from various flight attitudes and power. combinations with recovery initiated at the first indication of a stall, and recovery from a full stall.

__________ (11) Emergency procedures and equipment malfunctions.

__________ (12) Ground reference maneuvers.

__________ (13) Approaches to a landing area with simulated engine Malfunctions.

__________ (14) Slips to a landing; and

__________ (15) Go-arounds.

Testing

Completion Date and CFI Int.

__________ 1. 61.23(a)3(iii) Successfully pass a third-class medical exam

__________ 2. Hold a student pilot certificate (IACRA app with CFI, DPE, FAA)

__________ 3. 61.87(b) successfully pass a written exam administered by His/her instructor. ***Test corrected reviewed on completion*** covers:

(i) Applicable FAR from parts 61 and 91

(ii) Airspace rules and procedures for the airport where the solo flight will be performed

(iii) Flight characteristics and limitations, make and model of aircraft to be flown.

Endorsements

The student pilot must have the following written endorsements

_________ 1. Logbook – Pre solo aeronautical knowledge, administered by the Student's authorized instructor: 61.87(b)

_________ 2. Logbook - completion of 61.87(c) pre solo flight training

_________ 3. Logbook – current 90 day solo for make and model by the instructor who gave the training within the 90 days preceding the flight 61.87(n) and (p)

__________4. TSA endorsement (see below)

Instructor responsibilities 61.87 (p)

1. Give training in make and model
2. Student proficient in maneuvers/procedures
3. Student proficient in make and model
4. Endorsed logbook for make and model (90 day)
5. **Consider limitations on 90 day solo endorsement. i.e. crosswind, wx, etc.**

Example Endorsements (from AC 61-65K)

Endorsement of U.S. citizenship recommended by the Transportation Security Administration (TSA): Title 49 of the Code of Federal Regulations (49 CFR) § 1552.3(h). I certify that (First name, MI, Last name) has presented me a [insert type of document presented, such as a U.S. birth certificate or U.S. passport, and the relevant control or sequential number on the document, if any] establishing that [he or she] is a U.S. citizen or national in accordance with 49 CFR § 1552.3(h).

Pre-Solo Aeronautical Knowledge: I certify that __________________ has satisfactorily completed the pre solo knowledge exam of section 61.87(b) for the ____________(make/model). *Date/CFI signature/CFI certificate number/exp date*

Pre-Solo Flight Training:

I certify that __________________has received the required pre solo training in a ______________________(make and model aircraft). I have determined he/she has demonstrated proficiency and safety on the maneuvers and procedures required by 61.87 in this or similar make and model of aircraft to be flown.

Date/CFI signature/CFI certificate number/exp date

Solo flight (first 90-day period): § 61.87(n). I certify that ____________________ has received the required training to qualify for solo flying. I have determined he/she meets the applicable requirements of § 61.87**(n)** and is proficient to make solo flights in ______________(make and model). *Date/CFI signature/CFI certificate number/exp date*

Solo flight (each additional 90-day period): § 61.87(p). I certify that (First name, MI, Last name) has received the required training to qualify for solo flying. I have determined he/she meets the applicable requirements of § 61.87**(p)** and is proficient to make solo flights in (make and model). *Date/CFI signature/CFI certificate number/exp date*

Repeat Solo to Airport with in 25nm

61.93(b)1 Solo flights may be made to another airport that is within 25 nautical miles from the airport where the student pilot normally receives training for ***the purpose of practicing takeoffs and landings,*** provided:

Training 61.93(b)1(i)

Completion Date and CFI Int.

_________ 1. flight in both directions over the route
_________ 2. entering and exiting the traffic pattern
_________ 3. takeoffs and landings at the other airport

Endorsements

Completion Date and CFI Int.

Current solo endorsement:

_________ 1. Logbook – Pre-solo aeronautical knowledge, administered by the student's authorized instructor: 61.87(b)
_________ 2. Logbook - completion of 61.87(c) pre solo flight training
_________ 3. Logbook – current 90-day solo for make and model by the instructor who gave the training within the 90 days preceding the flight 61.87(n) and 61.87(p)

Endorsement for repeated flights within 25 nm (need new endorsement for each new airport student may travel to practice landings)

_________ 5. Logbook - solo to and from that airport from the instructor who gave the training who determines student is proficient to make the flight 61.93(b)1. ***Endorsement has no expiration date***

AC 61-65-K

I certify that (First name, MI, Last name) has received the required training of FAR 61.93(b)(1). I have determined that he/she is proficient to practice solo takeoffs and landings at ___________(airport name). The takeoffs and landings at ___________(airport name) are subject to the following conditions: ___________ (List any applicable conditions or limitations.) *Date/CFI Signature/CFI certificate number/exp date*

Introduction to Flight training basics

Training Pro Tips: are provided on many of the flight lessons that are helpful to both the student and CFI.

The first lessons on straight and level flight, turns, climbs and descents are the most important in learning airmanship, use of rudder and mastering the fundamentals of flying a pattern and approach to landing. These basic skills are the foundation for all the rest of your flying skills. Spend time "Training with Purpose" and it will pay great dividends when moving onto more complex maneuvers

Check lists and Standardized approach to maneuvers: Checklists are a special emphasis item for practical tests, and their proper use should be re-enforced. For example, the CFI should ensure the student use an after landing and before takeoff check list every time (in addition to a flow). Many accidents and check ride failures have occurred when carb heat was left on, control locks left in or take-off attempted with full flaps or parking brakes on.

While it may be impractical to create a check list for every item and phase of flight, every flight maneuver should begin in the same way to ensure safety and compliance with ACS requirements. It is recommended the CFI and student develop a pattern or mnemonic to complete prior to every flight maneuver to include key items. I have used the following mnemonic with success in training pilots "CPAC":

C-Clearing turns (two 90^0 or one 180^0 turn)
P- power setting to achieve desired speed
A-altitude to begin the maneuver
C-Configure aircraft (some use a "floor to door" flow to check carb heat and flaps, etc.)

Use of maneuver flash cards: In addition, I typically train pilots to use "flash cards" that include 4 to 6 items unique and critical to complete the maneuver. For example, clearing turns and trimming the aircraft should be part of every maneuver and are not typically included on the flash card. These flash cards can then be used to "chair fly" the maneuver to ensure the student has a grasp on the key elements before the flight. This saves many hours of wasted flight time, money and frustration. This also re-enforces the "Demonstration and Performance" method of training skills where both the CFI and the student must explain the maneuver prior to demonstrating the maneuver.

Cross wind correction for taxi, take-off and landing: I would estimate 80% of private pilot applicants do not apply appropriate wind correction during taxi, take-off and landings on their practical tests. This is a failure of training which can be remedied by the CFI requiring these inputs on every flight. Even in light winds, it is good practice to apply ailerons for wind correction, so it becomes a habit rather than an afterthought. My very lessons with students are taxing around the airport anticipating the control inputs before each turn. On calm wind days, I call out a "virtual" wind and require students to apply ailerons during taxi, take-off and landing.

Rudder use: Rudder use also seems to be an afterthought during training where students then panic before a check ride and start focusing on the ball during maneuvers. This does not work well. Accordingly, see the below refresher on this primary flight skill.

How to use rudder: The two most common ways rudder are taught is to "Step on the Ball" or "feel it in the seat of your pants". "Stepping on the ball" method requires the pilot to constantly stare at the ball instead of where they are flying or looking for traffic. Becoming task saturated in the pattern or with complex maneuvers, coordination goes the same place as common sense… out the window. "Feel it in the seat" method is difficult to appreciate by many of us with an insensitive bottom end or requires large yaw forces to get our attention. In both cases, it is required to fly un-coordinated to detect the deviation and correct it. This means the pilot is always chasing the plane and correcting mistakes. Hardly a professional way to fly an airplane and somewhat dangerous.

What if there is a way to easily visualize and PREVENT yaw without having to look at the ball or feel it in the seat of your pants? Do I have your attention? The following method is simple, easy to see and can keep the aircraft coordinated in real time. It is based on simple aerodynamic principles and easy to observe phenomena… if you know where and what to look for. Once you understand how to fly coordinated, you can occasionally glance at the "ball" to confirm that you are coordinated.

There are only six times rudder is required, and specific ways to determine HOW much rudder pressure to use. We will explore all six of these in detail.

Taxi -rudder is required to steer the aircraft and hold centerline. It is best to look as far down the taxiway as possible and use your peripheral vision to steer. This should be an idle taxi. If power is over 800 rpm (except for going up hills and over obstacles), you are going too fast or riding the brakes. Riding the brakes wears them out quickly (expensive) and leads to bad habits like landing with our feet touching the top of the pedals and putting flat spots on the tires (also expensive).

Take-off roll – much like taxi, rudder is used to oppose left turning tendencies and hold centerline. Focus on center line far down runway and use peripheral vision to steer. Weathervane can severely compromise rudder effectiveness. Make sure to apply cross wind correction. Apply sufficient rudder to keep on centerline during take-off roll.

Departure climbs or power on stalls, *holding wings level*, then apply enough rudder to hold course (see figures below). Holding wings level is the key to knowing how much rudder to apply and takes some practice. A pilot can detect the drift and yaw by observing ground references (tress, buildings, etc.) adjacent to the edge of the cowls (Lindberg reference). In a strong cross wind, is acceptable to let aircraft weathervane and use rudder to hold your track. (see tracking in lesson plans)

A full power climb at pitch attitude below stall speed (12-15^0 works in most trainers) is an excellent exercise to learn rudder skills for Vx/Vy climbs and power on stalls. Add 30^0 banks to learn the rudder pressures for climbing turns as used in Chandelles. See "Rudder in Turns" for technique. *It is the same in a climb as level except there is some "Baseline" right rudder pressure that is relieved or increased as needed*.

Rudder in a climb or power on stall: Rudder is used to offset left turning tendencies. If the wings are held level to the horizon, then apply enough rudder to keep aircraft from drifting left or right.

Insufficient Rudder in a climb: *Climb out with a right-wing low is the hall mark of insufficient right rudder.* The pilot is using aileron instead of rudder to control the left turning tendency. See below.

Straight and Level Flight

Description: The most fundamental maneuver whereby the airplane maintains a constant heading and altitude. This is fundamental to accurate navigation to maintain a heading or course, comply with ATC instructions, cross-country flight. *The emphasis is to hold heading and altitude by outside references primarily. Verify your efforts with occasional cross check of altimeter and directional gyro.*

Objective: To develop the fundamental techniques required for basic flight and tracking straight to an object.

Elements

- **Perform a "CPAC"**
  - **Clear Area**
  - **Power- 2100 rpm**
  - **Altitude -1500 ft AGL**
  - **Configuration – clean**
- **Select outside references** (point on the horizon corresponding to heading)
- **Hold altitude by keeping horizon stable relative to windshield/airframe** (if horizon rises, you are descending, horizon drops, you are climbing)
- **Maintain heading by "tracking" to object on horizon** (if target moves left on wind screen, you are drifting right, try referencing to mark on windscreen or airframe)
- **Cross check altitude and heading with instruments**
- **Look for traffic**

Instructor**:** Explains and demonstrates technique of strait and level flight, tracking to a point.

Student**:** Explains and demonstrates straight and level flight and tracking to a point

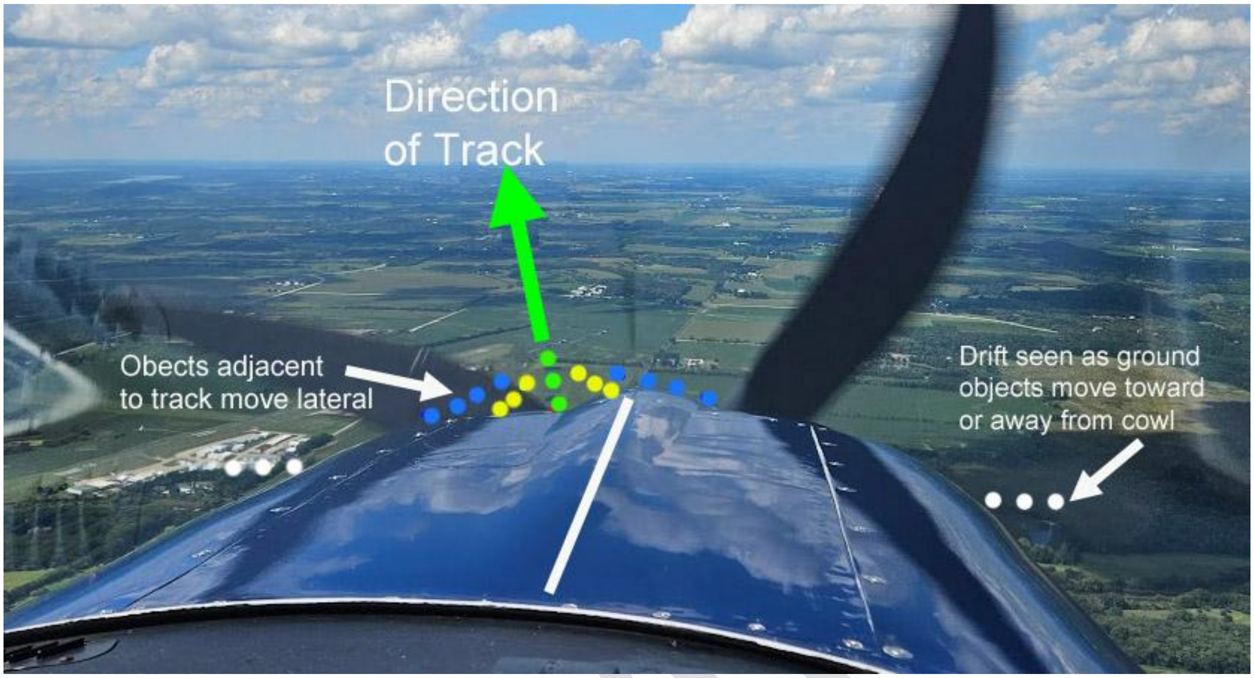
Common Errors

- Use improper reference points on the airplane to establish attitude
- Reliance on flight instruments rather than outside visual reference
- Tight grip, over-control, tired hands and lack of feel

Completion Standards: Student can discuss technique for Straight and Level Flight. Student can demonstrate appropriate checklist usage with proper configuration of aircraft, dividing attention between outside references and instrument scan, checking for traffic, applying power and control inputs smoothly with positive aircraft control.

