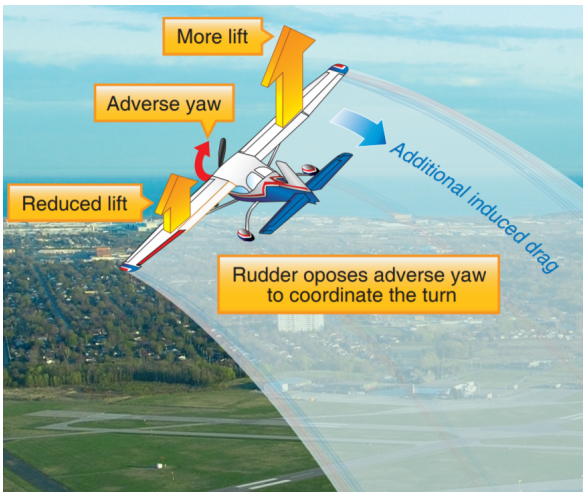
Level Turns

Objective	
To ensure the applicant learns the proper methods for performing level turns, as well as has an understanding of the purpose of the flight controls and the factors affecting turning flight.	
Purpose	
Turns are the building block for all the more advanced flying maneuvers. This maneuver introduces pilots to the primary flight controls, pitch trim, and the basics of turning flight, as well as the concept of coordination.	

Schedule	**Equipment**

• **Ground Lesson**: 15 minutes
• **Flight Lessons**
  ▪ **Flight**: 20 minutes - *Introduction to Maneuver*
  ▪ **Flight**: 10 minutes (per lesson) - *Improve Proficiency (Dual)*
• **Debrief**: 10 minutes (*per flight*)
	• Airplane Checklist
	• Whiteboard / Markers (optional)
	• Model Airplane (optional)

Student Actions	**Instructor Actions**
• Ask any questions, receive study material for the next lesson. • Watch linked video. • Review listed references.	• Deliver the ground lesson (below). • Demonstrate the maneuver in flight. • Debrief after each flight.

Completion Standards

- **Ground**: Student can explain the purpose and use of the flight controls and the factors affecting turning flight.
- **Flight**: Student can perform the maneuver to the following standards:
  - Maintains visual scan outside the cockpit while occasionally referencing the flight instruments.
  - Trims the airplane appropriately, maintains coordinated flight.
  - Turns to and rolls out on a heading +/- 15 degrees, maintains altitude +/- 100 feet, airspeed +/- 10 knots.

References

- Pilot Effect - “How an Airplane Turns”
    - YouTube - https://www.youtube.com/watch?v=VQLKYAf4h_U
- FAA-H-8083-3B (Airplane Flying Handbook) - Chapter 3, Page 2-4 [The Four Fundamentals/Effect and Use of Flight Controls], Chapter 3, Page 5-6 [Integrated Flight Instruction], Chapter 3, Page 10 [Trim Control], Chapter 3, Page 10-16 [Level Turns]
- FAA-H-8083-25B (Pilot’s Handbook of Aeronautical Knowledge) - Chapter 5, Page 1-8 [Forces Acting on an Aircraft/Thrust/Lift/Drag/Weight], Chapter 5, Page 12-13 [Axes of an Aircraft], Chapter 5, Page 22-23 [Forces in Turns], Chapter 6, Page 2-8 [Flight Controls/Ailerons/Elevator/Rudder], Chapter 6, Page 10-11 [Trim Systems], Chapter 8, Page 3-4 [Altimeter], Chapter 8, Page 8-9 [Airspeed Indicator], Chapter 8, Page 17-18 [Turn Coordinator], Chapter 8, Page 18-19 [Attitude Indicator]
- FAA-S-8081-6D (CFI PTS) - Area VIII Task B

