## II.E. Airplane Flight Controls

**References:** Airplane Flying Handbook (FAA-H-8083-3), Pilot's Handbook of Aeronautical Knowledge (FAA-H-8083-25)

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|---|---|
| Objectives | The student should develop knowledge of the elements related to primary flight controls, secondary flight controls, and trim. |
| Key Elements | 1. Primary Flight Controls – Airflow and Pressure Distribution<br>2. Trim relieves control pressures<br>3. Flaps increase lift and induced drag |
| Elements | 1. Overview<br>2. Primary Flight Controls<br>3. Secondary Flight Controls<br>4. Trim Controls |
| Schedule | 1. Discuss Objectives<br>2. Review material<br>3. Development<br>4. Conclusion |
| Equipment | 1. White board and markers<br>2. References |
| IP's Actions | 1. Discuss lesson objectives<br>2. Present Lecture<br>3. Ask and Answer Questions<br>4. Assign homework |
| SP's Actions | 1. Participate in discussion<br>2. Take notes<br>3. Ask and respond to questions |
| Completion Standards | The student can explain the primary and secondary flight controls and their function. The student will also understand how trim works and can effectively use it. |

**Instructor Notes:**

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**Introduction:**

**Attention**

Interesting fact or attention-grabbing story

Learning how the flight controls work and why the inputs you make result in the corresponding changes. This is what is actually going on when you move the control surfaces, adjust trim, or use the flaps.

**Overview**

Review Objectives and Elements/Key ideas

**What**

The airplane's attitude (rotation around the 3 axes) is controlled by deflection of the primary flight controls. These are hinged, moveable surfaces attached to the trailing edge of the wings and vertical and horizontal stabilizers. When deflected, these surfaces change the camber and angle of attack of the wing or stabilizer and thus change its lift and drag characteristics. Trim controls are used to relieve the control pressures and flaps create a compromise between a high cruise speed and low landing speed.

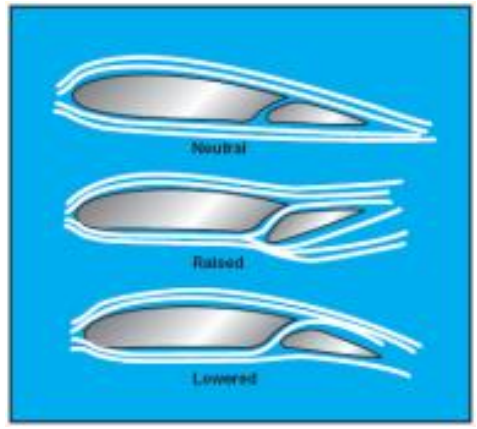
**Why**

Understanding how the airplane functions and the effects each control input will have on the airplane results in an understanding of how to control the airplane. Understanding how the airplane works results in a much more proficient pilot.

**How:**

1. **Overview**
    - A. Chord Line – An imaginary straight line drawn through an airfoil from the leading to the trailing edge
    - B. Camber – The characteristic curve of an airfoil's upper and lower surfaces
        - i. The upper camber is usually more pronounced, while the lower camber is relatively flat
            - a. This causes the velocity of the airflow immediately above the wing to be higher than below
        - ii. The more curved the upper surface, the more lift is generated
2. **Primary Flight Controls**
    - A. Primary flight controls are those required to safely control an airplane during flight

B. Ailerons




i. Control *roll* about the *longitudinal* axis

ii. Operated by cables, bell cranks, pulleys and/or push-pull tubes connected to the control wheel or stick

iii. How they Work

a. The ailerons are attached to the outboard trailing edge of each wing and move in opposite direction from each other

- One goes up, the other goes down
    - a In a right turn, the right aileron goes up and the left goes down
    - b In a left turn, the left aileron goes up and the right goes down

b. The upward deflected aileron decreases the camber of the wing resulting in decreased lift causing the wing to lower

c. The downward deflected aileron increases the camber of the wing and results in increased lift causing the wing to raise

d. The increased lift on one wing, and decreased lift on the other wing cause the aircraft to roll

iv. Adverse Yaw

a. Since the downward deflected aileron produces more lift, it also produces more induced drag