References
FAA-H-8083-3C Airplane Flying Handbook, ACS, POH

Heading, course and how to track. Wind is present on most days and pushes the aircraft in a different direction than the nose is pointing. To fly directly to any point we see, to fly square or circular paths, the pilot must be able to determine where the aircraft is moving. This skill is called tracking and is essential to visually navigating precise ground paths in traffic patterns and for ground reference maneuvers required to pass FAA practical tests.



In the above image, the blue and yellow dots represent the path of travel of small landmarks on the ground. The yellow and blue dots appear to move off to the left and right as the aircraft gets closer. The green dots represent a ground reference that is in the path of the aircraft track. As it gets closer to the cowl, it does not move left or right. Once the pilot identifies the object that is in the track of the aircraft, you can extend an imaginary arrow (green) to the horizon. This is where the aircraft is tracking. Notice the nose of the aircraft is pointing right of the actual path of travel. This is a crab.

Drift is most easily detected looking at side of cowl.

Track is detected by observing objects nearest front of cowl. The lower the altitude, the easier this is to detect.

> ***Heading:*** *The direction the nose is pointing.*
> ***Track=Course****: The direction the aircraft is traveling.*
> ***Wind Correction angle:*** *difference between our heading and track/course.*
> ***Zero wind:*** *the heading and track will be the same.*

Training Tip: Instruct student to maintain level flight while following a road in both directions in a "crab" with a cross wind. This teaches student how to fly a straight ground track. Then have them fly to a landmark (waypoint) without the benefit of a road to improve tracking skill (hint: keep waypoint from drifting left or right on windscreen, use bug or mark on windscreen as reference). Try observing objects on ground very close to bottom of wind screen or touching the front and side edges of the cowl. See notes in figure above.

Normal Landing

Description Approach and landing with headwind or light wind, hard surface of sufficient length and no obstructions. Prerequisites for learning to land include learning to fly a traffic pattern consistently the same way to set up for a stabilized approach. The fundamentals of level flight, tracking to a point, turns, constant airspeed descents, and rudder use should be well practiced prior to landing.

Objective To teach techniques necessary for a normal landing.

Elements

- **CPAC**
  - Clear – look for traffic
  - Power- 2100 rpm or 18" manifold pressure
  - Altitude – 1000 ft AGL
  - Configure- clean
- **Enter downwind**, maintaining traffic pattern altitude (typically 1000' AGL)
- **Abeam touchdown point, set power** *(1400 Rpm or 13" manifold) and* **First notch of flaps** *(10°)*
- **Coordinated turn to base** when reference point is 45° behind the wing
- **On base: second (& third if needed) notch of flaps**, add up trim for 1.4 Vso + 10 kts
- **turn to** final approach fully configured and on Vref airspeed. Check traffic
- **Adjust and stabilize airspeed to no MORE than 1.3 Vso with pitch before making any power adjustments (Airspeed + 5, -0 kts max)**
- **Estimate glide path, descent rate to aiming point** (numbers or other mark)
- **Adjust power for altitude (no more than +/- 200 to 300 rpm, or 3 inches manifold pressure)- use "spot landing method"**
- **Trim** to relieve control pressures
- **Make sure feet are not on brakes**
- **"Round out" to level attitude 10' off ground and reduce throttle to idle**
- **"Flair" by gradually apply back pressure to pitch for landing attitude**, Nose just above horizon
- **Touchdown on main gear** just above stalling speed
- **Keep some back pressure for aerodynamic braking.**
- **Gentle braking** as required

Instructor: Discuss 4 phases of approach and landing (see below)
Discuss power and flap configuration, air speed in various parts of the approach
Discuss use of flaps
Discuss Estimating height, movement and glide path, stabilized approach
Discuss longitudinal axis alignment
Discuss landing attitude, rate of descent, aerodynamic braking
Describe and demonstrate landing technique with emphasis on check list and stabilized approach
.

Student: Describe and demonstrate landing technique with utilization of check list

Completion Standards: Student is able to demonstrate appropriate checklist usage with proper configuration of aircraft, dividing attention to traffic pattern, checking for traffic, apply power and control inputs smoothly with positive aircraft control with a stabilized approach. Lands after, but within 400 ft of aiming point, no side drift, minimum float and the airplanes longitudinal axis aligned with and over the runway center/landing path.

Common Errors

- Setting approach and landing configuration at appropriate time or proper sequence
- Large power adjustments, un-stabilized approach
- Poor air speed control, typically too fast!!!!
- Reducing throttle before rounding out to compensate for high or fast approach
- Poor directional control (rudder use)
- Insufficient aerodynamic breaking (hold back pressure on yoke)
- Failure to apply and increase cross wind correction on landing and roll out
- Overshooting or undershooting the turn onto final approach
- Attempting to maintain altitude or dive for runway using elevator alone
- Rounding out too high and landing hard
- Landing with too much airspeed and ballooning and floating
- Touching down prior to attaining proper landing attitude (nose low, flat attitude)

References FAA-H-8083-3C Airplane Flying Handbook, POH

Training Pro Tips for landing: proper airspeed and a stabilized approach are the critical determinants of making a good and safe landing. I recommend the following is accomplished be the time we turn final:

1) Fully configured (flaps and gear)
2) On airspeed (no more than 1.3 Vso) for current aircraft weight
3) Approximately 500 ft AGL on ½ mile final.

If there is difficulty in stabilizing the approach (Large throttle adjustments, overbanking to get lined up, poor airspeed control, power brought to idle when high and fast) then a go around (balked approach) should be initiated. Go arounds are for un-stabilized or sloppy approaches BEFORE you get over the runway. It is much safer to execute a go around 200 ft above runway than 10 feet above runway. ***Landing is the reward for a stabilized approach.***

I recommend for a stabilized approach (for training purposes) as limiting power use to no more than +/- 300 rpm (3" manifold pressure). If more than 300 rpm change or power is brought to idle before round out, then a go-a-round should be executed.

Four Phases of Landing:

1) **The Pattern.** Fly by the numbers (power settings and aircraft configurations). A consistent pattern, same altitude, distance from runway, base turn, power and flap settings during the pattern will improve the chance for a stabilized approach. To fly a consistent pattern requires mental discipline and tracking skills with appropriate wind correction. (see lessons on Straight-and-Level flight and Rectangular pattern)
    a. Use reference on wing or strut to determine lateral distance from runway (painters masking tape is good teaching tool)
    b. Must be at pattern altitude to keep same lateral distance from runway (geometry of using reference on wing or strut)
    c. Using tracking to a point to correct for wind drift
    d. Use same power settings for each position in the pattern
    e. Apply flaps and power at same places in pattern
    f. Target speed is 1.4 Vso on base, no greater than 1.3 Vso on final

2) **Final approach:** Aircraft should be fully configured and on Vref by the time you turn final or shortly after. Vref is 1.3 Vso or as published. *Rule of thumb, Vref decreases approximately 1 kt for every 100 lbs below max gross.*
    a. Altitude cannot be determined on final until air speed is corrected (see discussion on energy management and stabilized approach)
    b. **Correct air speed first with pitch, Altitude with power second**. (as experience is gained, the pilot can apply inputs simultaneously)
    c. Keep this same "Deck Angle" or pitch attitude till directly over aiming point. This will keep the air speed and descent rate constant on short final. *Resist the urge to gradually bring the nose up, this will decrease air speed, loss of energy and a hard landing.*
    d. Keep the nose down till the round out over the aiming point. **The aiming point** is where aircraft would IMPACT ground if there is no round out. Aiming point is typically 50 to 75 ft BEFORE touch down point. See "spot landing method" below.

3) **<u>Round out:</u>** Occurs over aiming point**.**
    a. The aircraft is smoothly pulled into a *level pitch attitude,* approximately 10 feet above the runway over the aiming point.
    b. **The power is pulled to idle at the round out.** NOT BEFORE. NOT AFTER. If you vary when you pull the power, you will never have the same result twice and have a difficult time landing well consistently.
    c. **How do you tell how high to round out?** Check out Rod Machado's video on "Runway Expansion Effect" https://www.youtube.com/watch?v=9JfoZERqM7Q .

4) **<u>Flair:</u>** After the round out, we wait to see the aircraft is starting to descend to the runway, the nose of the aircraft is smoothly pitched up to stop the "Settling" or descent of the aircraft. The pilots gaze will necessarily have to move to the side of the runway as the nose blocks forward visualization of runway. As the aircraft slows, the control stick will have to be gradually brought further back to keep nose above horizon and to slow the rate of descent till touchdown. In effect, you are raising the nose to try and keep the aircraft off the ground (although it will

land despite your efforts!). This allows the main wheels to touch down first at a very slow rate of descent. After the main wheels touch, hold the nose up for aerodynamic braking to save on tires and brake assembly wear. **Ideally, the yoke or stick should be FULL aft on touch down.**

Recommended Training exercises

Airspeed control on final approach. With your instructor on board, start at 2000 to 5000 ft AGL. Set up aircraft in landing configuration (20 degrees of flaps, 1400 RPM). Pitch and **trim** to 1.3 Vso and hold that airspeed as accurately as possible while descending to 1000 ft AGL. Repeat as necessary till consistently able to maintain approach air speed. *Check trim by asking student to release yoke and observe!*

Pitch control for air speed on final: With aircraft configured for landing and at approach power setting, begin a descent from a safe altitude. Make sure aircraft is trimmed to a "hands off" stable airspeed and descent rate. Then add and subtract 100 or 200 rpm and note the pitch attitude will increase and decrease with power a small amount but the air speed remains the same. Here the student is learning not to over control. Let the pitch attitude change slightly with power to maintain the same airspeed.

Altitude Control on Final Approach: Start at 2000 ft AGL and approximately 3 miles from runway or similar visible point. In approach configuration and power setting, make small power adjustments while descending at 1.3 Vso to the aiming point.

Spot Landing Method: *If aiming point is rising in windscreen, add (small amount) power to slow descent, if point is moving down on windscreen, reduce small increments of power.* Repeat as needed.

Note, use of a PAPI or VASI in the initial phases of training instead of an aiming point can have a negative effect and make it difficult to land at the other 90% of runways that don't have this equipment.

The round out height: Watch Rod Machados "Runway expansion effect" on YouTube. Fear narrows the perceptual field and flying prevents students from seeing what we want them to see. The instructor will fly the approach and have the student call out the "runway expansion". This relieves the student of the stress and fear of flying so they can see the phenomena. When they call it out, the instructor can determine they have seen the correct phenomena. Once the student can consistently see the "runway expansion" effect, they will then be able to round out at the correct height.

Maintaining level pitch attitude after round out. Have Your instructor control power. During round out, your instructor will add power and have you fly 10 feet above the runway, all the way down the runway and then before the end of runway, add full power and go around. Do these two or three times and you will get a good feel for the round out height and level off. Only do this with qualified instructor on board.

When to begin the flair: After rounding out, hold aircraft level above the runway, at the first indication of aircraft settling or descending (detected with horizon rising in windscreen with peripheral vision), then gently pitch up just enough to arrest the descent in small increments. Continue till aircraft is in touch down attitude, nose just above horizon. Training for this can be done first with instructor flying a "soft field" approach with small amount of power (1300 rpm) over a long runway. *The student observes the CFI flies!* This reduces the fear response and other distractions of trying to land so the student can concentrate on detecting the settling or aircraft descent. The student tells the instructor when to pitch up to arrest the descent. The call out should be a simple word like "pull" directing the instructor to pull back on yoke to arrest the descent. They may have to call out the descent three or 4 times till the aircraft is on the ground. After a couple of repetitions, the student can then perform the "soft field" power on landing to learn when to begin the flair. Then transition to normal landing with power to idle at round out. If done properly, the control stick will be full aft and the pitch attitude about 7^0 up at touch down.

Flair Attitude: "High Speed" Taxi in landing configuration with enough power to hold nose just above horizon down runway (nose wheel may be off ground) Repeat as needed. Instructor must be on board. This also improves rudder control and focus gaze at side of runway during flair to keep aircraft on center of runway. Final flair attitude is about 7^0 up at touchdown, same as rotation and Vy climb attitude.

Where we look matters

Where we fix our gaze is important. If we stare at a general area, the brain has a difficult time picking up relative motion of objects in our field of view. If we fix our gaze on a small very specific object (the beginning edge of a runway strip, a tree, edge of a cloud, runway light), then our brain can rapidly identify objects in our peripheral view that are moving relative to the object we have locked onto. Consequently, *we are much more likely to perceive traffic in our scan if our eyes move from one specific object to the next across our field of view.* This same concept helps us visualize the relative motion of the aircraft and our surrounding environment during the landing sequence. It is common advice to pick an aiming point such as the "numbers" or a "runway stripe" before our intended touchdown point. These are too large of an area to optimize our ability to see the "Runway expansion effect" or make sure we don't have "aiming point drift" such that we don't maintain our glide path exactly where we intend. It is much better to pick a high contrast, specific and small point to fix our gaze. This could be the bottom corner of a runway number or strip. In the landing sequence, after rounding out, we are told to transfer our gaze to the horizon or the end of the runway. This is too large of an area to fix our gaze to optimize our ability to then see the aircraft "settle" or start to descend to the runway so we can continue to use pitch to arrest the descent. I recommend after rounding out to transition the gaze to a specific "beginning edge" of a runway stripe about 1/3 to ½ way down the runway (in the case of tail dragger with poor forward visibility use a runway edge light or similar). As the aircraft begins to settle, the relative motion of the aircraft to the chosen "runway strip" or horizon is very distinct. In fact, you can visualize the nose of the aircraft "rotating up" as you flair as distinct and separate from the aircraft climbing or descending. This takes practice, but when mastered, excellent landings are much more likely.

