XI.A. Maneuvering During Slow Flight

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

Objectives	To develop an understanding and proficiency of the flight characteristics and degree of controllability of an aircraft in slow flight. A "feel" for the airplane at very low speeds should be developed to avoid inadvertent stalls and to operate the aircraft with precision. In flight, the student should perform the maneuver in varying configurations to ACS/PTS standards.
Key Elements	1. Pitch for Airspeed 2. Power for Altitude 3. Stay Coordinated
Elements	1. What is Slow Flight 2. Flight Characteristics and Controllability a. Power b. Maneuvering Loads & Turns c. Weight d. Center of Gravity 3. Slow Flight and Critical Flight Situations 4. Slow Flight and the Senses 5. Performing Slow Flight
Schedule	1. Discuss Objectives 2. Review material 3. Development 4. Conclusion
Equipment	1. White board and markers 2. References
IP's Actions	1. Discuss lesson objectives 2. Present Lecture 3. Ask and Answer Questions 4. Assign homework
SP's Actions	1. Participate in discussion 2. Take notes 3. Ask and respond to questions
Completion Standards	The lesson is complete when the student understands factors affecting flight characteristics and controllability and shows the ability to control the airplane effectively in different configurations of slow flight.

Instructor Notes:

Introduction:

Attention

Interesting fact or attention-grabbing story

When the aircraft is flying at just above the stall speed, there is little margin for error. This maneuver will greatly improve your piloting skills.

Overview

Review Objectives and Elements/Key ideas

What

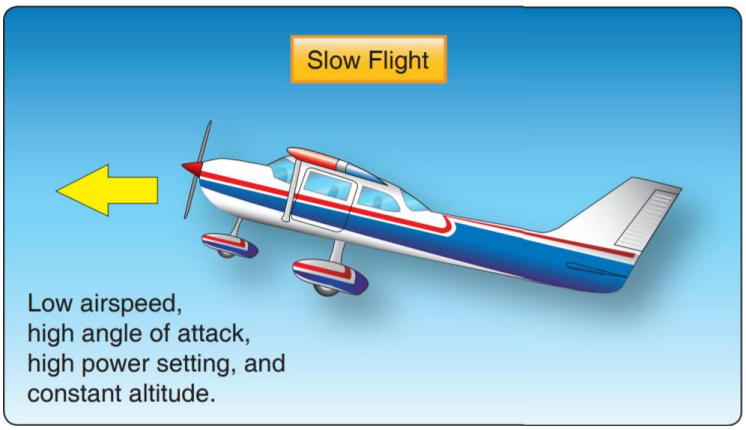
Slow flight is flight at a speed which any further increase in angle of attack or load factor, or reduction in power will cause an immediate stall.

Why

The aircraft performs and is controlled differently at slower airspeeds. Maneuvering during slow flight demonstrates the flight characteristics and degree of controllability of an aircraft near the critical angle of attack. In normal operations, the aircraft would not be flown this close to the critical AOA, but because the aircraft is flown at higher angles of attack and slower airspeeds in many phases of flight (takeoff, landing, go-around), understanding how the aircraft performs and is controlled at reduced speeds is essential, especially in the case the aircraft ends up slower than intended.

How:

1. **What is Slow Flight**
   - A. Technically, slow flight is any speed that is less than cruise speed, however, in pilot training, it can be broken down into two elements
     - i. The establishment, maintenance of, and maneuvering of the aircraft at airspeeds and in configurations appropriate to takeoffs, climbs, descents, landing approaches and go-arounds
       - a. i.e. phases of flight other than cruise
       - b. This description is most applicable to every day flying
     - ii. Flight at a speed which any further increase in angle of attack or load factor, or reduction in power will cause an immediate stall.
       - a. This description is what is used for the slow flight maneuver
       - b. The objective is to understand the flight characteristics and how the aircraft's flight controls feel near the critical angle of attack