Ground Lesson Outline

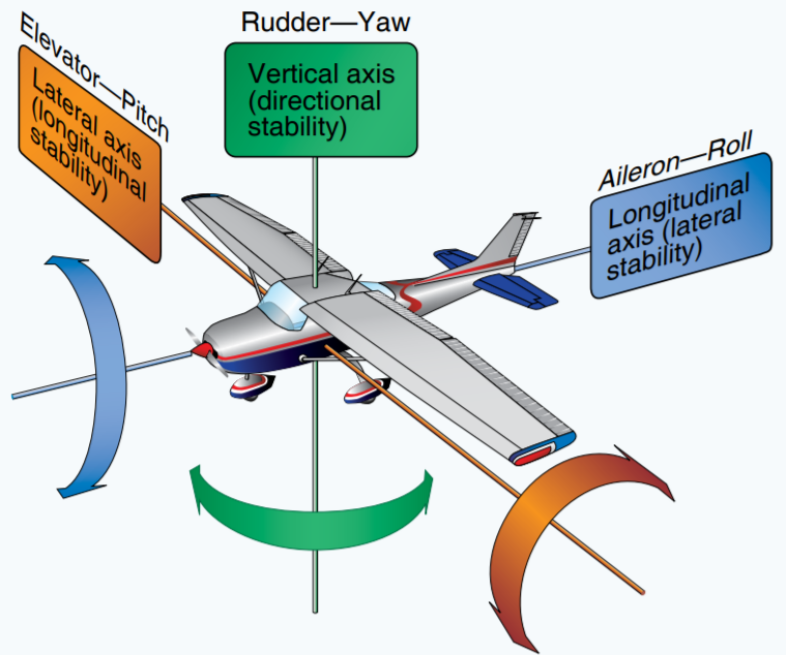
- Introduction to the Four Fundamentals
    - Straight-and-level, Turns, Climbs, and Descents
    - Most airplanes are inherently stable
    - Yaw/Pitch/Roll
    - Airplanes turn by banking
- The Primary Flight Controls
    - Ailerons, Elevator, Rudder
- The Elevator Trim
    - Relieving elevator pressure
    - Trim wheel, trim tabs
- Proper Yoke Grip and Overcontrolling
    - One-handed grip
    - Control movements vs control pressures
- How Airplanes Turn
    - Airplanes turn with bank
    - Flight controls are mostly neutral in a constant turn
- Establishing and Maintaining Level Turns
    - Heading and Altitude (the altimeter), Rollout
- Outside and Inside References
    - Sight picture
    - Attitude Indicator, Heading Indicator/Compass
- The Four Forces
    - Weight, Lift, Thrust, Drag
- Aerodynamics of Turning Flight
    - Load Factor, Weathervaning, Adverse Yaw, Two Phases - Banking and Turning
    - Coordinated Flight and use of rudder
- Relationship of Thrust to Maintaining Altitude
    - Airplanes don’t climb or descend with elevator alone
    - Tachometer, listening to the engine

Common Errors

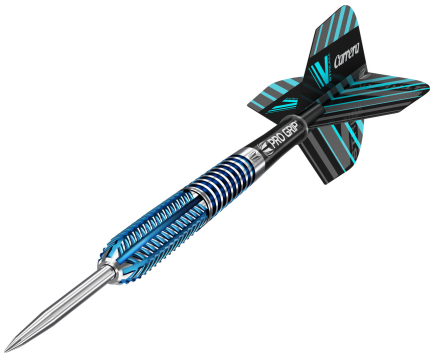
- **Failure to cross-check and correctly interpret outside and instrument references.**
- Application of control movements rather than pressures.
- **Uncoordinated use of flight controls.**
- **Faulty altitude and bank control.**

Ground Lesson Content

- **Introduction to the Four Fundamentals** - The *four fundamentals* of flight are **straight-and-level flight, turns, climbs, and descents**. Every flight training curriculum begins with mastering the fundamentals.
    - Most airplanes are inherently stable. The good news for aspiring pilots is that, for the most part, an airplane can be 'flown' without touching the controls at all. Of course, if the airplane is to go where *the pilot* wants it to go, the pilot will need to continuously monitor the airplane and make corrections using the *flight controls*.
    - Unlike cars, which turn only left or right in two dimensions, airplanes can move in three dimensions, and rotate around 3 separate axes. The orientation of the airplane is called the *attitude*. The 3 axes of flight are:
        - **Yaw** - *Yaw* is the familiar 'turning' left and right. Rotating around the *vertical axis*.
        - **Pitch** - *Pitch* is the up and down axis. The airplane is rotating around the *lateral axis*, and the nose will be pointing 'uphill' or 'downhill'.
        - **Roll** - *Roll* is somewhat unique to airplanes. **Roll is also often called *bank*.** The airplane is rotating around the *longitudinal* axis. There is no real similarity to cars in this dimension, but it can be thought of as the airplane *leaning* left or right.



    - Airplanes climb and descend in part by increasing or decreasing pitch, however, somewhat unexpectedly, **airplanes do not turn by simply changing yaw. Airplanes turn by banking towards the direction of the turn**, which directs the wings lift force to the side. The vertical tail surface keeps the airplane aligned with the direction of travel, causing the airplane to yaw. This is similar to how the fins or feathers on a dart or arrow keep it flying in the direction it is thrown.



- **The Primary Flight Controls**
  - Airplanes are commonly designed with 3 *primary* flight controls:
    - **Ailerons** - Ailerons move the airplane around its *Roll* axis. **The angle of roll is called the *bank angle* and pilots use the airplane to *bank* in the direction they wish to turn.** Most airplanes control the ailerons with a *yoke*, which is similar to a steering wheel. Turning the wheel left or right causes the airplane to bank left or right.