- The added drag attempts to yaw the nose in the direction of the raised wing (Adverse Yaw)

b. Rudder must be used to counteract and maintain coordinated flight

- The amount needed is greatest at low speeds, high AOA, and with large aileron deflections

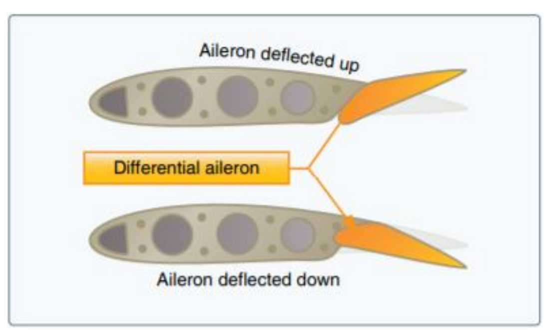
v. Types of Ailerons

a. Manufacturers have engineered four different types of ailerons to counter adverse yaw (additional drag due to the raised wing producing more lift)

- Differential ailerons
- Frise-type ailerons
- Coupled ailerons and rudder
- Flaperons

b. Differential Ailerons

- Normally, ailerons moving an equal amount up and down during a turn
- Differential ailerons: the upward moving aileron raises higher than the downward moving aileron lowers
    - a The ailerons have a greater range of movement upward than downward. For example, if the controls were fully deflected in one direction, the upward aileron might move 15°, while the downward moving aileron would only move 10°



- This produces increased drag on the descending wing (raised aileron) to counter the drag associated with adverse yaw
  a. Reduces adverse yaw, but does not eliminate it

c. Frise-Type Ailerons
- The raised aileron pivots on an offset hinge, projecting the leading edge of the aileron into the airflow which creates drag and reduces adverse yaw
- Also forms a slot so air flows smoothly over the lowered aileron, making it more effective at high angles of attack
- Reduces adverse yaw, but does not eliminate it

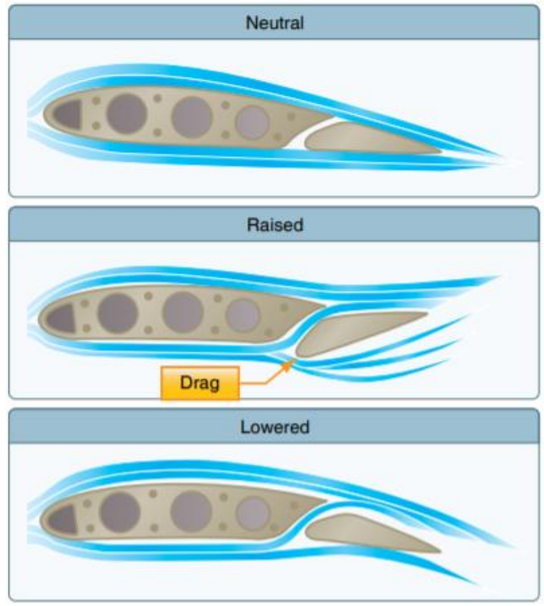


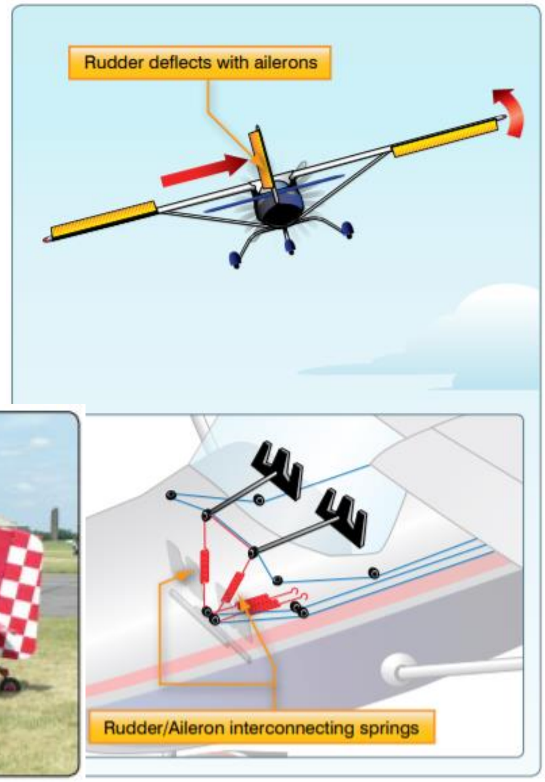

**Figure 6-7.** *Frise-type ailerons.*

d. Coupled Ailerons and Rudder
- The ailerons and rudder are linked with interconnect springs which automatically deflect the rudder at the same time the ailerons are deflected
  a. For example, when the pilot rolls left, the interconnect cable and springs pull forward on the left rudder pedal just enough to prevent the aircraft from yawing to the right
- The force applied by the rudder springs can be overridden by the pilot, when necessary