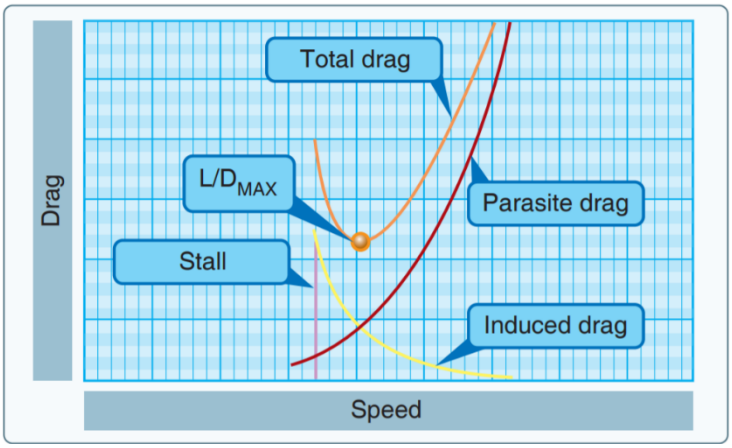
2. Flight Characteristics and Controllability

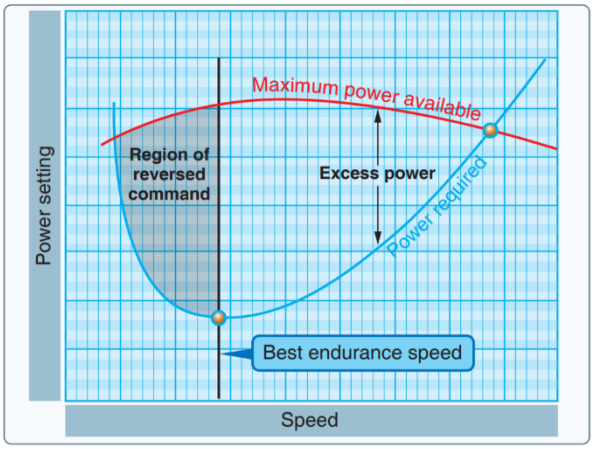
A. **Power**

i. Region of Reversed Command

a. Normal vs Reversed Command

- Normal Command
  - a As airspeed decreases, total drag decreases, until reaching a point (L/D_{MAX})
    1. This is the normal region of command – while maintaining an altitude, higher speeds require higher power settings, and lower speeds require lower power settings
- Region of Reversed Command
  - a As airspeed decreases below L/D_{MAX}, total drag begins to increase
    1. This is referred to as the region of reversed command
- Below L/D_{MAX}, while maintaining altitude, slower airspeeds require higher power settings and faster airspeeds require lower power
- Thus, when performing slow flight (maneuver or in real life), the slower the airspeed, the more power required