Common Errors:

Excessive air speed: excessive air speed leads to floating and ballooning. Combined with being high leads students to pull power on descent to runway, this makes the landing point uncertain. Excess air speed combined with flat touch down attitude increases risk of porpoise with prop strike or wheelbarrowing and runway excursion. *Over 90% of landing accidents are related to excess speed, less than 2% are related to being too slow.* Excessive float is poorly defined, but I recommend floating more than 50 ft in most general aviation training aircraft indicates the approach was too fast. Floating more than 100 ft in very high-performance aircraft such as light twins and high wing loaded aircraft indicates excess approach speed.

Ballooning results from excessive air speed (or sometimes a strong wind gust) is usually followed by rapid settling on to runway and a hard landing. At this point, if the aircraft starts descending rapidly, power will be needed to soften the touch down or a go around executed.

Insufficient air speed: high descent rate on round out with hard landing.

High round out: as the flair reaches maximum pitch attitude, the aircraft starts descending rapidly, power will be needed soften the touch down or a go around executed.

Long and gradual round out before reaching aiming point: As runway approaches, the natural tendency is to pull back on the yoke, air speed bleeds off, excessive descent rate and hard landing. Then approach speeds are increased to compensate. With continuously changing air speed, the pilot will not be able to determine where aircraft will run out of energy and land. Hold the “deck angle” all the way to the round out.

Poor directional control: If you land in a crab, flat or fast you may have uncontrolled swerving

Landing in a Crab: the aircraft will lurch to one side or feel like it is skipping sideways on the runway.

Landing flat: places more weight on nose wheel and may result in “Wheel barrowing” which results in swerving all over runway.

Lading flat and fast risks porpoising, nose gear collapse and prop strike.

Landing with insufficient aileron on cross wind, the aircraft will weathervane into wind and swerve off runway.

Landing flat, in a crab, fast and insufficient aileron will make for an exciting YouTube video, NTSB report and a really bad day.

Touch and GO vs Full Stop Taxi Back

I do not recommend touch and go's for the following reasons:

1) There is no time for adequate debrief or student to self-evaluate the maneuver (Student Centered or Collaborative assessment)
2) If student doesn’t self-evaluate, Instructor cannot know if they understand what they did wrong or how they may fix it.
3) It is not realistic to how we fly (scenarios based)
4) We are not using after landing and before take-off check lists
5) repetition of potentially bad habits that will later become very difficult to change
6) high workload leads to short cuts and mistakes
7) teaches students check lists are not important.
8) transition to retractable gear aircraft increases risk of raising gear instead of flaps or gear up landing.
9) Touch and goes (aka "Block" practice) increase motor skills, but at expense of learning and understanding the maneuver and limits application.
10) May fool instructor that student has acquired a skill. When student makes 2 or 3 good landings after doing 15 in a row does not mean they will be able to land tomorrow. Check again on another day.

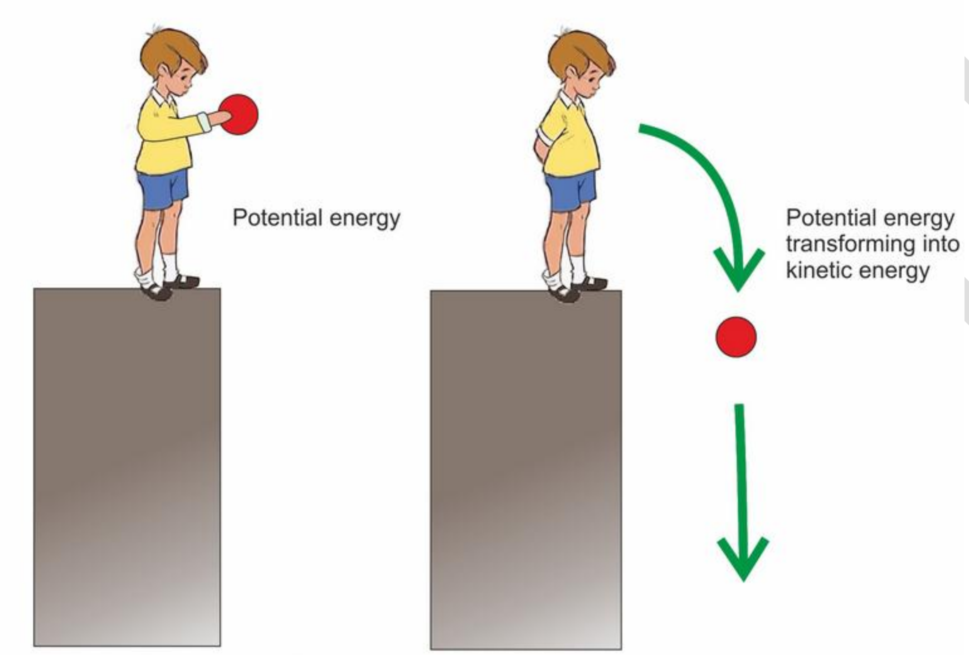
My perspective is students learn to land proficiently in a shorter amount of time with full stop taxi backs. In a crisis or under stress, we do not “rise to the occasion”, rather we perform at the “lowest level” of our training. However, full stop taxi back is not always practical at a busy towered airport. Consider going to a smaller uncontrolled airport, if available. *While touch goes have their place, they should not be used as a primary training maneuver.*

Energy Management

(Airplane Flying Handbook, Chapter 4)

Potential Energy= mass of aircraft (kg) x height (m) x acceleration of gravity (9.8m/s/s). Potential energy is also considered "stored" energy, like a ball at the top of a building. Note, during an approach to landing, neither the mass of aircraft nor gravity changes significantly. So, we can consider our height above ground as a relative measure of potential energy. Pilots are pretty good at estimating height with practice.

Kinetic Energy = ½ mass of aircraft (kg) x Velocity^2. Kinetic energy is movement energy, like a ball rolling down a hill or tossed from atop a building. Notice our kinetic energy varies with the square of the velocity. Double our velocity means quadruple our energy! Pilots are terrible at detecting relative speed and then squaring the result.



Total Energy = Kinetic + Potential. Energy is neither created nor destroyed. However, kinetic energy can be converted into potential and visa versa! As the ball rolls down a hill or is dropped from a height, the potential energy is converted to kinetic as the ball speeds up. Conversely as a ball rolls up a hill it slows down as it converts its kinetic energy to height. We can do this same thing with the "Kinetic energy converter" installed in every aircraft – it is called the "Elevator". Pulling back on the yoke will convert our kinetic energy (speed) to potential energy (altitude). Hence the concept of "trading" speed for altitude or trading altitude for speed. The key point here is our energy state doesn't change significantly. An example of this is if we are high on final approach, pitching down lowers our altitude but increases our speed. Our total energy state doesn't change much and consequently will still land at approximately the same place! (note there is some increase in parasitic (speed) drag when we pitch down and some induced (AOA) drag when we pitch up but neither bleed much energy.) *Moral of the story is NEVER dive for the runway if you are high and NEVER "stretch" a glide by pitching up. Neither works. The solution is change in power.*

Determining Height above runway on Final. Consider two training aircraft of same weight on final. A is traveling at 50 KIAS, B at 70 KIAS. They are both 300 ft above the ground. Both pilots believe they are at proper altitude and energy state to land on their spot. In this example, both have the same potential energy as they have the same weight and height above the ground. However, aircraft B has nearly double the kinetic energy (70^2 =4900 vs 50^2=2500). If we pitch up aircraft B to slow to 50 KIAS, it will climb approximately 113 ft! **Pilot B will land much further down the runway.** The only way to estimate our height above the runway is if we are ON SPEED! See figures 1 and 2.

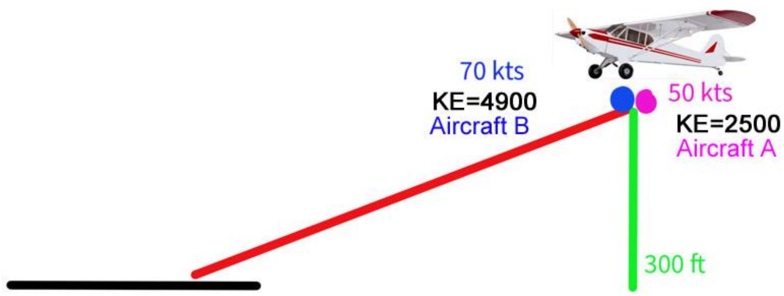


Figure 1. Aircraft A at 300 ft AGL and 50 kts. Aircraft B at same altitude and 70 kts has almost double the kinetic energy assuming same weights.

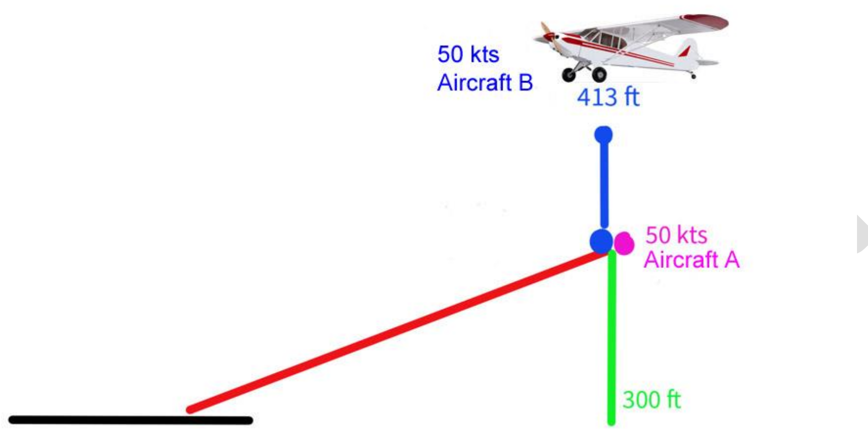


Figure 2. If Aircraft B travelling 70 kts were to use the elevator to reduce speed to 50 kts, it would climb approximately 113 ft (assuming gross weight of 2200 lbs).

Hence, on final approach, I recommend correcting airspeed FIRST with pitch, then adjust descent rate with power. This does not preclude simultaneously using both power and pitch if really low or really high. However, in these cases, a go around should be considered as the approach is not stable.

Many pilots are taught to gradually decrease speed from downwind, base, and up to short final, adding the last notch of flaps if needed. If we have continuously changing aircraft speed and configuration during our approach, only reaching Vref on short final, the pilot has little time to change power and pitch to make the landing. In practice, the earlier we slow to Vref, the more time we have to adjust our glide path (with power) to make our accuracy landing.

Stabilized Approach

The Airplane Flying Handbook (AFH) recommends no greater than 1.4 Vso on base and 1.3 Vso on final. Additionally, the AFH defines a stabilized VFR approach as being fully configured and 1.3 Vso no later than 500 ft AGL on a 3^0 glide path (approximately 1.5 miles from runway). This conflicts with the other AFH recommendation that full flaps are applied after final established. My recommendations for a stabilized approach:

- Fly consistent pattern (see lessons rectangular course)
- On Base: No faster than 1.4 Vso
- ½ mile Final and 500 ft AGL
    - Fully configured (no flap or gear changes)
    - 1.3 Vso or slower (Private ± 5 kts, Commercial ± 1 kt)
    - Fully trimmed (hands off to check trim)
- Use no more than ± 300 rpm to adjust descent (at private pilot level)
- Power to idle on round out (10 to 20 ft above runway, level pitch attitude)

Indications for a Go Around: during initial training or at the private pilot level a go around should be initiated if the above criteria are not met. *Landing is the reward for a stabilized approach.* It is safer to execute a go around at 300 ft AGL than a few feet over runway.

Rule of thumb: *In general aviation aircraft, you can reduce approach speed by 1 kt for every 100 lbs below max gross weight. 5 kts excess airspeed increases float by approximately 100 ft.*

Excess speed makes it difficult to judge altitude and perform precision approaches. Additionally, more than 90% of landing accidents are related to excess speed and less than 2% from being too slow. *I recommend no faster than 1.3 Vso, fully configured and trimmed no later than ½ mile final and 500 ft AGL*.

Note on controlling air speed and altitude on final*: Some argue air speed should be controlled with power and altitude with pitch. However, air speed responds slowly to power inputs and changes glide path making precise control difficult. Final approach speed places the aircraft in slow flight and the region of reverse command where pitch controls air speed, and power rate of descent.*

During slow flight, if the aircraft if trimmed and only light pressure applied, if vigorous power is applied, the aircraft will pitch up and airspeed will actually decline. If power is maintained, light for and aft pressures of the control stick will make significant changes in airspeed but altitude will change little. This demonstrates the relative independent control of airspeed and altitude.

If power is used to increase airspeed in slow flight (or on final approach) simultaneous firm forward control pressures are required to keep aircraft from climbing with significant trim change. This results in large changes in energy state which cause a delayed response to airspeed. If using pitch to control descent rate and altitude, simultaneous power changes will still need to be made. Consequently, using power for airspeed is more complex and destabilizing. It is this author's recommendation to use Pitch for Airspeed and Power for Altitude corrections.

Aerodynamics

Attention/Motivation: Understanding basic Aerodynamics allows a pilot to understand the behavior and flight characteristics of aircraft. More importantly, provides a basis of understanding for limitations of aircraft and provides a margin of safety for flight.

Objective

To teach basic aerodynamic principles to the student pilot to aid in decision making and rational for safe operating procedures of aircraft.