e. Flaperons
- Combine flaps and ailerons

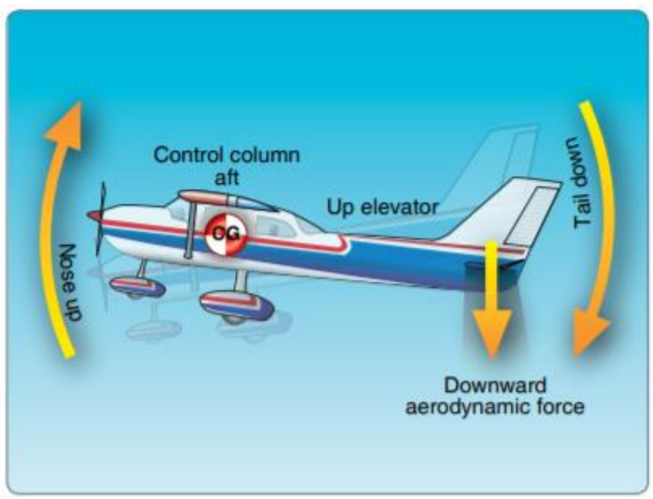
- They control the bank of the aircraft but can also be lowered together to function like a dedicated set of flaps
    - a The pilot retains separate controls for ailerons and flaps
    - b A mixer is used to combine the separate pilot inputs into the single set of control surfaces
- Often mounted away from the wing to provide undisturbed airflow at high angles of attack and/or low airspeeds

**Figure 6-9.** *Flaperons on a Skystar Kitfox MK 7.*




**8.** *Coupled ailerons and rudder.*

C. Elevator
   i. Controls *pitch* about the *lateral* axis
   ii. Like ailerons, operated by a series of mechanical linkages
   iii. How It Works
      a. Pulling the controls backward deflects the trailing edge up
         - Changes the camber of the horizontal stabilizer, creating a downward aerodynamic force
         - The overall effect causes the tail to move down and the nose to move up (about the CG)
            - a Strength is determined by the distance between the CG and horizontal tail surface

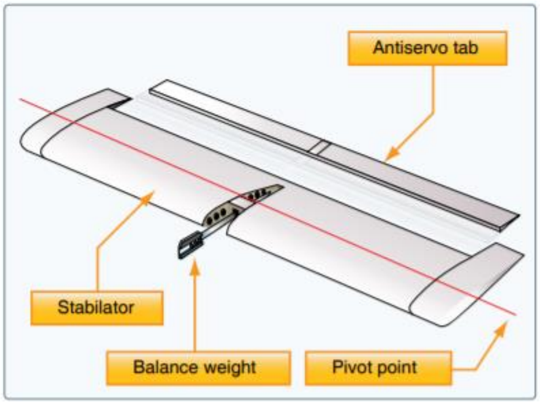



      b. Moving the controls forward deflects the trailing edge of the elevator surface down
         - Changes the camber of the horizontal stabilizer, creating an upward force
         - Moves the tail upward, pitching the nose down (also about the Center of Gravity)
   iv. Types of Elevators
      a. T-Tail