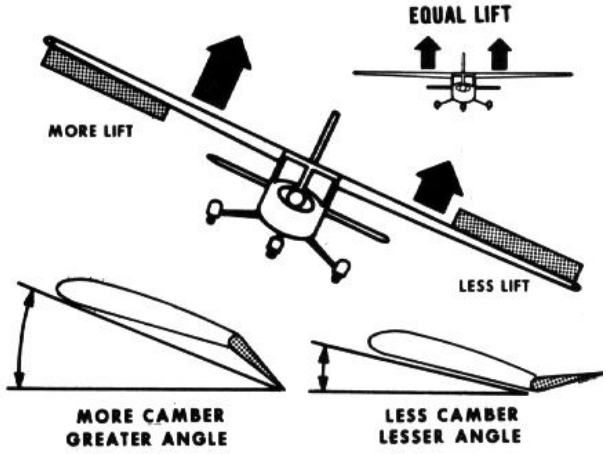
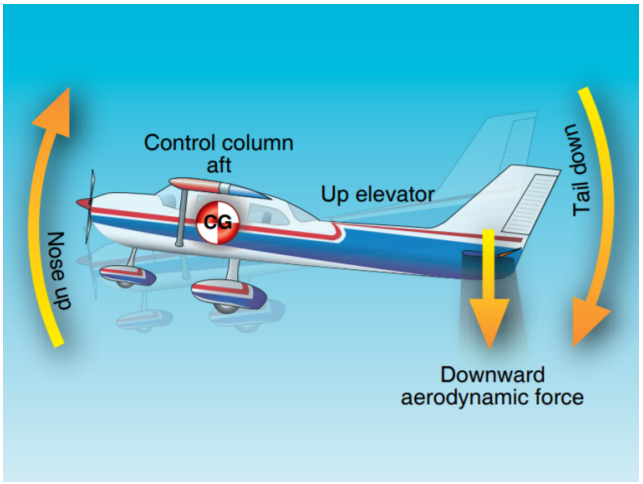
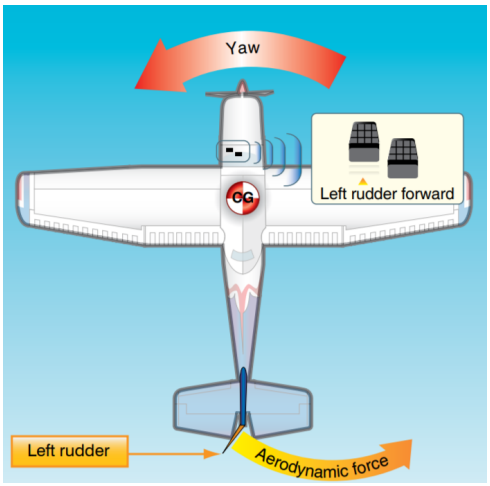


Figure 4–3 Forces Exerted by Ailerons

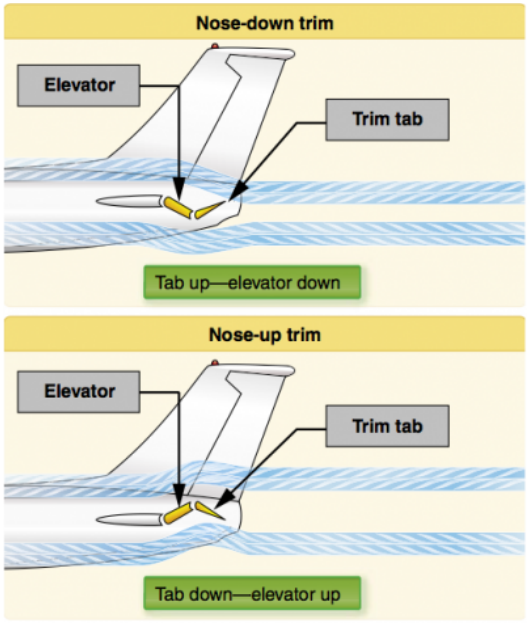
    - **Elevator** - The Elevator moves the airplane around its *Pitch* axis. Pilots can initiate a climb or descent by pulling back or pushing forward on the yoke, respectively.