Elements

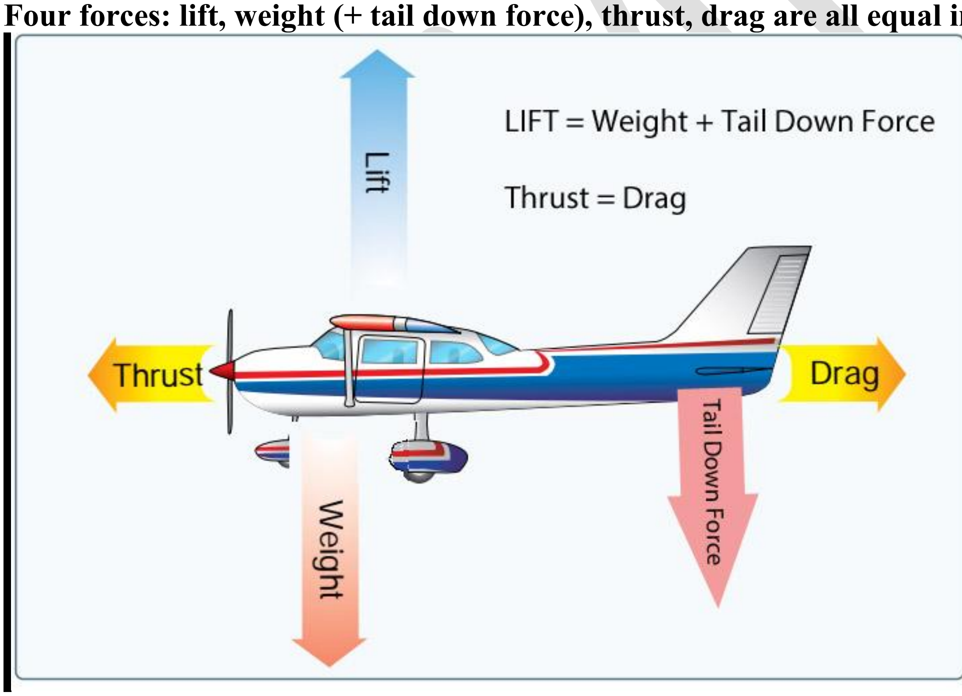
- Four forces (*what about tail down force?)*
- Airfoils
- Drag
- Turning Tendencies
- Ground Effect
- Wingtip vortices

Drag
Stability & Controllability
Load Factors
Wingtip vortices

Schedule	***Equipment***
Discussion 2:00 Equipment	Model airplane, white board

Instructor Actions

Four forces: lift, weight (+ tail down force), thrust, drag are all equal in steady flight. (newton's 3rd)



Note*: Most depictions show only 4 of the forces. The tail down force (negative lift) is frequently combined into the positive lift component to show the resultant force opposing gravity. This makes it confusing when the tail down force must be considered later.*

Wing definitions: leading edge, trailing edge, camber(curve), chord line.

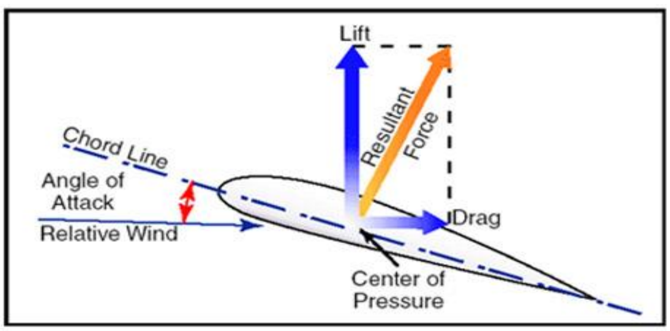
- Aspect ratio—wingspan to mean chord line

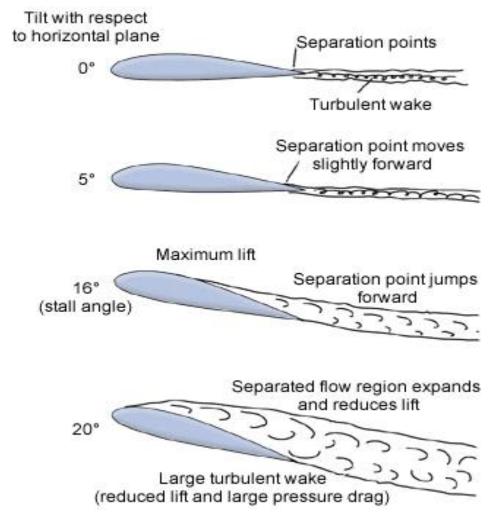
  High aspect ratio (long & skinny) = more lift, less drag. (glider)

- Angle of incidence—Angle between the chord and the longitudinal axis of aircraft- Typically, wings are pitched up 0^0 to 4^0

- Angle of attack (AoA) –Angle between relative wind and chord of airfoil

Camber- Curve of wing surfaces- increases efficiency of lift generation
Relative wind- opposite to the direction of travel of aircraft, lift is perpendicular to relative wind
Chord line- straight line from front to back of airfoil
Angle of Attack (AOA)- Angle between Chord line and relative wind



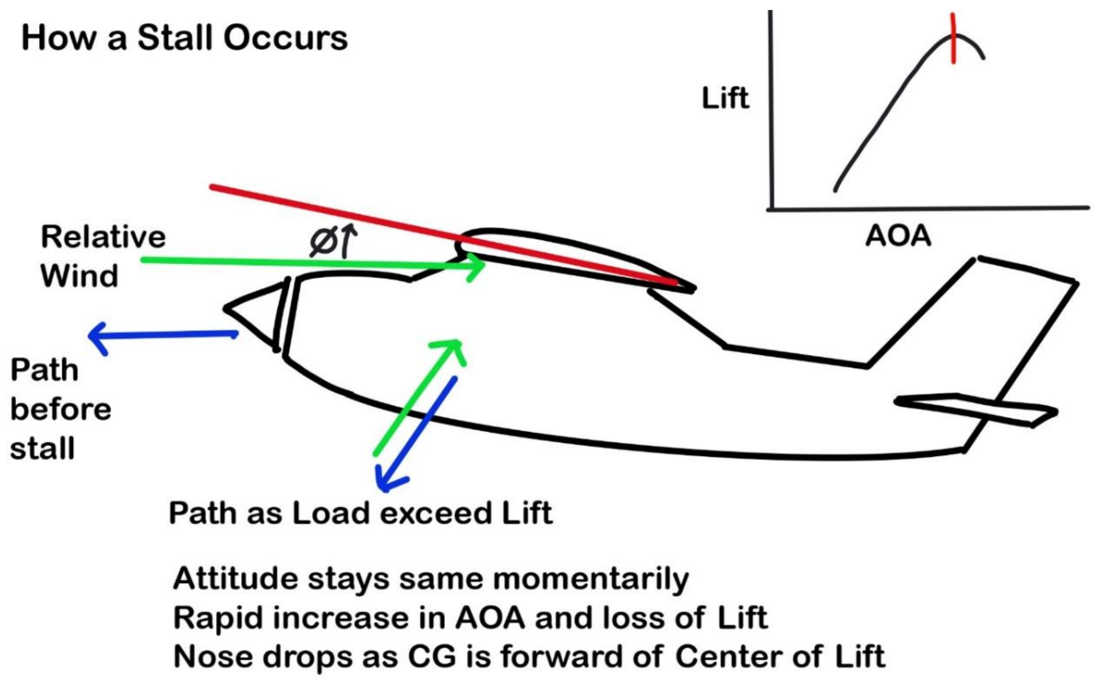


Critical AOA-Angle of maximum lift. Greater AOA result in dramatic drop in lift (does not go to zero). Typical is 16^0

Critical AOA exceeded when aircraft travels in a direction very different from projected Chord line of the wing. This is when the load on the aircraft becomes greater than the lift. *The most common way to increase the load in positive G (upright) flight is aft movement of the controls. The larger the magnitude and rate of the aft movement, the larger the load applied (both in a turn and level flight). Alternatively, flying at minimum air speed and rolling into a steep bank can increase the load greater than the lift.* The Load pulls the aircraft in a direction of travel significantly different than the apparent or intended path of travel. As a rule of thumb: *if the aircraft is moving in a direction significantly different than where the nose is pointed, you are likely to have exceeded the critical AOA.*

Stall speed: minimum air speed at the critical AOA (Coefficient of maximum lift) to maintain level flight. Any further reduction in speed will result in a stall (Lift is less than load).

Stall- Critical AOA exceeded results in dramatic loss of lift production (not zero) Any airspeed, any attitude!



Allowing the speed to decay while operating near the critical AOA (slow fight), the load will exceed the lift generated. In a steep turn or with brisk aft application of the elevator control, large loads can be applied to the aircraft (accelerated stalls). If the load becomes greater than the lift generated by the wing, the aircraft will be "pulled" in a direction significantly different than the intended travel. In the figure above, the load pulls the aircraft down while the pitch attitude is still above the horizon. In a steep turn, the load pulls the aircraft outside of the turn. In either case, this causes the relative wind to strike the wing at a much larger angle. Exceeding the critical AOA, there is rapid loss of lift, and then the nose drops.

Lift:

- Bernoulli's principle: increase velocity/decreased pressure over top of wing
- Newtons 3rd Law- Down wash of air = up movement of aircraft

The Lift equation demonstrates lift is proportionate to several parameters.

$$\boldsymbol{Lift = C_L \left(\frac{1}{2}\rho v^2\right) A}$$

$\boldsymbol{C_L}$= coefficient of lift, $\boldsymbol{\rho}$ = density of air, **v**= true airspeed**,** **A** = area of wing

($\boldsymbol{\frac{1}{2}\rho v^2}$) = **<u>Dynamic Pressure</u>** is an indication of the *mass rate of air traveling over the wing* and what the air speed indicator measures! The more mass over the wing, the more lift can be generated (if there is a positive angle of attack)

$\boldsymbol{C_L}$ is related to design of wing and varies with AOA*. The AOA increases the acceleration of air over the wing up to the Critical AOA*. If the AOA is effectively zero, then no acceleration of the air will occur, and no lift will be generated.

- **Increase in AOA** = increases acceleration of air (coefficient of lift) creating more lift and induced drag

- **Increase in TAS** = increase in rate (volume) of air over the wing. This increases the mass of air for a given air density. If positive angle of attack, lift and parasitic drag increase *by the square of speed.*
  - Double TAS = 4 x increase in Lift.
- **Density of air**. More dense air increases the mass of air passing over the wing for a given airspeed and AOA. More mass = more lift. Less dense air decreases lift for a given air speed and AOA. At High altitude (low air density), must increase TAS, AOA or both to maintain LIFT

Drag:

• **Parasite: "high speed drag" at low AOA increases as the square of the airspeed**

o **Form drag—shape of the aircraft,** i.e. streamlined object

o Skin friction—surface finish

o Interference—Intersection of two surfaces at angle – i.e. wing to fuselage.

• **Induced: "low speed drag" from high AOA.** By product of lift (horizontal component) and Wing tip vortices, varies **inversely as the square of the airspeed.** *Diminished in ground effect.*

L/Dmax drag graph. Drag vs Airspeed (figure 5-6 below) Max Range and Best Glide Vg occur at L/D max. **max endurance** –lowest power to sustain level flight occurs a slightly lower airspeed.
Region of reversed command-air speed between stall and max endurance (more power to fly slower!)

- *As air speed increases, a lower AOA is required to generate required lift.*
- *As air speed decreases, the AOA must increase to generate required lift.*

This is why induced drag predominates at low airspeeds. Because of the high drag at high AOA, more power is required to fly slower!

Slow flight and approach to landing occur in this region at slow speeds. Power controls descent rate, pitch controls air speed. See discussion in Aircraft Performance.

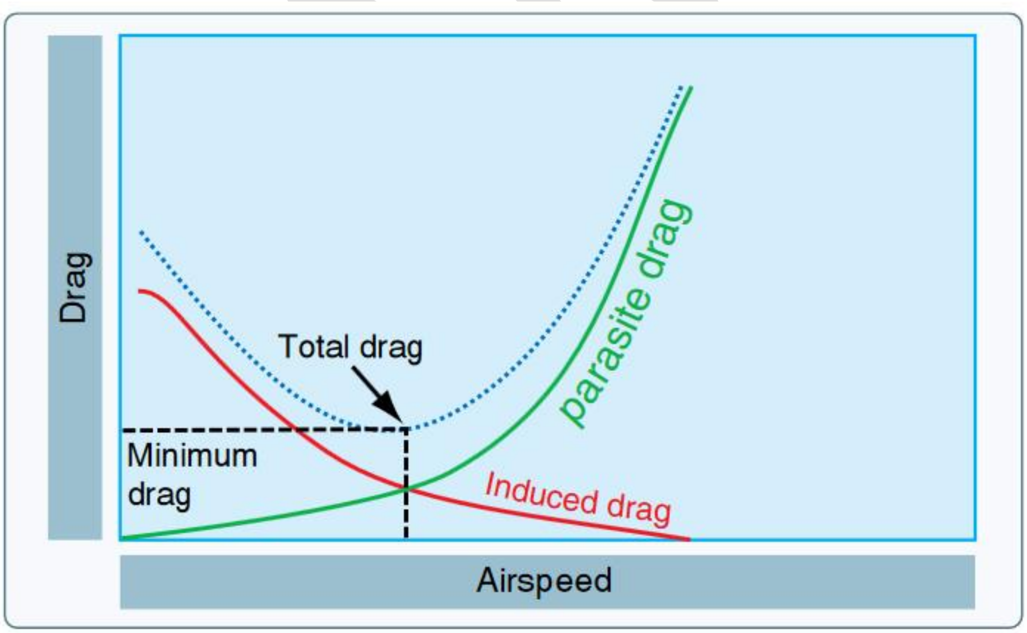


Figure 5-6. *Drag versus speed.*

Wing vortices (PHAK 5-8):

- Spanwise movement of air along wing due to pressure differential (over simplified)
- Air from bottom of wing moves outward and upward over the wingtips, creating a vortex

NOTE: *The PHAK errantly relates "wingtip" vortices as cause of wake turbulence. It is the larger mass & volume of downwash from the whole wing that creates "Wing Vortices" or "Wing Sheet Vortices" that cause wake turbulence. (Anderson & Eberhardt, Understanding Flight, 2nd ed.)*

- High angle of attack increases the DOWN WASH behind wing = more violent vortices
- **Heavier** aircraft need more lift, more downwash= bigger vortices
- **Slower** aircraft need high AOA = more violent vortices
- **Clean** Aircraft need higher AOA = more violent vortices

Wake turbulence on take-off/landing: Wake turbulence occurs BELOW a flying aircraft. Avoid the runway UNDER a large aircraft approach or climb out. The runway between is safe.