- The elevator is above most effects of downwash from the propeller and airflow around the fuselage and wings in normal flight
  - a Operating in this air makes for consistent control movements in most flight regimes
- Popular on light, as well as large airplanes (removes elevator from exhaust), and sea planes
- At slow speeds, the elevator must be moved through a larger number of degrees to raise the nose a given amount as compared to a conventional tail aircraft
  - a The conventional tail has the downwash from the propeller to assist in raising the nose

b. Stabilator

- "All-moving tail." A fully movable aircraft stabilizer
- Essentially a one-piece horizontal stabilizer that pivots from a central hinge point. When the controls are pulled back, the stabilator's trailing edge raises, rotating the nose up
- Pushing forward lowers the trailing edge and pitches the nose down
- Antiservo tabs are incorporated on the trailing edge to decrease sensitivity
  - a Because a stabilator pivots around a central hinge point, it allows the pilot to generate a given pitching moment with lower control force
    1. Because they are easier to move, to be certified an aircraft must show an increasing resistance to increasing pilot input
    2. To provide this resistance, stabilators on small aircraft contain an anti-servo trim tab that deflects in the same direction as the stabilator, providing an aerodynamic force resisting the pilot's input and making it less prone to overcontrolling




D. Rudder

i. Controls *yaw* about the *vertical* axis

a. Typically used to maintain coordination

ii. Often operated through cables, but like the other controls, can be operated by various mechanisms

iii. How it Works

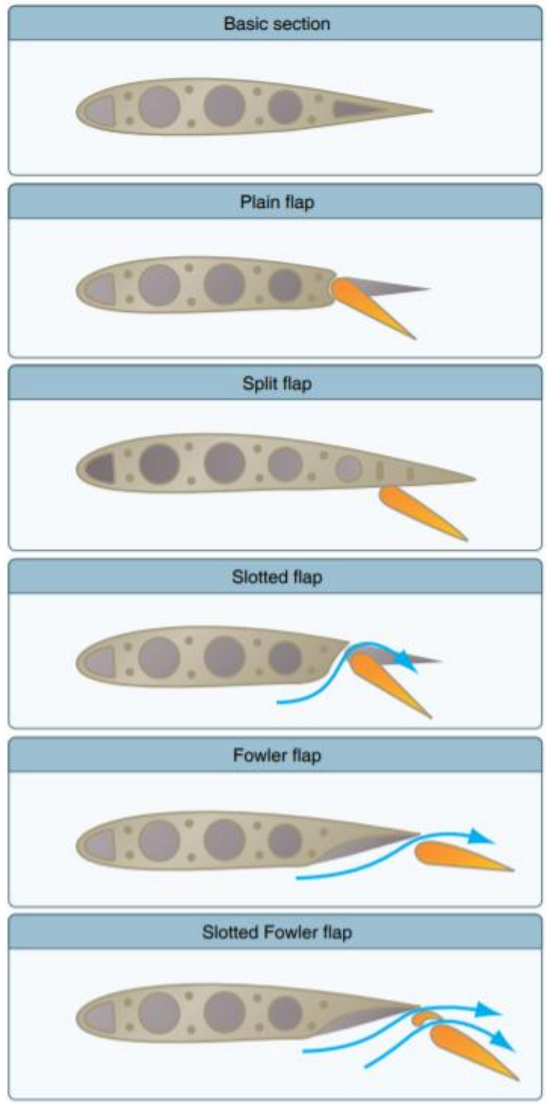
a. When the rudder is deflected into the airflow, a horizontal force is exerted in the opposite direction

- Pushing the left pedal moves the rudder left
  - a This alters the airflow around the vertical stabilizer creating a sideward lift moving the tail right and yawing the nose to the left
    1. Moving the rudder in either direction increases the camber, and therefore increases lift on one side of the rudder. Additionally, pushing the rudder into the relative wind creates a force which moves the aircraft's nose in the same direction

b. As is the same with all flight controls, rudder effectiveness increases with speed

- Large deflections may be necessary at low speeds and small deflections at high speeds
- In a propeller driven airplane, any slipstream flowing over the rudder increases effectiveness