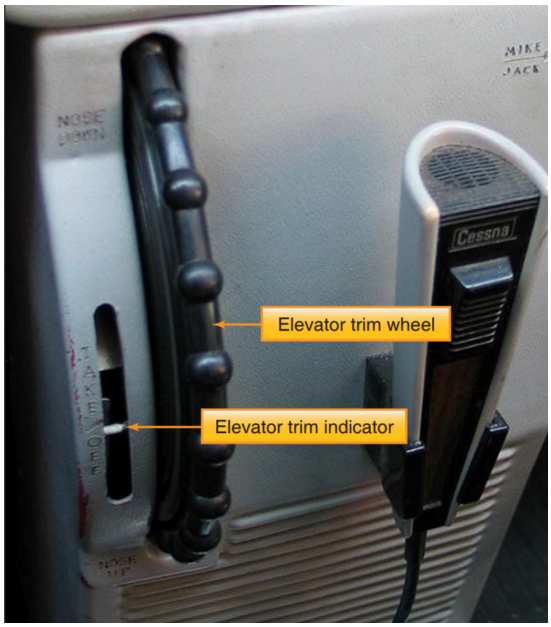


- **Rudder** - The Rudder moves the airplane around its *Yaw* axis. The rudder is a very mysterious control for most new pilots, because **it is not used to turn the airplane**, as one might expect. The sole purpose of the rudder is to aid the airplane in maintaining a proper (called *coordinated*) flight path during turns made with the ailerons (bank).



- **The Elevator Trim** - In order to hold the nose the proper distance from the horizon and maintain altitude, **new pilots often discover that it may require continuous forwards or backwards elevator pressure on the control yoke**. This is not only uncomfortable, it also requires pilots to devote more attention to maintaining straight and level flight and prevents them from multitasking effectively. There is another, *secondary* flight control, called *pitch trim* or *elevator trim*. These terms are interchangeable, and refer to a control wheel **(the *trim wheel*) which can be used to relieve these control pressures**.
  - The trim mechanism is different on different airplanes, but it usually consists of a small tab, called the *trim tab* on the elevator control surface itself. The trim tab services to 'rebalance' the neutral position of the elevator control and help maintain low control pressures.
  - The trim tab is moved with the *trim wheel*, which when rolled forward moves the trim *nose down*, and when rolled rearwards, moves the trim *nose up*.





- **Proper Yoke Grip and Overcontrolling** - Proper control of the airplane requires that pilots avoid *overcontrolling*. Unlike driving a car, which requires large movements of the wheel, flying an airplane rarely requires large movements, or a lot of force on the controls.
    - Pilots who grip the yoke tightly with both hands often struggle with maintaining straight and level flight or making smooth turns or other maneuvers. Pilots coping with turbulent or bumpy conditions often make the bumpiness *worse* by holding the yoke too firmly.
    - In most situations, pilots should attempt to relax, as **the airplane can be flown mostly with *control pressures*, rather than *control movements***. A one-handed, light grip on the yoke also frees the pilots other hand for manipulating the throttle, or adjusting the radios, etc.

- **How Airplanes Turn** - It is critically important for new pilots to understand how airplanes turn. Turning an airplane requires *banking* the airplane towards the desired direction, holding the airplane in the bank until the desired turn is achieved, and then leveling the wings again. For example, to complete a left turn:
    - **Step 1** - The pilot applies left aileron input (turns the yoke left) to begin banking the airplane to the left.
    - **Step 2** - When a modest bank (usually 30 degrees) is established, the pilot neutralizes the yoke. The airplane will tend to remain in the bank, and begin turning.
    - **Step 3** - When the desired turn is accomplished, the pilot applies right aileron input (turns the yoke right) to return the airplane to level flight.

- **Establishing and Maintaining Level Turns** - Maintaining a banked turn is simple. Pilots must manage the airplane so that it continues turning until it is flying in the desired *direction* (called *heading*), while maintaining the desired *altitude*.
    - **Heading** - Attaining the desired **heading is accomplished by banking**, by **turning the airplane left or right using the ailerons**, as described above. Heading can be determined by simply judging how closely the nose of the airplane is aimed at prominent visual landmarks.
        - When finishing a turn, the airplane takes some time to roll back to straight-and-level, so the pilot must 'lead' the rollout by beginning a bit before the desired heading is reached.
    - **Altitude** - When established in a level turn, **pilots can manage the altitude with pitch**: by climbing or descending by pitching up (pulling back on the yoke), or pitching down (pushing forward on the yoke).

- Unlike heading, which can be judged visually, it is not usually possible to visually estimate altitude with any accuracy. Therefore, pilots must use an instrument called an *altimeter*, which reports how high the airplane is above sea level.