- Stay above glidepath
- Land or take-off beyond the point of landing heavier aircraft
- Lift off prior to the point a larger aircraft takes off
- Light quartering tailwind keeps vortices on the runway the longest (the most dangerous)

Figure 5-14. *Avoid turbulence from another aircraft.*

Ground effect (PHAK 5-11): LESS than one wingspan of the landing surface, there are complex changes in airflow around the wing which may include:

- Decrease in wing sheet vortices (ground interferes with full development)
- Underwing air compressed against ground increasing under wing pressure.
- More lift at lower angles of attack

Results in

- decrease in induced drag
- requires less thrust
- any excess speed results in "floating"

Risk: If over gross weight or force Lift off before flying speed may travel distance and then fail to climb out of ground effect or settle back to ground (hopefully with runway remaining)

Axes of rotation (about CG): longitudinal (roll/ailerons), lateral (pitch/elevator), vertical (yaw/rudder).

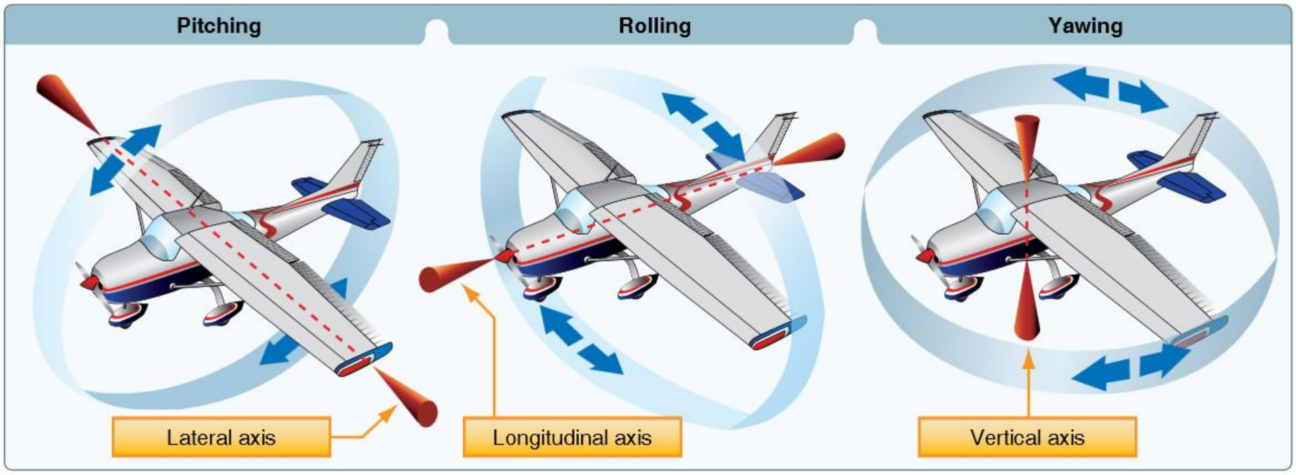


Figure 5-18. *Axes of an airplane.*

Stability (see PHAK 4-12) (Use marble and bowl analogy):

- Stability is the inherent quality of an airplane to correct for conditions that may disturb its equilibrium, and to return or to continue on the original flight path
- **Static stability: Initial tendency** of an object to return to its original position after being disturbed
  - o positive returns to original state; neutral: remains at new state; negative: keeps moving beyond
- **Dynamic Stability: Oscillation Response over time**
  - o Positive: dampened oscillations; neutral: oscillations unchanged; negative: oscillations increase in magnitude

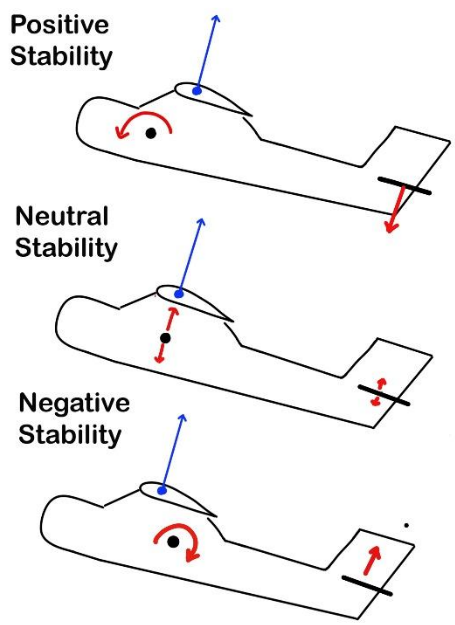
Longitudinal stability (about lateral axis: pitch):

- Most affected by pilot, especially aircraft loading
- Draw Center of Pressure (Lift), CG, horizontal stabilizer down force (balance CL)
- **Horizontal stabilizer -** downward force to balance the forward CG.
- Unstable if CG moves too close to or behind the center of lift
- NOTE: tail down force should be 5th force acting on aircraft (thrust vs drag, lift vs weight/tail down force.

Figure 5-23. *Longitudinal stability.*

Change in the center of pressure (CP). Many texts describe the center of pressure on the wing moving with changes in AOA or deployment of flaps. While the CP does move, this does not contribute significantly to pitching moments as much as the change in total lift. As the CP moves, so does the length of the arm that it acts upon the aircraft. With increases in AOA, the magnitude of the CP increases but also moves forward, the arm decreases. The net effect is *all changes* in CP act through the "Aerodynamic Center" (AC), typically 25% of the cord length aft of the leading edge. For stability, nearly all aircraft are designed with the CG forward of the AC. Increases in lift produce a down pitching moment.

Stability, Stall recovery and CG location. Longitudinal (Pitch) Stability of the aircraft requires the CG to be located forward of the Center of Lift. With forward CG, a pitch up disturbance results in an increased AOA and increased lift *BEHIND the CG*. *The aircraft will rotate around the CG* causing a restoring down pitching moment (positive stability). If the CG is moved aft to the Center of Lift, then any displacements will not produce any opposing pitching moment resulting in neutral stability. If the CG is moved behind the AC, then a pitch up displacement will increase AOA and lift which then causes a further pitch up moment and further increase in AOA. This is negative stability. CG aft of manufacture's limits may result in a highly unstable aircraft that is incapable of recovering from a stall. Forward CG increases stability and allows recovery from a stall.



Control Forces: Most aircraft CG normal operating envelope is forward of the Center of Lift (aerodynamic center AC). CG in this envelop balances with tail down force and results in normal control forces. As the CG moves forward, it requires larger control forces to change pitch. As the aircraft slows to land, elevator authority is reduced and may not be sufficient to flair with CG forward of the manufactures' range. As the CG moves aft, less tail down force and lower control forces are required. If the CG moves aft of the Center of Lift, up pitching movements are unopposed or even increased. Opposite control inputs may be required. This is highly unstable and my not be able to pitch down sufficiently to recover from a stall.

Lateral stability (about longitudinal axis: "Roll stability")

- Dihedral (sideslip, low wing w/ higher AOA)
- Wing position—high wing aircraft are more laterally stable than low wings (Cg moment arm lower)

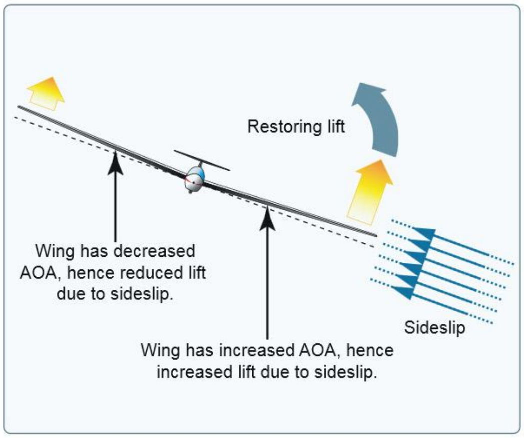


Figure 5-29. *Sideslip causing different AOA on each blade.*

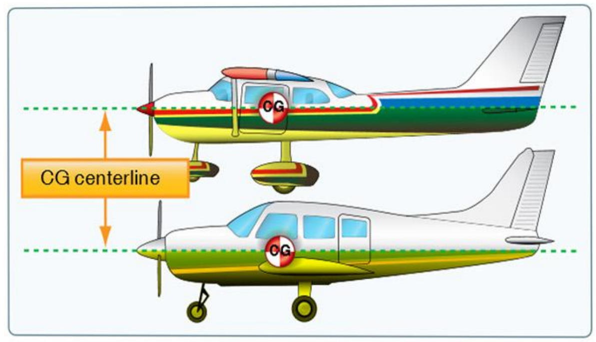


Figure 5-31. *Keel area for lateral stability.*

Vertical stability (about the vertical axis: "Yaw stability")

- Vertical stabilizer and aft fuselage: weathervane-directional stability (Keel effect)
- Swept back wings also provide directional stability
- Increased induced drag on the wing that is moved forward pulls it back, Causes Dutch roll tendency

Controllability versus Maneuverability

- Controllability—capability of an aircraft to respond/displace to the pilot's control inputs
- Maneuverability— determined by its ability to change attitude/velocity/flight path (includes withstanding stresses/G loads)-
- An F-16 sacrifices stability for maneuverability but requires computer assistance to maintain CONTROL!

Turning tendencies (PHAK 5-28)

- **Torque**—opposite reaction to engine rotation (Newton's third law): leads to a left roll
- **Spiraling slipstream**—pushes on port side of vertical stabilizer, causing left yaw
- **Gyroscopic action (**precession)a pitch down (raising the tail) will cause a left yaw 90º from the top of the propeller, a pitch up will cause a right yaw 90º from the bottom of the propeller disk. This is most common in tail wheel aircraft where lifting the tail off the ground causes the aircraft to deviate to the left.
- **P-factor**—downward blade has a higher angle of attack during a *high pitch attitude*, causing greater thrust on the right side of the propeller disk, creating a left yaw (and vice versa). P factor minimized in level flight.

Load Factor: Ratio of lift required for flight to the weight of aircraft. Commonly expressed in G's. Load can also be thought of as an increase or decrease in the apparent weight of the aircraft relative to unaccelerated 1 G flight. If during maneuvers, the acceleration forces increase or decrease, the apparent weight changes as does the required lift.

LOAD factor in a Turn. All forces must be equal to maintain level flight**.** In the diagram below, the vertical component of lift must equal the weight of the aircraft in all bank angles. In a bank, there is additional lift required in the horizontal plane to turn the aircraft. This is opposed by the centrifugal force which must be equal and opposite the horizontal component. The centrifugal force is in addition to the weight of the aircraft. The steeper the bank, the more horizontal lift created and the more centrifugal force (Load) that is added. This increases the total load of the aircraft and the total lift required. Higher air speed is required to prevent a stall.

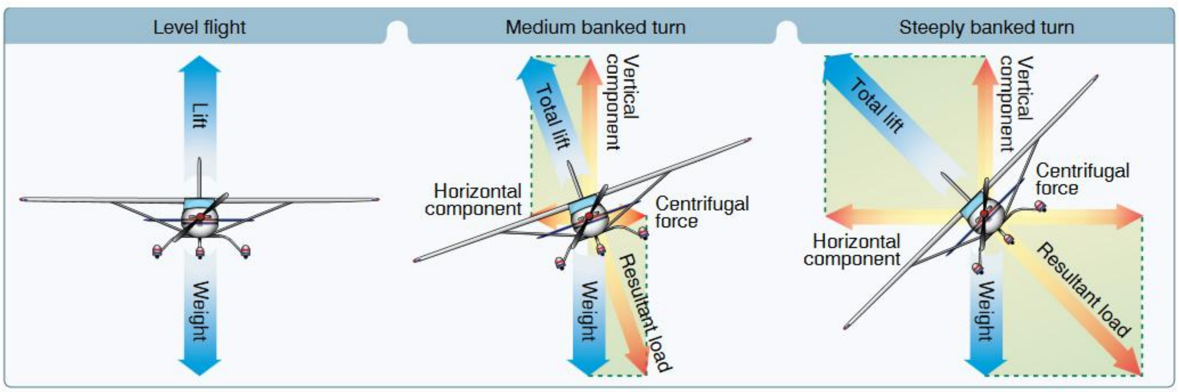


Figure 5-34. *Forces during normal, coordinated turn at constant altitude.*

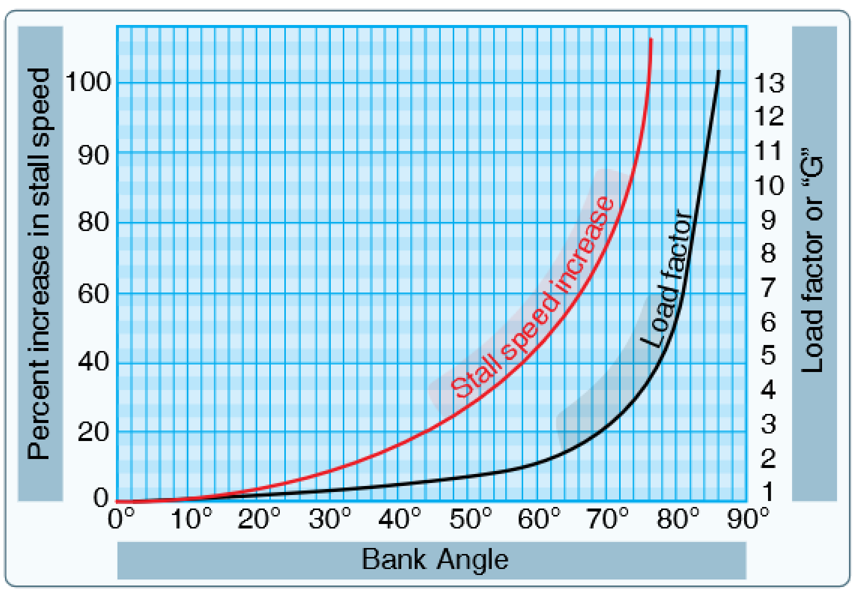


Figure 5-39. *Increase in stall speed and load factor.*

Stall speed proportional to square root of load factor. The load factor in a 60^0 bank is 2 Gs. $\sqrt{2}$= 1.41. So the stall speed increases 41% in a 60^0 bank.