3. **Secondary Flight Controls**
   A. Secondary control systems improve performance characteristics or relieve excessive control forces
      i. Wing Flaps, leading edge devices, spoilers and trim systems
         a. We'll focus on the more common items – wing flaps, spoilers, and trim
   B. Flaps
      i. The most common high lift devices used on practically all airplanes
         a. Attached to the trailing edge of each wing to increase induced drag and lift for any given AOA
         b. Important Functions
            - Increased lift allows the aircraft to get airborne at lower speeds, reducing the amount of runway required, and improves climb performance
            - The increased drag allows for steeper approaches
               a. A great example of this are military aircraft, specifically C-130s and C-17s, which can use flaps to their advantage to perform steep approach and landings
            - The lower landing speeds provide shorting landing distances
            - Although many of these factors don't have a huge impact on general aviation aircraft, these functions make large differences for airliners which would otherwise need tremendous amounts of runway to takeoff and land
      ii. There are four common types of flaps: Plain, Split, Slotted, and Fowler




iii. Plain Flaps
   a. Simplest of the types
   b. They increase camber, resulting in a significant increase in the coefficient of lift at a given AOA
   c. Drag is greatly increased, and the center of pressure moves aft resulting in a nose down pitching moment

iv. Split Flaps
   a. Deflect from the lower surface of the airfoil and produces a slightly greater increase in lift than the plain flap
   b. More drag is produced because of the turbulent airflow behind the airfoil
   c. When fully extended, both plain and split flaps produce high drag with little additional lift

v. Slotted Flap
   a. Most popular on airplanes today
   b. Increase the lift coefficient significantly more than plain and split flaps
   c. When lowered, it forms a duct between the flap well in the wing, and the flap's leading edge
      a High energy air from the lower surface is ducted to the upper surface which accelerates the upper boundary layer and delays airflow separation, providing a higher $C_L$

vi. Fowler Flaps
   a. A type of slotted flap which changes the camber of the wing and increases the wing area
   b. It slides backward on tracks and then retracts downward
   c. The first portion of its extension increases drag very little but increases lift a great deal
      - As extension continues, the flap drops downward; drag increases with little increase in lift

vii. Flap Control
   a. Mechanically, electrically, or hydraulically operated
      - Can also be a combination
         a For example, many flaps are electrically powered and hydraulically actuated
            1. An electric switch activates the hydraulic pump(s) which physically move the flaps
   b. Be aware of any flap operating speeds for your particular aircraft
   c. *Flap Settings in the DA20
      - The flaps are controlled by a 3-position operating switch
         a Cruise – 0º
         b T/O – 15º
         c LDG – 45º

C. Spoilers

i. High drag devices deployed from the wings to spoil the smooth airflow over the wing, reducing lift and increasing drag

ii. Uses

a. Reduce Airspeed

- Increased drag allows for a more rapid reduction of airspeed in flight, and decreases ground roll during landing
  - a On landing, airspeed decreases due to the spoilers being raised, and the destruction of lift transfers the weight from the wings to the wheels, improving braking effectiveness

b. Increased Rate of Descent

- The aircraft can descend at a faster rate without increasing airspeed

c. Roll control

- To turn, the spoiler on one of the wing's is deployed destroying some of the lift and creating more drag on that wing
  - a The wing with the spoiler deployed will drop and the aircraft banks and yaws in that direction
  - b Adverse yaw is eliminated

**4. Trim Controls**

A. Trim systems are used to relieve the need to maintain constant pressure on the flight controls

B. They usually consist of cockpit controls and small hinged devices attached to the trailing edge of one or more of the primary control surfaces

i. They minimize workload by aerodynamically assisting movement and the position of the controls they're attached to

C. How a Trim Tab Works

i. The most common installation is a single trim tab attached to the trailing edge of the elevator

ii. Operation

a. Often operated manually through a small, vertically mounted control wheel (or trim crank)

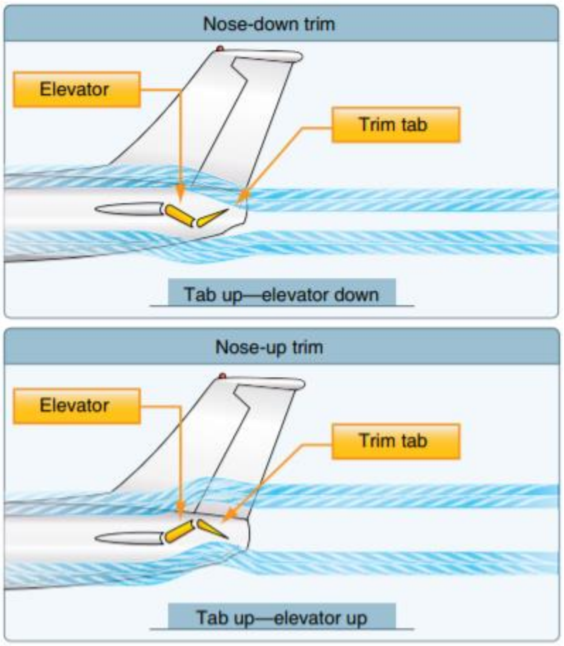
b. The trim tab moves in the opposite direction of the elevator surface

c. Placing the trim in full nose-down moves the tab to its full up position (pictured, right)