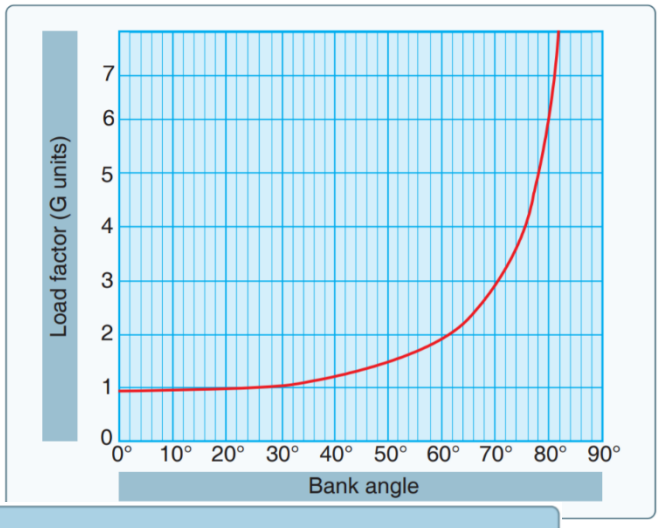
ii. Controllability

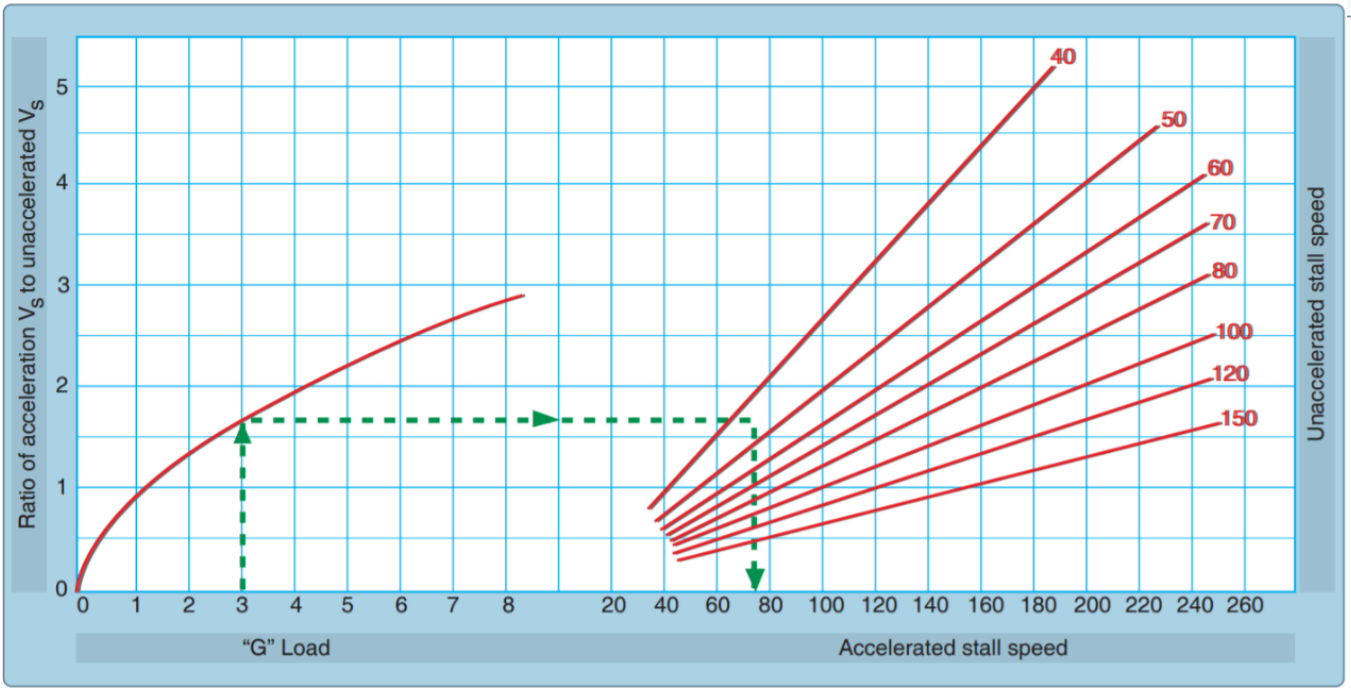
a. Increased power at slow airspeeds and high angles of attack results in increased left turning tendencies

- Anticipate considerable right rudder to maintain coordination

B. **Maneuvering Loads & Turns**

i. Load factor is the ratio of the total load acting on the aircraft to the gross weight of the aircraft
   a. Expressed in terms of G's
ii. Any increase in the load factor increases the stall speed
iii. Turns
   a. Increased load factors are a characteristic of all banked turns
   b. Load factor increases at a high rate after 45°-50° of bank
      - At approx. 63° of bank the stall speed is increased by approximately ½





iv. Controllability
   a. The increased load factor associated with a level turn in slow flight can quickly put the aircraft into a stall
      - Use gentle, coordinated, low bank turns during slow flight to prevent a potential stall
         a 10° of bank is generally a good target (depending on the aircraft)
         b Straight and level slow flight requires considerable right rudder to maintain coordination. In a right turn, more right rudder is required. Right rudder is still necessary in a left turn, although it will be less than in straight and level flight
            1. Right turn = more right rudder
            2. Left turn = less right rudder (still requires right rudder)
         c Do not use aggressive control inputs – slow and smooth

C. **Weight**

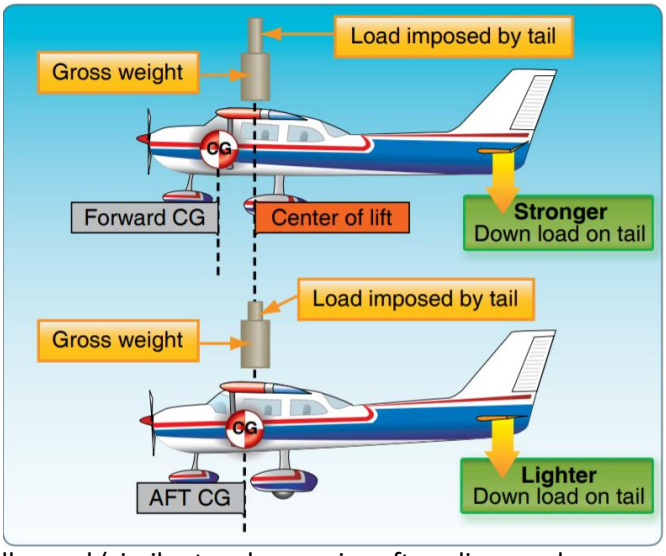
i. The heavier the aircraft is, the more lift is necessary to maintain altitude
   a. As more lift is required, the angle of attack required to maintain level flight is increased
      - An increased angle of attack brings the aircraft closer to the critical angle of attack, and therefore the stall speed will be reached sooner (at a higher airspeed) than if the aircraft were lighter