- **Outside and Inside References** - Pilots use both *outside* (looking out the window) and *inside* (looking at the *flight instruments*) to maintain aircraft attitude. **It is important for pilots to use *both* of these references when flying an airplane**, to prevent optical illusions or poor outside visibility from disorienting the pilot. Comparing multiple independent sources of information about aircraft attitude is called *cross-checking*. The *integrated flight instruction* method recommended by the FAA emphasizes pilots utilizing both outside and inside references from the very beginning of their flying career to develop proper habits of cross-checking these references.
  - **Turning Sight Picture** - Pilots can visually judge their pitch and bank by using something called a *sight picture*. A sight picture is just a familiar appearance of the horizon relative to the airplane's *instrument panel* (dashboard), and is used to judge the *attitude*.
  - When making a turn at a given speed, the bank angle should be judged based on the angle the instrument panel makes with the horizon.

  - **Judging pitch during turns can be more difficult, as the nose appears to rise or descend when rolling due to the fact that pilots don't sit in the center of the airplane.** Pitch attitude can be more accurately judged by the place on the instrument panel that intersects the horizon.
  - Notice that during turns, **the point on the horizon that intersects the instrument panel changes depending on whether the airplane is climbing, flying level, or descending**.

- The *inside* reference for pitch and bank is an instrument called the *attitude indicator*, which is also sometimes called an *artificial horizon*.
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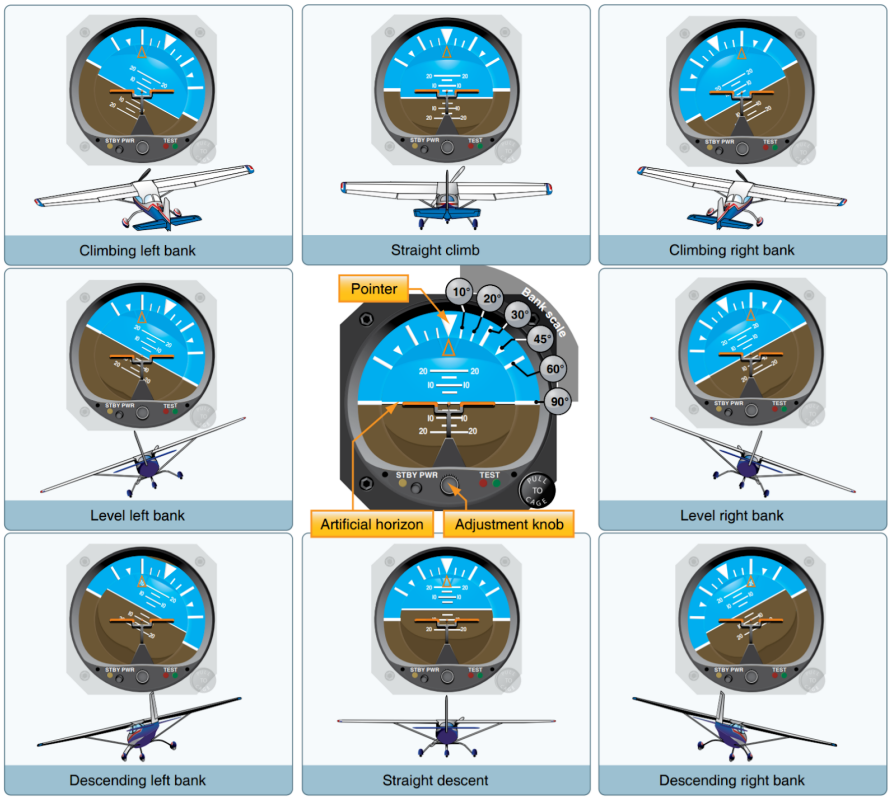
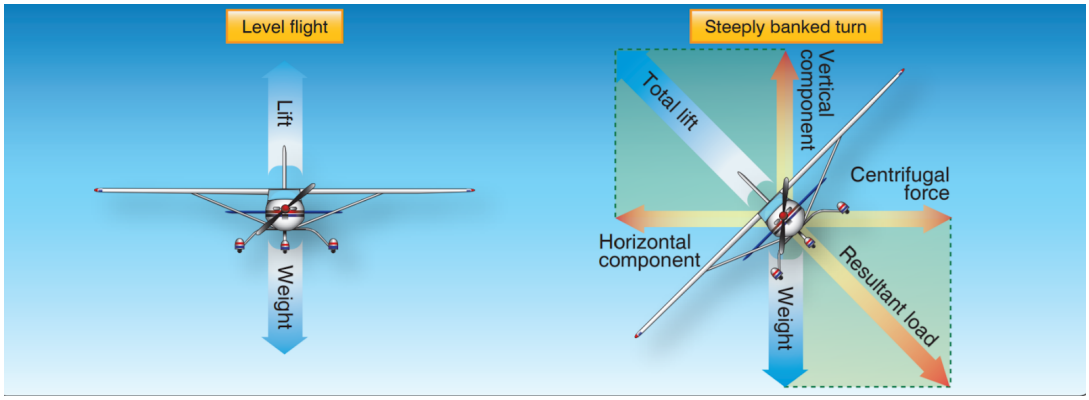
- The attitude indicator is used to back up the out-the-window sight picture for all phases of flight: straight-and-level, climbs, turns, and descents.