Change in load = change in stall speed. With increased load, more speed is required at the critical AOA to generate sufficient lift**.** With decreased load, less lift is required. ***Stall speed is t****he minimum speed at the critical AOA to maintain level flight.*

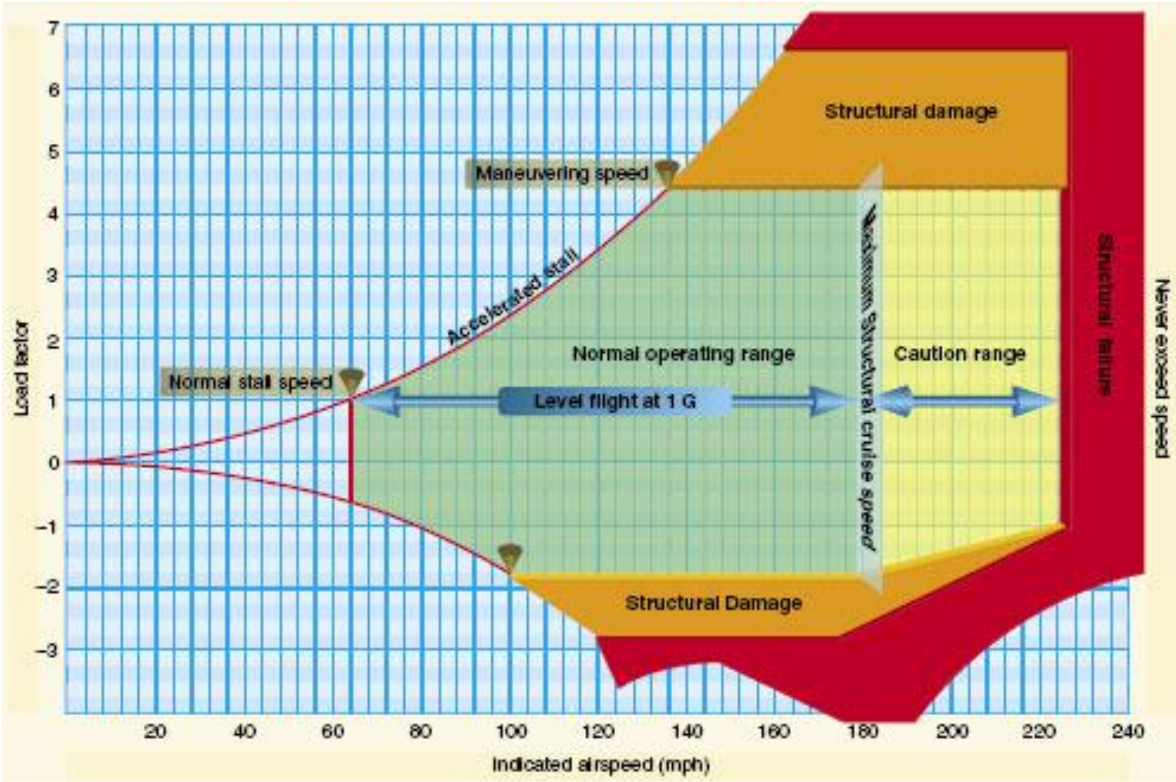
Accelerated Stall speed. As we increase the load in a turn, lift must be increased without exceeding the critical AOA. AS we reach the critical AOA, the only way to produce enough lift is higher airspeed. Therefore, the *required* Airspeed to prevent a stall must increase.

Stall speed with changes in gross weight. If we increase or decrease the weight of the aircraft, we change the load and consequently the lift required to maintain level flight. Since stall speeds are published at max gross weight, the stall speed is lower than published at reduced weights. It can be calculated in the equations that follow in the advanced discussion that follows. A rule of thumb for GA is the stall speed decreases by approximately 1 kt for every 100 lbs. below max gross weight. Since approach speeds are based on stall speed, the approach speed will also decrease with decrease in weight in a similar fashion.

Maneuvering Speed: is simply the *accelerated stall speed* at the *maximum load factor* the aircraft was designed for. Therefore, **Va=maneuvering speed** is the *accelerated stall speed* at the design limit load factor (3.8 G for normal category aircraft). If we increase the weight of the aircraft, we increase the stall speed and the maneuvering speed. Lower weight decreases both the stall speed and maneuvering speed. See discussion below (caution, some math involved).

Turbulence penetrations speed: Turbulence penetration speed is typically LOWER than Va and is not published for many general aviation aircraft. Va is tested with a single control input in one direction to verify airframe withstands calculated design loads limits. Va is NOT tested to withstand multiple combined control movements NOR the rapid recurrent loads that may be sustained in turbulent air penetration. In turbulent air, both positive and negative G loads may be sustained. Turbulence penetration speeds consider the “gust” factors that can briefly increase the indicated airspeed. Speeds below Va are required to account for this “gust” factor. In the absence of a published turbulence penetration speed, a cautious pilot would slow to a safe margin below Va.

Vg diagram (PHAK Fig. 5-55). Load factor vs Airspeed for given gross weight/altitude



Accelerated stall speed: the curved line between Normal and Maneuvering stall speeds

Normal stall speed at 1 g

Maneuvering Speed accelerated stall speed at design load limit (4.4 utility category)

Normal Operating range:

Left to right between 1 G stall speed and Vno (Max Cruise speed)

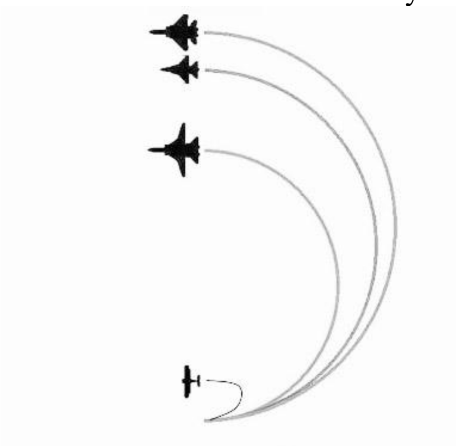
Top to bottom between Positive and negative design load limits (4.4 & -1.76)

Vno: max structural cruise speed. Operate in smooth air only.

Vne: Never exceed "red line" speed. You're a test pilot. You're going to break something.

Discuss Rate of Turn (how fast to change direction) **vs Radius of Turn** (How much space is required to turn around)

Radius of turn: proportional to V^2 (*double speed = 4X radius*).
Radius of turn inversely to bank angle (*double bank angle =1/2 turn radius*)



Rate of turn (change in degrees of heading per second): Slow down and increase bank to turn around the fastest!

Increased Rate of turn	**Decreased Rate of Turn**
Higher bank angles	Lower bank angles
Lower ground speeds	Higher ground speeds

Evaluation

Lesson is complete when student can demonstrate fundamental understanding of aerodynamics through discussion of outlined principles, answer questions related to these principles.

References

FAA-H-8083-25B Pilot's Handbook of Aeronautical Knowledge (PHAK) Chapter 4 and 5
Aeronautical Information Manual (AIM) 7-3-1

Aircraft Systems

Objective To teach the student the basics of aircraft systems.

Elements

- Primary flight controls: elevator, ailerons, rudder
- Secondary Flight Controls: Flaps, leading edge devices, spoilers, trim
- Power plant
- Oil
- Avionics

Schedule

Discussion 0:45

Equipment

Aircraft, Pilot Operating Handbook (POH) or FAA-approved Airplane Flight Manual (AFM). Model aircraft

Instructor Actions

Discuss the components of primary flight controls:

Primary Flight Controls:

Primary control surface	**Airplane movement**	**Axis of rotation**	**Type of stability**
aileron	**roll**	longitudinal	lateral
elevator	**pitch**	lateral	longitudinal
rudder	**yaw**	vertical	directional

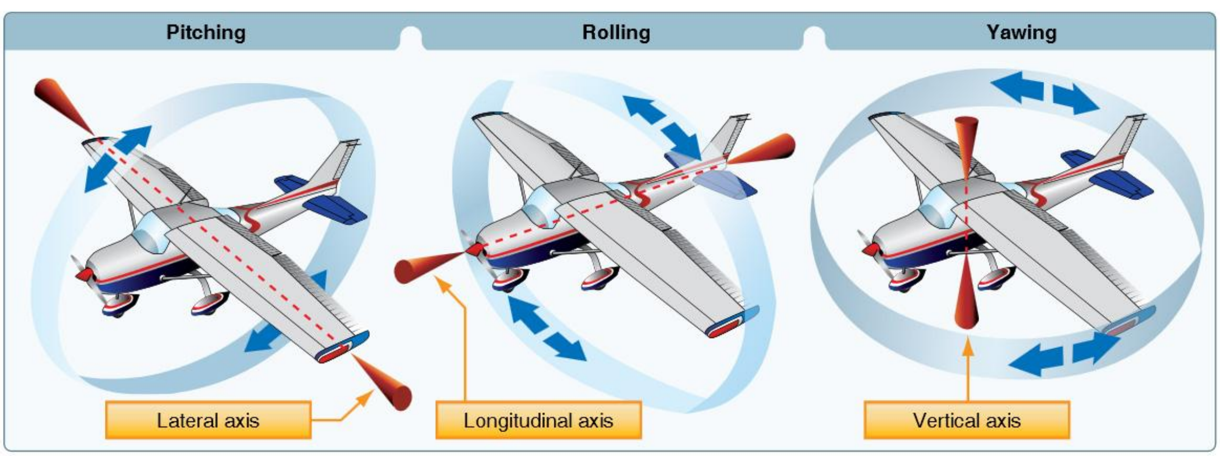
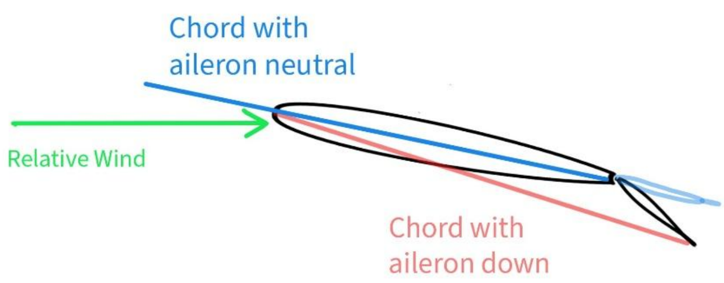


Figure 5-18. *Axes of an airplane.*

Control Surfaces work by changing the AOA on the airfoil. For example, downward deflection of an aileron increases the AOA (changes chord line to relative wind) on the wing increasing lift and drag. Upward displacement of the aileron decreases the AOA which decreases both lift and drag. Elevators and Rudders change the AOA on their stabilizers which produces the pitch and yaw effect described below.



Ailerons:

- o Control roll about longitudinal axis
- o **Adverse yaw** can be counter acted with rudder use, or special aileron designs: differential ailerons, Frise-type ailerons, ailerons coupled to the rudder

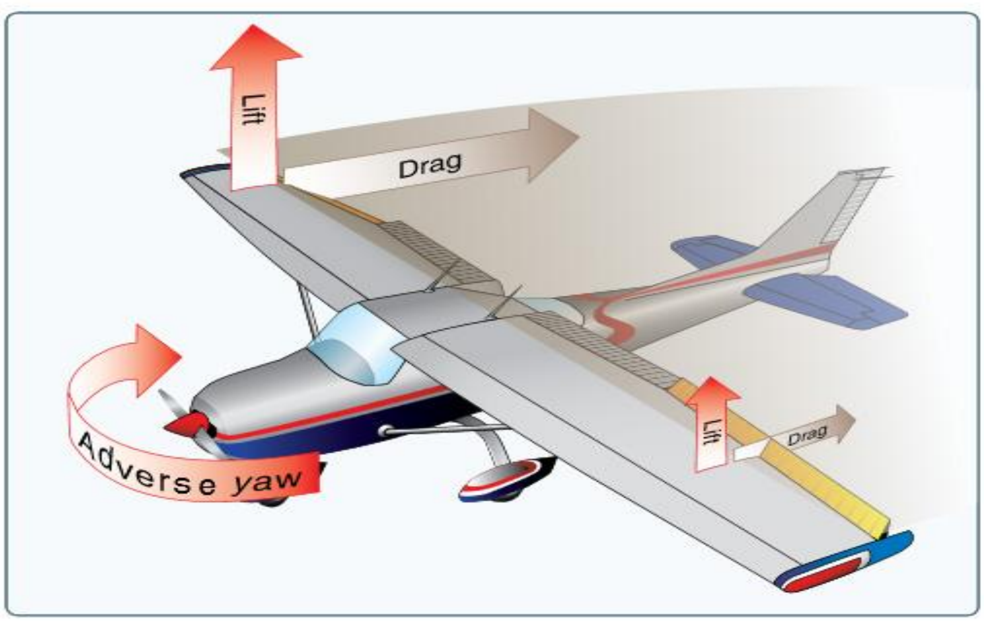
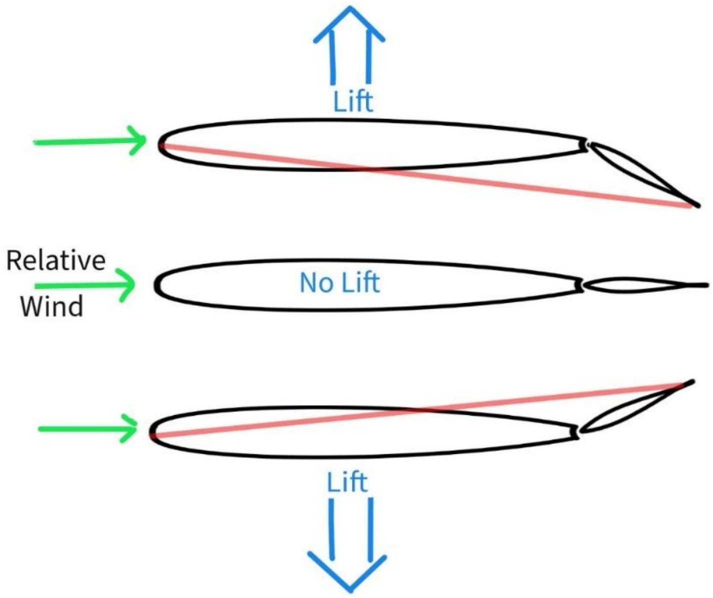