ii. A heavier aircraft is more stable than a lighter aircraft (generally, the position of the center of gravity has more effect on the stability)
   a. It takes more force to move a heavier object than a lighter one, therefore outside forces, such as gusts, will have less of an effect on the aircraft

iii. Controllability
   a. Because a heavier aircraft is already at a higher angle of attack for a given airspeed, less pitch will be required to reach the critical angle of attack
   b. The increased weight and stability may help in controlling the aircraft

D. **Center of Gravity**

i. Forward Loaded Aircraft
   a. The aircraft acts heavier, and consequently slower (for a given power setting) than the same aircraft with a further aft center of gravity
      - More nose up elevator pressure and/or trim is required to maintain altitude
      - The higher nose requires the tail surface to produce a greater download
      - The increased download adds to the wing loading and results in an increase in the total lift required to maintain altitude



   b. The higher angle of attack results in more induced drag as well as a higher stall speed (similar to a heavy aircraft as discussed above)
   c. Controllability
      - A forward loaded aircraft is more controllable than an aft loaded aircraft
        a. This is due to the longer arm from the elevator to the center of gravity
        b. Weight x Arm = Moment. The longer the arm, the greater the moment and thus more controllable the aircraft

ii. Aft Loaded Aircraft
   a. The aircraft acts lighter, and consequently faster (for a given power setting) than the same aircraft with a further forward center of gravity
      - Less nose up elevator pressure/trim is required to maintain altitude
      - The lower nose requires less of a down load from the tail
      - The decreased down load reduces wing loading and results in a decrease in the total lift required to maintain altitude
   b. The lower angle of attack results in less induced drag allowing for a faster cruise speed as well as a lower stall speed
   c. Controllability

- Recovery from a stall becomes progressively more difficult as the center of gravity moves aft
    a. Moving the center of gravity aft shortens the arm from it to the elevator, and reducing the amount of force it can apply
    b. Again, Weight X Arm = Moment. The shorter the arm, the smaller the moment and therefore less controllable

3. Slow Flight and Critical Flight Situations

A. It is very important the pilot understands the control responses of the aircraft at the low speeds associated with slow flight and the region of reversed command, especially since the majority of the time the aircraft is in slow flight/the region of reversed command is close to the ground
   i. In general, takeoffs, climbs, landings, and go-arounds
   ii. Examples from the Pilot's Handbook of Aeronautical Knowledge:
      a. An airplane performing a low airspeed, high pitch attitude power approach for a short-field landing is an example of operating in the region of reversed command. If an unacceptably high sink rate should develop, it may be possible for the pilot to reduce or stop the descent by applying power. But without further use of power, the airplane would probably stall or be incapable of flaring for the landing. Merely lowering the nose of the airplane to regain flying speed in this situation, without the use of power, would result in a rapid sink rate and corresponding loss of altitude
   iii. If during a soft-field takeoff and climb, for example, the pilot attempts to climb out of ground effect without first attaining normal climb pitch attitude and airspeed, the airplane may inadvertently enter the region of reversed command at a dangerously low altitude. Even with full power, the airplane may be incapable of climbing or even maintaining altitude. The pilot's only recourse in this situation is to lower the pitch attitude in order to increase airspeed, which inevitably results in a loss of altitude

B. Pilots must give particular attention to precise control of airspeed when operating in the low flight speeds of the region of reversed command