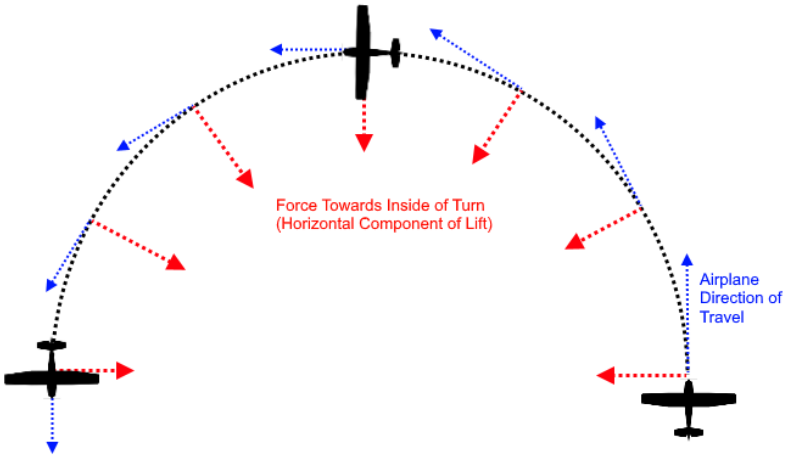
- Pilots also judge their heading by using an instrument called a *directional gyro*, which indicates the compass direction (North, South, East, West, etc) the nose of the airplane is pointing.

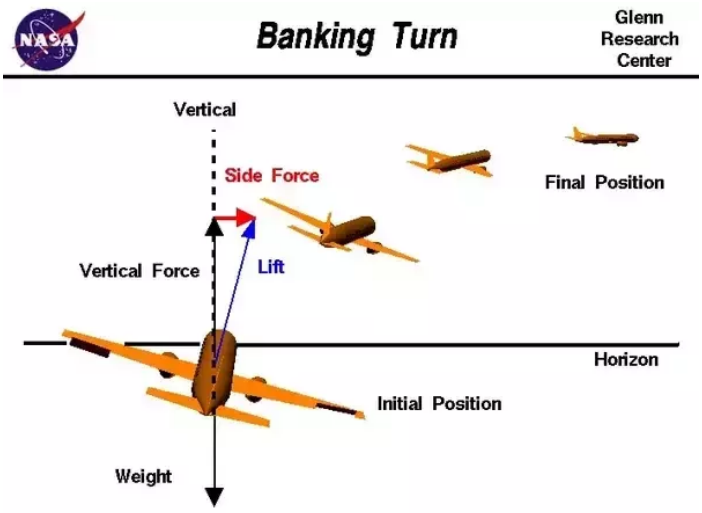
- **The Four Forces** - Airplanes in straight and level flight are subject to 4 basic forces:
  - **Weight** - *Weight* is the downward force provided by gravity. As an airplane sits stationary on the ground, the only force acting on it is gravity.
  - **Lift** - *Lift* is the upward force provided by the wing. As air flows over and around the wing, it is redirected downward, providing an upward force which during flight balances the downward force of gravity.
  - **Thrust** - *Thrust* is the forward force provided by the engine. Airplanes must move forward to generate lift, and this movement is provided by engine thrust.
  - **Drag** - *Drag* is the rearward force of air resistance, which opposes thrust. Most pilots are already familiar with air resistance… holding a hand out of the window of a moving car is a simple demonstration of drag.

- **Aerodynamics of Turning Flight** - New pilots discover quickly and intuitively that turning an airplane requires banking, however the physics and aerodynamics of turning flight are important for all pilots to understand.
  - **Load Factor** - One of the most important points to understand is that **turning an airplane requires the airplane generate more lift than in straight and level flight.** Because Newton's laws require that objects in motion will remain in motion unless acted upon by another force, changing the direction an airplane is flying requires providing this force. To do so, the airplane must create 'excess' lift, which is directed towards the center of the turn and changes the direction of motion. This causes the wing to support more than the normal weight of the airplane, and is felt in the form of 'g-forces'. The amount of load supported by the wing is called *load factor*.