Figure 6-5. *Adverse yaw is caused by higher drag on the outside wing that is producing more lift.*

Rudder, Elevator and trim tabs. The horizontal and vertical stabilizers are typically symmetric airfoils which have a symmetric pressure distribution with zero lift at zero degrees of angle of attack. When the elevator or rudder are displaced, the cord line changes and these airfoils will produce lift in either direction efficiently. Cambered airfoils can produce lift in either direction but require significant AOA below zero to produce negative lift. It is common misconception the displacement of the control surface impacts and thus "deflects" the airstream to produces the required pitch or yaw moments. *The force generated by impact of the free air stream against a displaced control surface is very small compared to the lift force generated through AOA created by the same control surface.*



Elevator: Controls pitch about lateral axis. The Main purpose is to pitch up and pitch down relative to the pilot. For example, in a steep turn, the elevator will "pitch" the aircraft further into the turn. Pulling aft on the elevator generally increases the load and angle of attack in upright (positive G) flight

Stabilator: Some aircraft (e.g. Pipers) use a stabilator with an anti-servo tab. The entire horizontal stabilizer moves to induce pitch changes. The Anti-servo tab moves the opposite direction of the stabilator to decrease control stick forces for the pilot. The anti-servo tab can be adjusted in the cabin and function as a trim tab.

Rudder: Controls the airplane about its vertical axis – **yaw** (nose going left/right). The primary purpose is to offset adverse turning tendencies (adverse yaw in turns and left turning tendencies on take-off, climbs), cross wind landings, and taxiing.

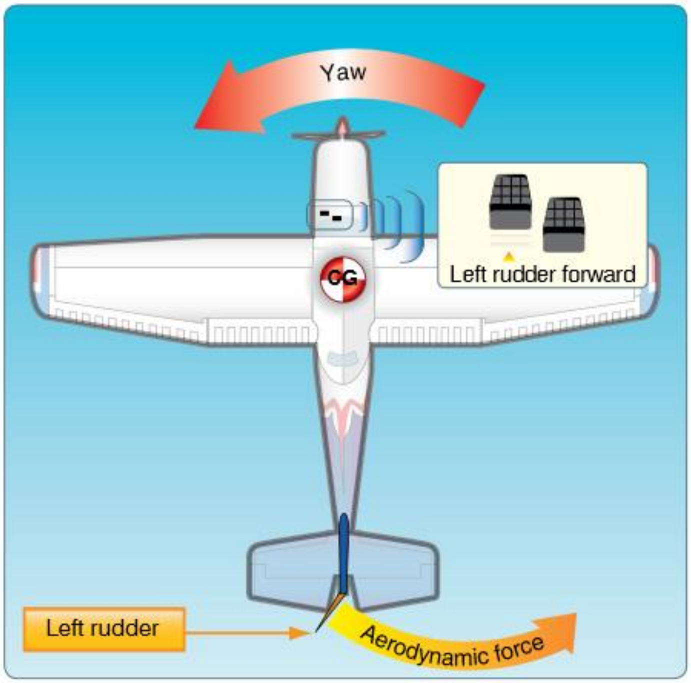
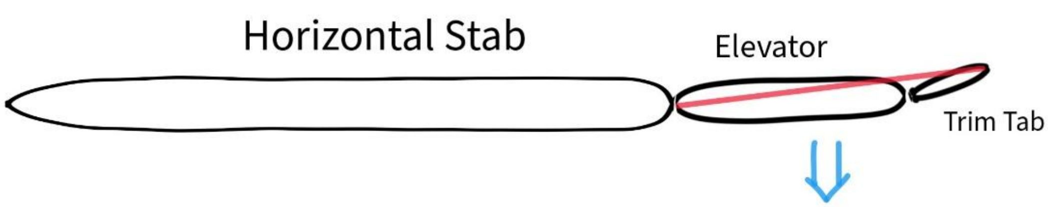


Figure 6-15. *The effect of left rudder pressure.*

Secondary Controls:

- **Trim:** Used to relieve control pressures, Trim tabs, ground adjustable tabs

  Trim tabs affect the elevator, rudder and ailerons in the same fashion. However, the trim tabs move opposite as the desired primary control surface direction. In the diagram below, the local negative AOA moves the elevator down till it reaches equilibrium with other aerodynamic forces or reaches zero local AOA. The Elevator displaced downward causes the AOA to increase in the horizontal stabilizer moving the tail up and the nose down (*aircraft rotates around CG*).



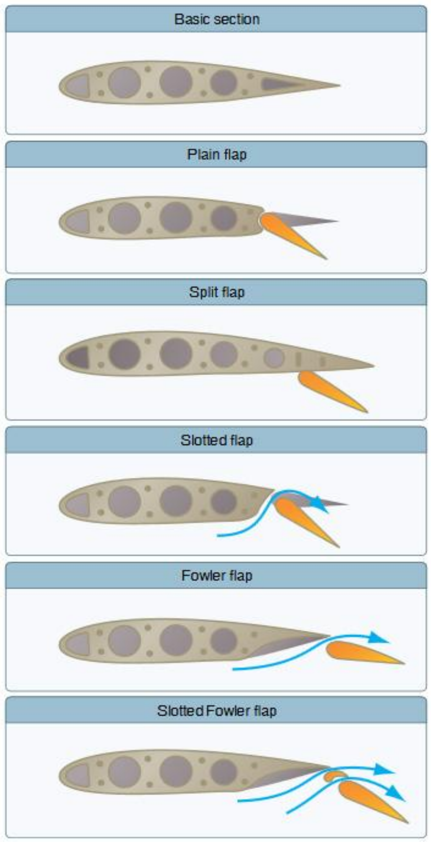


Figure 6-17. *Five common types of flaps.*

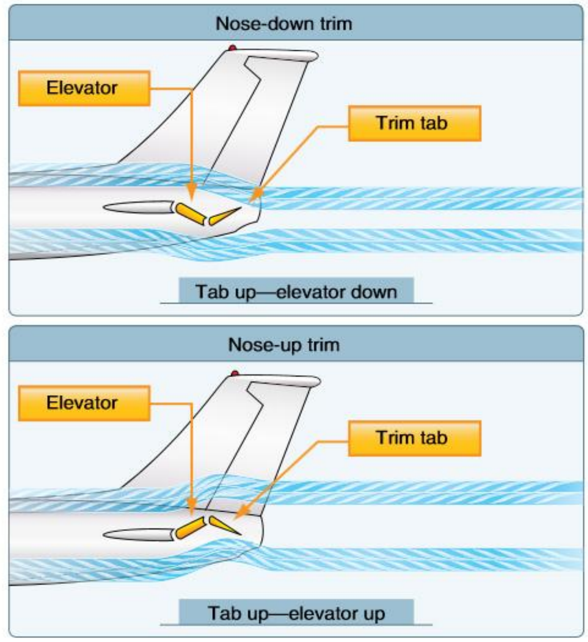


Figure 6-20. *The movement of the elevator is opposite to the direction of movement of the elevator trim tab.*

- **Flaps:**
  - o Increase lift and drag.
  - o **Flaps have three main functions:**
    - **slower landing speed** *(reduces stalls speed)*
    - **steeper angle of flight path** *(by allowing slower approach speed)*
    - **shorten takeoff** (*increase in coefficient of lift*)

  - o Plain—simplest, changes camber, increases lift, greatly increases drag
  - o Split—more lift and more drag
  - o Slotted—(most common) increases lift more than drag. Delays air separation.
  - o Fowler flap—a variety of slotted flap; changes camber and increases wing area

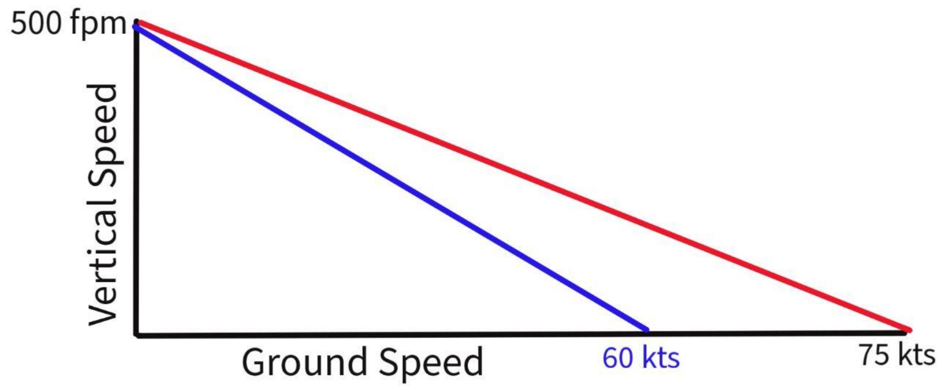
- **Leading edge devices**:
  - o Fixed slots—direct airflow to upper wing surface and delay airflow separation by energizing boundary layer; stall is delayed to greater angle of attack which allows greater lift production.
  - o Moveable slats—leading edge segments on tracks; may be automatic or pilot-operated
  - o Leading edge flaps—increase coefficient of lift and camber
- **Spoilers:**
  - o High-drag device; reduces lift, increases drag
  - o Used for roll control on some aircraft , can shorten ground roll

Flaps and approach considerations

Pitch attitude: Flap deployment requires a lower AOA to generate required lift at a given speed and pitch attitude will be lower. No flap landings require a higher pitch attitude

***NOTE**: pitch attitude does not equal steeper descent angle. See discussion below.*

- **Descent angle:** Flaps, *by themselves* DO NOT cause a steeper approach path to clear an obstacle. The descent angle depends on both *ground speed AND rate of descent*. Low ground speeds and higher rates of descent increase the descent angle. See figure below.
  - Flaps lower the stall speed which allows a *slower approach speed which steepens the approach angle*. However, if the approach speed is not reduced, neither will the descent angle.
  - Flaps add drag which increases the descent rate for a given power setting and given air speed. The *increased descent rate will increase the descent angle for a particular airspeed*. However, if too much power or air speed is carried in the approach, there will not be an increase in descent angle.



Note: Steeping the approach is accomplished by lowering ground speed. This can be done by slowing the approach or in the case of strong headwinds. More power is required to maintain glide path on an approach into a strong headwind. Maintain air speed with pitch.

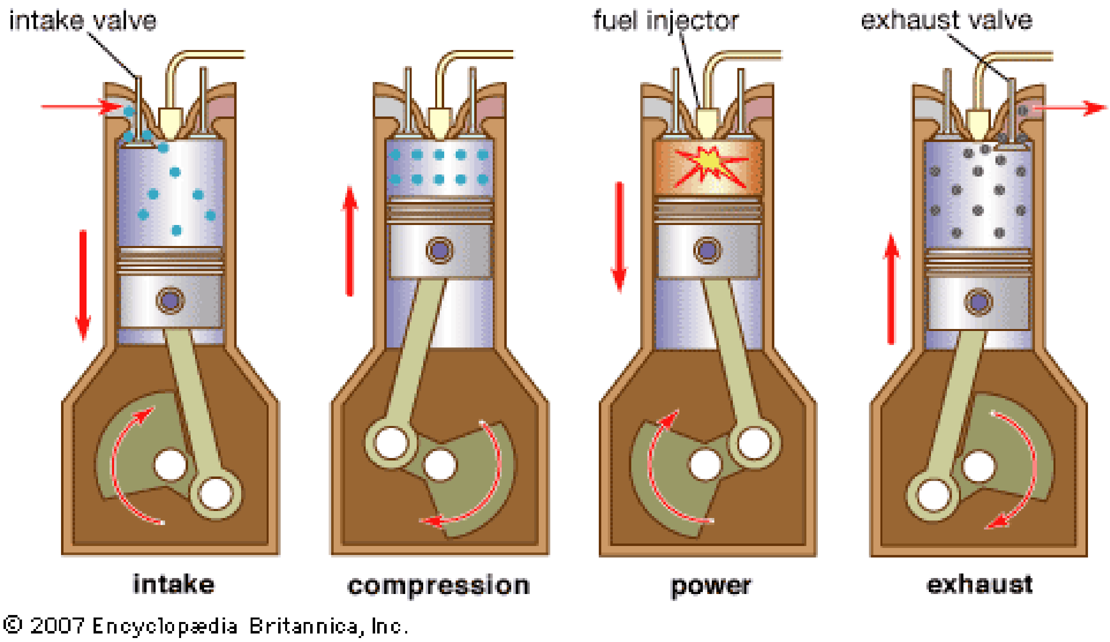
Introduction to other aircraft systems.

Reciprocating engines classified by cylinder arrangement (radial, inline, v-type, opposed), method of cooling (liquid or air), method of intake (carburetor, fuel-injection, turbo-charged), etc.