4. Slow Flight and the Senses

A. Visually
   i. As you pitch up, you will be looking at more sky (nose above the horizon)
      a. There will be few if any visual references at this point
         - Possibly a couple of clouds
   ii. Hearing
      a. Initially, with the reduction of power, sound will decrease
      b. As you approach the stall, the stall warning horn will sound
      c. When power is reintroduced, the sound of the engine increases
         - The sound of the plane moving through the air stays softer due to the slow airspeed
   iii. Feel
      a. As the aircraft's speed continues to decrease, the controls will become progressively less responsive
         - Larger movements will be necessary to control the aircraft as the air flow over the control surfaces has been reduced
      b. Right rudder will be necessary to maintain coordination as the aircraft begins to yaw to the left
         - This is due to the left turning tendencies upon reintroduction of power
         - Due to reduced control effectiveness, more right rudder than normal is required
      c. Just prior to stalling the aircraft will begin to buffet

5. Performing Slow Flight

A. Definition
   i. Flight at a speed which any further increase in angle of attack or load factor, or reduction in power will cause an immediate stall

B. Purpose
   i. Demonstrates the flight characteristics and degree of controllability of the airplane at its minimum flying speed

C. Performing the Maneuver
   i. Overview of the Basics
      a. Pitch for Airspeed, Power for Altitude
         - This is necessary on the backside of the power curve
      b. Use both instrument indications and visual references
         - Frequently reference the instruments, especially the attitude indicator
         - A "feel" for the airplane at very low speeds must be developed to avoid inadvertent stalls and to operate the plane with precision
   ii. The Maneuver
      a. Properly clear the area
      b. Pre-maneuver checklist
      c. Select an altitude
         - No lower than 1,500' AGL
         - Select an altitude that is easy to read on the altimeter
         - 500' increments are easiest
      d. Configuration
         - Different configurations can be used in order to develop a feel for the airplane in different situations
            a The 'dirtier' (more flaps), the slower we can get
               1. Stall speed is reduced
            b The 'cleaner' the aircraft, the higher the stall speed, therefore a higher airspeed is required for slow flight
         - Common Error - Failure to establish specified gear and flap configuration
      e. *Begin slowing by gently reducing the throttle (to approximately 1500 RPM)
         - Maintain altitude as power is lost
            a Use visual references backed up by the instruments to reference the pitch attitude at the start of the maneuver. Gently increase pitch attitude as airspeed slows to maintain altitude
               1. Too little pitch/back pressure will result in a loss of altitude and could lead to stagnant or increasing airspeed
               2. Excessive pitch/back pressure will result in a climb followed by a rapid decrease in airspeed
      f. Continually trim the aircraft
         - Add nose up trim to maintain altitude, this will make the maneuver considerably easier
         - Re-trim as often as necessary to compensate for changing control pressure
         - Common Error - Improper trim technique
      g. Full flaps should be lowered as the airspeed reaches the flap airspeed limits
         - Lowering the flaps one at a time allows the pilot to adjust the pitch for the changing lift and maintain better control

    a. Extending full flaps immediately is more difficult to control than incremental changes
    b. Anticipate changes in lift as flaps are extended or retracted
        1. Lowering the flaps will require nose down pitch to compensate for increased lift

h. Note the feel/sounds
- As airspeed decreases, the pilot should note the feel of the flight controls (especially elevator)
- Also note the sound of the airflow as it gets quieter

i. Flight Control Effectiveness
- Flight controls are much less effective with the reduction in airspeed
    a. Elevators become less responsive
    b. Flight control inputs are not as smooth to control the airplane
        1. Larger movements are needed for the aircraft to respond

j. Reintroduce power
- Additional power will be required as airspeed decreases below L/D_{MAX} to maintain altitude
    a. *As the airspeed is approaching the specified maneuver speed (approximately 40 knots) introduce power to maintain altitude, and airspeed just above the stall
    b. Be familiar with the approximate pitch and power settings for your aircraft
        1. When approaching the desired speed, set that pitch and power, and adjust from there
- The additional power produces a strong left yaw
    a. Considerable right rudder is necessary to maintain coordinated flight
    b. Common Error - Uncoordinated use of flight controls/Improper correction for torque effect
        1. Anticipate the need for right rudder
            a. Anticipate the need for power to allow for a slow, smooth throttle increase
            b. As power comes up slow and smooth, increase right rudder to maintain coordination
                i. An outside reference works great – maintain wings level, and as power is introduced add right rudder. If the aircraft swings right, reduce the rudder input. If the aircraft swings left, increase the right rudder input
        2. Use coordinated rudder and aileron to maintain heading
            a. Uncoordinated flight (too much or too little rudder to compensate for torque) combined with a stall can quickly result in a spin
- Avoid losing too much speed/using too little power
    a. Proactively increase power to the approximate setting that will maintain altitude at the specified maneuver speed
- Common Error - Unintentional stalls
    a. Avoid being aggressive with the power and pitch applications
    b. Small, controlled corrections are most effective in maintaining control during slow flight
    c. Anticipate the power introduction to allow for a slow, smooth power push
- Common Error - Inappropriate removal of hand from throttles