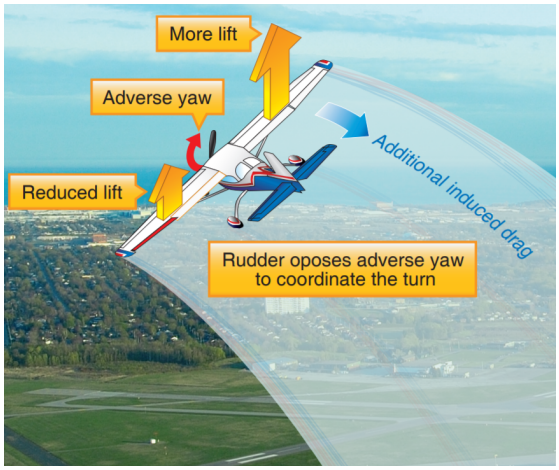


- **Weathervaning** - As the airplane flies around the turn, there is a horizontal component of lift, which is a force directed towards the center of the turn, and a vertical component of lift, which acts upward and opposes gravity. **As the airplane begins to move sideways, the relative wind strikes the vertical tail surfaces, and causes it to rotate towards the wind, just as in a weather vane.** This keeps the nose of the airplane pointed towards the relative wind, producing a *yaw* in the direction of the bank.





- **Two 'Phases' of Turning Flight** - The above explanation, however, is oversimplified. There are two distinct phases that an airplane goes through in turning flight:
  - **Banking** - Although banks *cause* airplanes to turn, banking by itself is not a turn. When banking, the airplane uses its ailerons to roll the airplane around the longitudinal axis. The *outside* (away from the turn) wing aileron lowers, producing a higher angle of attack and more lift, and the *inside* wing aileron raises, producing a lower angle of attack and less lift. **This increase in lift on the outside wing causes that wing to produce more drag on that side, which actually initially causes the airplane to turn away from the intended direction of turn!** This tendency is called *adverse yaw*. **Pilots should correct for adverse yaw by using the rudder pedals to counteract it whenever they use the ailerons.**



- **Turning** - Once the airplane is established in a bank, the effects of adverse yaw are mostly no longer present since the ailerons are neutral or nearly neutral. **However, an airplane banked towards a turn will still not by itself fly perfectly in line with the relative wind!** This is because, due to the curve flight path, the relative wind is angled slightly differently at the front and rear of the airplane. The larger, vertical tail surface will tend to assume an orientation that is aligned with the wind, but this causes the nose of the airplane to actually point slightly outside of the turn! This is called a *slipping turn*. A turn where the nose points to the inside of the turn is called a *skidding turn*, and is fairly similar to a car skidding turing a turn. (The turn is 'too flat', with not enough bank angle for the rate of turn) **Both slipping and skidding turns are undesirable!**

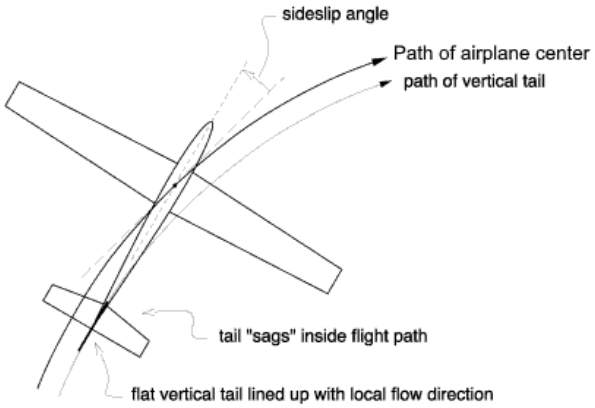


Figure 1a. Zero rudder deflection in sustained tight turn produces sideslip.