Main components:

cylinders (contain intake/exhaust valves, spark plugs, pistons);
crankcase (contains crankshaft, connecting rods)
Propellor and engine accessories turned by crankshaft.

Four-stroke operating cycle: intake, compression, power, exhaust rapid engine failure)



Normal combustion vs pre-ignition (carbon deposits) vs detonation (hot, high-power, lean, low octane fuel-causes

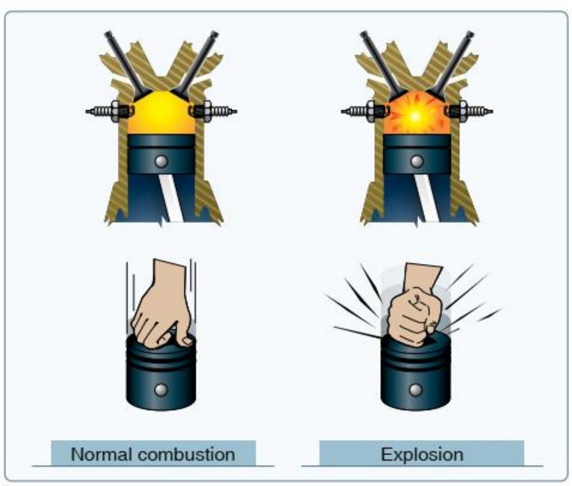


Figure 7-21. *Normal combustion and explosive combustion.*

Normal Ignition: fuel air mixture burns in a progressive wave from spark plug toward retreating cylinder on the power stroke adding push to cylinder.

Detonation: fuel air mixture explodes all at same time with violent expansion faster than retreating piston. *More likely with lean mixture, high-power settings with poor cooling* (low airspeed in a climb). Detonation also occurs with using *LOW octane fuel- using Jet A or 80 octane in aircraft designed for 100 octane fuel.* Respond with reduced power, enrichen mixture, descend for airspeed to cool engine.
Pre-ignition: Carbon or silica deposits in cylinder or on spark plug become red hot and cause air fuel mixture to ignite prematurely against an advancing cylinder on the compression stroke. Silica deposits from ingesting unfiltered air (Carb heat on when on ground), silica is trapped in spark plugs and can become hot source for pre-ignition! Watch carb heat, clean spark plugs!

Magnetos- 2 per engine (each supply one spark plug per cylinder with 2 sets of spark plugs per cylinder, see diagram end of lesson) generates own spark (no electrical system needed), Uses P-lead to ground out and prevent "spark" when ignition turned to off. 2 plugs per cylinder increases efficiency of fuel burn and 2 magnetos redundancy for reliable engine operation.

Testing Mags: Switching to a single mag- **RPM drop** is related to incomplete fuel combustion by loss of one of two spark plugs on each cylinder

Larger than expected drop- mag need service or fowled spark plugs

No RPM drop- P lead is broken and will have hot mag. Engine can still run with both mags "OFF". Risk of spontaneous engine start with prop handling.

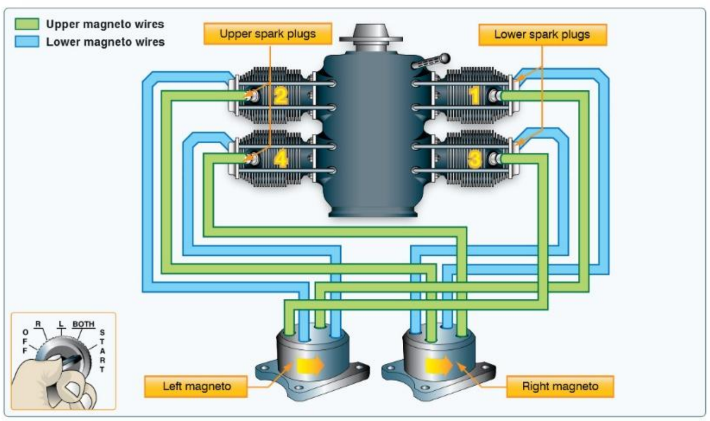


Figure 7-16. *Ignition system components.*

Oil: Lubricates, reduces friction, cools. If low oil pressure, check oil temp! This could indicate loss of oil which will *lead to engine failure*. Oil Pressure and Oil temperature gauges are required instruments.

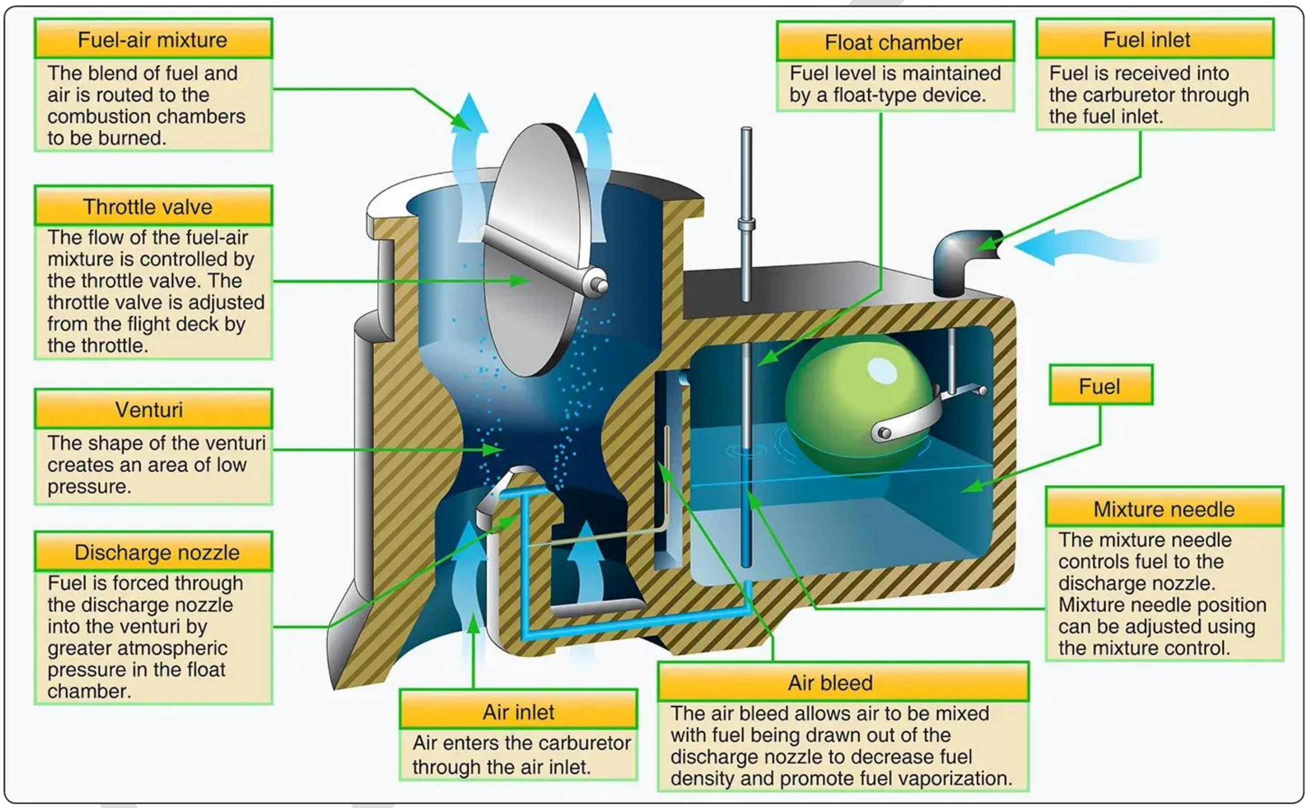
Carburetor:

Venturi effect: The narrowing of the throttle body of the carburetor accelerates the air. The acceleration of the air decreases the pressure per Bernoulli's equation. It is the drop in pressure that promotes more rapid fuel vaporization in the slip stream. This pressure drop is a small amount (1 or 2" Hg or about 1 psi) compared to the pressure drop from low power settings (10-15" Hg). See below. Lower pressure by itself DOES NOT decrease the temperature. This is why fuel injected engines DO NOT develop ice in the throttle body (fuel is vaporized in top of cylinder)

Low power settings: The engine is an "air pump" with the vacuum on the intake (carburetor) side and pressure on the "exhaust" side. The "Butterfly" valve closing in the throttle body of the carburetor restricts airflow into engine thus creating a relative "Vacuum" in the throttle body of the carburetor. This creates larger pressure drops (15" Hg or about 7 psi drop) and promotes the most rapid fuel vaporization.

Latent heat of vaporization: Rapid fuel evaporation in the carburetor causes large temperature drops below freezing and thus ice formation. Carb Icing detected by drop in RPM or Manifold pressure- The engine will only run rough right before it quits. Add FULL Carb Heat when in low power settings or power loss starts to occur. **Note:** Carb Ice is promoted by LOW power settings and humid cooler days. Carb heat should be applied when power reduced in pattern or for prolonged low power descents and maneuvers.

Hot days (think 80^0F +)- turn carb heat OFF on short final. Carb heat creates lower density of incoming air, relatively rich mixture and significant loss of power and may cause engine to stumble in case of go around or balked landing.



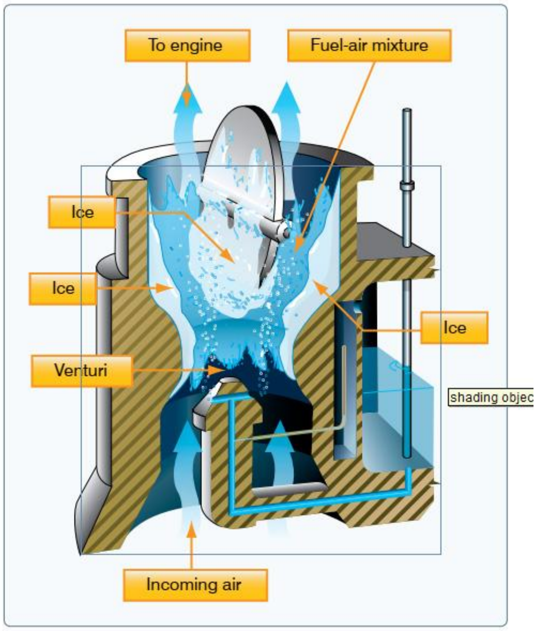


Figure 7-11. *The formation of carburetor ice may reduce or block fuel-air flow to the engine.*

Fuel Injection: The fuel-air control unit has both a "throttle body" that controls air flow into the intake manifold and a "fuel control unit" that controls fuel flow to the fuel injectors (located directly above intake valve of each cylinder). The fuel is not "evaporated" into the throttle body like a carburetor and thus is not prone to "Carb Ice".

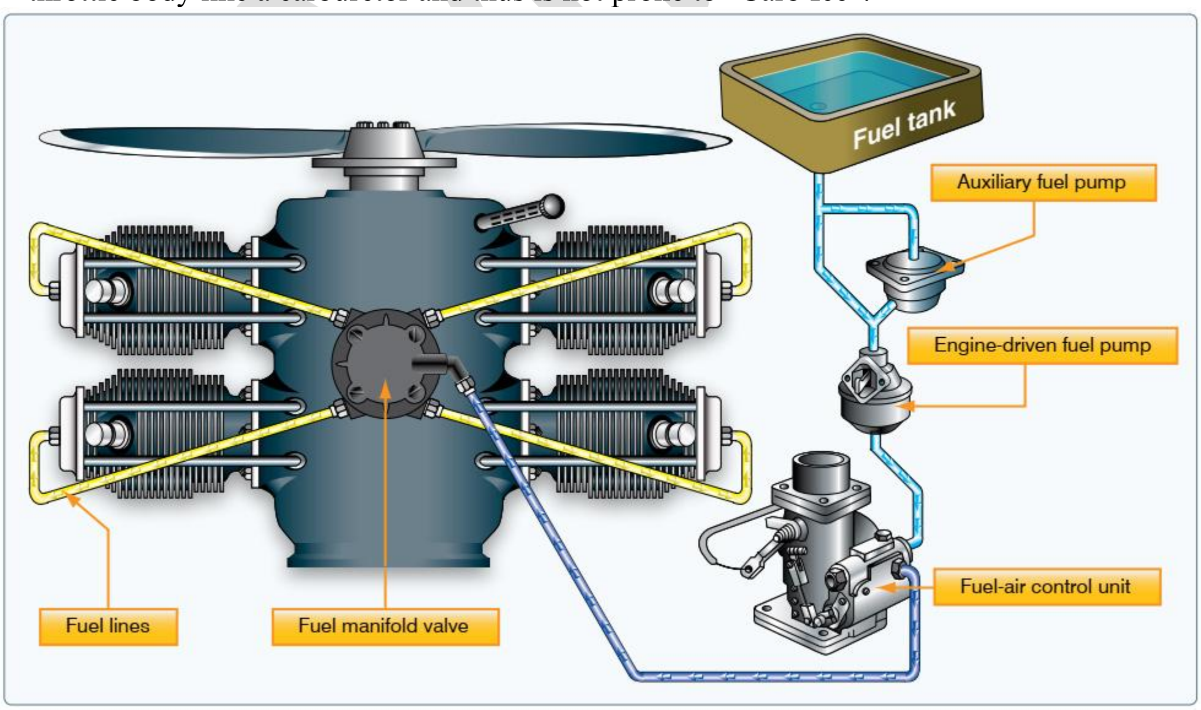


Figure 7-13. *Fuel injection system.*

• Avionics:
  - Communication and navigation radios
  - VOR, ADF, GPS
  - Transponder
  - Autopilot (if available)
  - Avionics cooling fan—cools and eliminates moisture (if available)
  - Microphone/headset intercom
  - Static dischargers (wicks)

Evaluation

Lesson is complete when student can demonstrate and discuss aircraft control surfaces, power plant and other major systems.

References

FAA-H-8083-25 Pilot's Handbook of Aeronautical Knowledge Chapter 4-5, POH / AFM Chapter 7