a. Keep your hand on the throttles as much as possible
    1. Due to the proximity to a stall, immediate power may be necessary

k. Establish the desired pitch attitude to maintain airspeed
- Cross check the instruments (attitude indicator, heading indicator, airspeed, turn coordinator), as well as outside references to ensure precise control of the aircraft
- Do not fixate on any instruments, primarily the airspeed indicator and altimeter
- Throughout the maneuver, be proactive in fixing altitude, heading, etc. changes
    a. Don't let the airplane get away from you as this will result in larger control inputs to correct
    b. Common Error - Failure to establish and maintain the specified airspeed
        1. *Increase power approximately 5 knots prior to the slow flight speed
            a. This should result in the airspeed settling at the desired speed
        2. Adjust pitch to maintain the desired airspeed
            a. If fast, pitch up – use very small changes in pitch (1-2^{o} at a time)
            b. If slow, pitch down – again, very small changes in pitch (1-2^{o} at a time)
        3. If the pitch adjustment affects altitude, increase or decrease power to maintain altitude
            a. Continue adjusting pitch and power to maintain airspeed and altitude
                i. Maintain your crosscheck inside and outside
                ii. Generally, a change in pitch requires a change in power. Understand how changes in pitch and power affect each other in slow flight and anticipate the changes
    c. Common Error - Excessive variations of altitude and heading when a constant altitude and heading are specified
        1. Use small, controlled changes in pitch and power to maintain heading and altitude
            a. Know the approximate pitch and power setting required to maintain slow flight in the aircraft; set that pitch and power and make small adjustments from there
        2. Large inputs will result in chasing the airspeed and altitude
        3. Set and maintain the rudder pressure required to maintain coordination
            a. Sloppy rudder inputs can quickly lead to variations

l. Common Error - Improper entry technique
- Follow the specified procedures to help ensure a smooth, controlled entry
- It is very important to maintain positive control of the aircraft during the entry
    a. A sloppy entry can easily result in a stall
    b. Know the approximate pitch and power settings for slow flight in your aircraft. Set those and adjust from there
- Common Error - Unintentional stalls
    a. Smooth, controlled, coordinated control movements are integral
    b. A consistent crosscheck will help you catch deviations before they become an issue

m. Maintain straight and level flight and perform the required level turns at a constant altitude
- Introducing Bank
    a. Use smooth, controlled control inputs

1. Aggressive inputs can lead to increased load factors, and deviations in heading/altitude
2. The Airplane Flying Handbook discusses practicing medium banked (20°) turns

b. Adjust pitch and power as needed to maintain altitude and airspeed
1. Generally, additional power will be necessary. Increased power likely leads to increased pitch to maintain airspeed – anticipate these inputs
a. A turn and change in power requires a change in the rudder. Adjust as necessary to maintain coordination

- Maintaining the Bank Angle
  a. In slow flight, even a small amount of bank results in an overbanking tendency
  1. Opposite aileron is necessary to maintain the bank angle
- Adverse Yaw in the Turn
  a. The downward deflected aileron produces more lift and therefore more drag
  b. The airplane will try to yaw toward the outside wing during the turn
  1. Maintain coordination
  2. Right rudder is necessary to maintain straight flight, right turns will require more right rudder, while left turns will require less right rudder (anticipate some right rudder pressure even in a left turn)
  c. Common Error - Uncoordinated use of flight controls
- Extreme Bank
  a. Extreme bank situations, like steep turns, are not used in slow flight
  1. As banks exceeds 30°, the stall speed noticeably increases
  a. Obviously, this is unsafe when already close to the stall speed

n. Maintain coordinated flight as climbs/descents or climbing/descending turns are performed
- Adjust the power to begin the climb or descent, and simultaneously adjust the pitch attitude to maintain the desired airspeed
  a. Pitch for airspeed, Power for altitude
  1. You will gain altitude by increasing power, and lose altitude by decreasing power
  a. Adjust pitch to maintain airspeed
  b. Anticipate increased right rudder with an increase in power, and vice versa

iii. Reestablishment of cruise flight
a. Very similar to a stall recovery:
- Full Power
  a. Smoothly increase the power
- Nose Down (forward pressure)
  a. Smooth, controlled forward pressure to maintain the current altitude
  1. Don't dive
  b. Retrim the aircraft as it accelerates to avoid excessive control pressures
  1. If the nose was trimmed up, the aircraft will try to fly up as it accelerates
  c. As airspeed increases, right rudder pressure is reduced to maintain coordination
- Cleanup
  a. Flaps
  1. Remove the flaps in stages, based on airspeed requirements