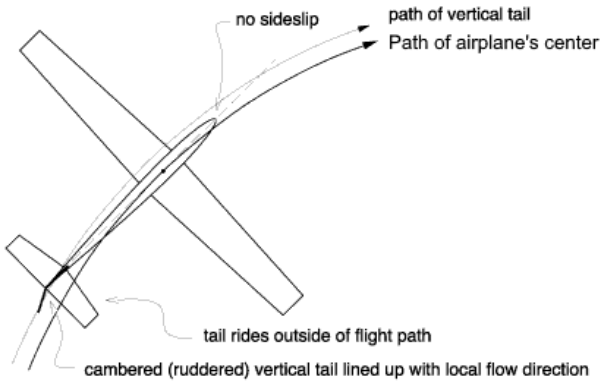
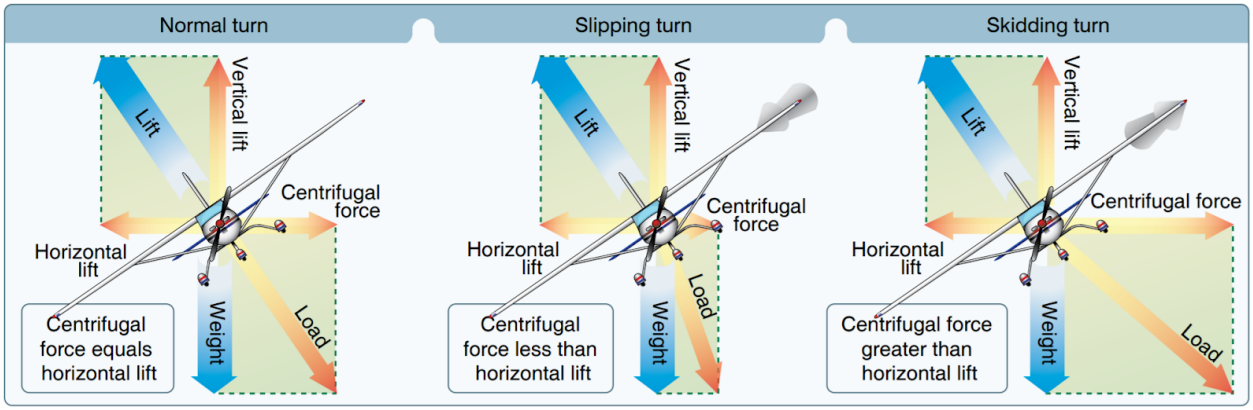
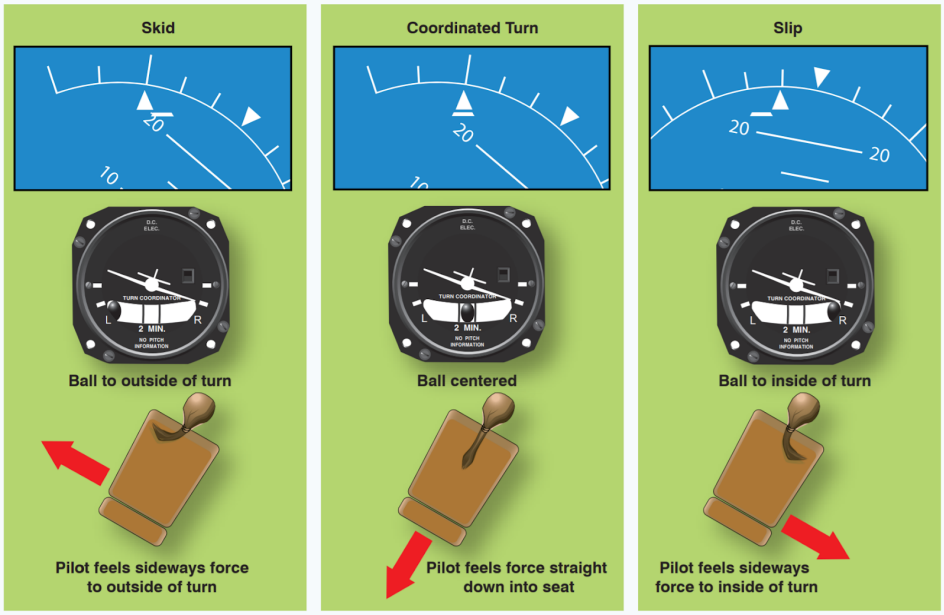


Figure 1b. Rudder deflection for zero sideslip.



- **Coordinated Flight** - In order to correct for these tendencies, pilots must use the rudder pedals to manage the amount of sideslip or skidding as the pilot rolls the airplane or maintains a turn. Flying with no skid or sideslip is called *coordinated flight.* The instrument which gives the pilot direct information about this is called the *turn coordinator*, however **pilots can also learn to sense when they are being pushed away from the turn or towards the turn.**



- **Relationship of Thrust to Maintaining Altitude** - Most non-pilots generally understand that "the engine makes the airplane go". Although pilots can use the elevator control to climb, descend, or fly level, without adjusting the *engine thrust*, the airplane may have insufficient power to climb or descend in response to pilot inputs.
  - When an airplane is flying at given speed (called *airspeed*), all of the four forces are in equilibrium, which means that **the thrust precisely equals the drag**. Therefore, a basic task that pilots must accomplish to maintain a constant altitude is managing the engine thrust.
  - Somewhat like a car coasting uphill or downhill, **if the airplane is being held at a given altitude with the control yoke, insufficient power will cause the airplane to slow down, and excess power will cause the airplane to speed up.**
  - Pilots can manage an airplane's thrust by using another instrument, called the *tachometer*. Similar to a car, it indicates how many revolutions per minute (RPM) the propeller is spinning. Higher values equal more power. It is also useful for pilots to use their ears to judge the power setting. **With experience, pilots can develop the ability to judge whether the power setting is too high or low from the engine noise alone.**