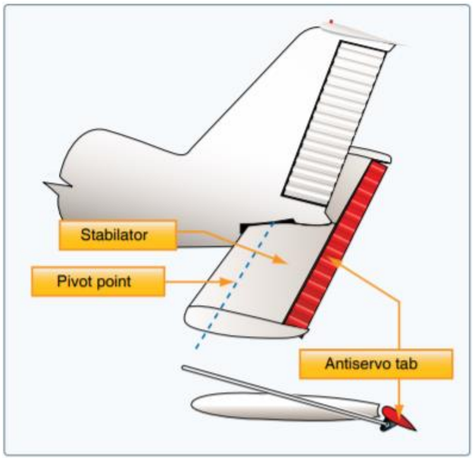
- With the tab up, into the airstream, airflow over the tail forces the elevator down
  - a Causes the tail to move up and results in a nose-down pitch change

d. In the full nose-up position, the tab moves to its full down position (pictured, right)

- Air flowing under the tail hits the tab forcing the elevator up, reducing the elevator's AOA
  - a Causes the tail to move down and results in a nose-up pitch change



      - Note: The bottom picture says "Tab up," but should say "Tab down"
- D. Operation
  - i. Establish the desired power, pitch attitude, and configuration, then trim to relieve pressures
  - ii. Any time power, pitch attitude, or configuration is changed, re-trim for the new condition
- E. Balance Tabs
  - i. Look and function just like trim tabs, but the balance tab is coupled to the control surface rod
    - a. When the controls are deflected, the tab automatically moves in the opposite direction
      - Any time the control surface is deflected, the tab moves the opposite direction
      - Airflow against the tab counterbalances some of the air pressure against the control surface enabling the pilot to move the control more easily and hold the control surface in position
  - ii. If the linkage is adjustable from the cockpit, the tab acts as both a trim and balance tab
- F. Servo Tabs (primarily used in large aircraft)
  - i. Vey similar in operation and appearance to trim tabs and balance tabs
  - ii. A servo tab is a small portion of a flight control that deploys in such a way that it helps to move the entire flight control surface in the direction that the pilot wishes it to go
  - iii. Aids in moving the control surface and holding it in the desired position
  - iv. Only the servo tab moves in response to movement of the flight controls
    - a. The force of the airflow on the servo tab then moves the control surface
- G. Antiservo Tabs
  - i. Antiservo tabs decrease sensitivity of the stabilator, and act as a trim device
  - ii. Operation
    - a. Work the same as a balance tab, but it moves in the same direction as the flight control (rather than opposite)
    - b. When the trailing edge of the stabilator moves up, the trailing edge of the tab moves up




- H. Ground Adjustable Tabs
  - i. Metal trim tab on the rudder bent in either direction while on the ground to apply a trim force
    - a. Displacement is found through trial and error
- I. Adjustable Stabilizer
  - i. Instead of using a trim tab on the elevator, some aircraft can adjust the entire stabilizer
    - a. This is driven by a jackscrew (motor driven on large aircraft and cranked on small aircraft)

**Conclusion**:
Brief review of the main points
The airplane's attitude (rotation around the 3 axes) is controlled by deflection of the primary flight controls. When deflected, these surfaces change the camber and AOA of the wing or stabilizer and thus change its lift and drag characteristics. Trim controls are used to relieve the control pressures necessary and flaps increase lift and induced drag and create a compromise between a high cruise speed and low landing speed.

**PTS Requirements:**

To determine that the applicant exhibits instructional knowledge of the elements related to the airplane flight controls by describing the purpose, location, direction of movement, effect and proper procedure for use of the:

1. Primary Flight Controls.
2. Secondary Flight Controls.
3. Trim Controls.