2. Anticipate the change in lift as the flaps are retracted and maintain altitude
    a. The aircraft will have a tendency to sink, increase back pressure to counter this
- b Gear (If necessary)

- Establish straight and level flight at V_A, or the desired speed
  - a Set the power for the desired speed
  - b Finalize the trim

Common Errors:

- Failure to establish specified gear and flap configuration
- Improper entry technique
- Failure to establish and maintain the specified airspeed
- Excessive variations of altitude and heading when a constant altitude and heading are specified
- Uncoordinated use of flight controls
- Improper correction for torque effect
- Improper trim technique
- Unintentional stalls
- Inappropriate removal of hand from throttles

Conclusion:

Brief review of the main points

Understanding the characteristics that affect slow flight and how to perform this maneuver is an extremely important part of a pilot's training. Slow flight develops the student's awareness of the characteristics, feel and control responses during flight at slow speed (takeoff, climb, landings and go-arounds) to maintain safe flight, and avoid unintentional stalls.

PTS Requirements:

To determine that the applicant:

1. Exhibits instructional knowledge of the elements of maneuvering during slow flight by describing:
    a. Relationship of configuration, weight, center of gravity, maneuvering loads, angle of bank, and power to flight characteristics and controllability.
    b. Relationship of the maneuver to critical flight situations, such as a go-around.
    c. Performance of the maneuver with selected landing gear and flap configurations in straight-and-level flight and level turns.
    d. Specified airspeed for the maneuver.
    e. Coordination of flight controls.
    f. Trim technique.
    g. Reestablishment of cruise flight.
2. Exhibits instructional knowledge of common errors related to maneuvering during slow flight by describing:
    a. Failure to establish specified gear and flap configuration.
    b. Improper entry technique.
    c. Failure to establish and maintain the specified airspeed.
    d. Excessive variations of altitude and heading when a constant altitude and heading are specified.
    e. Uncoordinated use of flight controls.

    f. Improper correction for torque effect.
    g. Improper trim technique.
    h. Unintentional stalls.
    i. Inappropriate removal of hand from throttles.
3. Demonstrates and simultaneously explains maneuvering during slow flight from an instructional standpoint.
4. Analyzes and corrects simulated common errors related to maneuvering during slow flight.

Private Pilot ACS Skills Standards

1. Clear the area.
2. Select an entry altitude that will allow the Task to be completed no lower than 1,500 feet AGL (ASEL) or 3,000 feet AGL (AMEL).
3. Establish and maintain an airspeed at which any further increase in angle of attack, increase in load factor, or reduction in power, would result in a stall warning (e.g., aircraft buffet, stall horn, etc.).
4. Accomplish coordinated straight-and-level flight, turns, climbs, and descents with landing gear and flap configurations specified by the evaluator without a stall warning (e.g., aircraft buffet, stall horn, etc.).
5. Maintain the specified altitude, ±100 feet; specified heading, ±10°; airspeed +10/-0 knots; and specified angle of bank, ±10°.

Commercial Pilot ACS Skills Standards

1. Clear the area.
2. Select an entry altitude that will allow the Task to be completed no lower than 1,500 feet AGL (ASEL) or 3,000 feet AGL (AMEL).
3. Establish and maintain an airspeed at which any further increase in angle of attack, increase in load factor, or reduction in power, would result in a stall warning (e.g., aircraft buffet, stall horn, etc.).
4. Accomplish coordinated straight-and-level flight, turns, climbs, and descents with landing gear and flap configurations specified by the evaluator without a stall warning (e.g., aircraft buffet, stall horn, etc.).
5. Maintain the specified altitude, ±50 feet; specified heading, ±10°; airspeed +5/-0 knots; and specified angle of bank, ±5°.