VIII.B. Level Turns

References: Airplane Flying Handbook (FAA-H-8083-3)

Objectives	The student should develop knowledge of the elements related to establishing and maintaining a level turn.
Key Elements	1. Increased Back Pressure (HCL/VCL) 2. Coordination (Adverse Yaw) 3. Control *Pressures*
Elements	1. Flight Controls 2. How the Turn Works 3. Control Pressures and Over Controlling 4. Trim Technique 5. Integrated Flight Instruction 6. Level Turns
Schedule	1. Discuss Objectives 2. Review material 3. Development 4. Conclusion
Equipment	1. White board and markers 2. References 3. Model Airplane
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 student has the ability to turn at varying degrees of bank, maintaining altitude and airspeed.

Instructor Notes:

Introduction:

Attention

Interesting fact or attention-grabbing story

Level turns sound boring and simple, but there is a lot more to turning than you might think, and a strong grasp on this will make many other maneuvers considerably easier.

Overview

Review Objectives and Elements/Key ideas

What

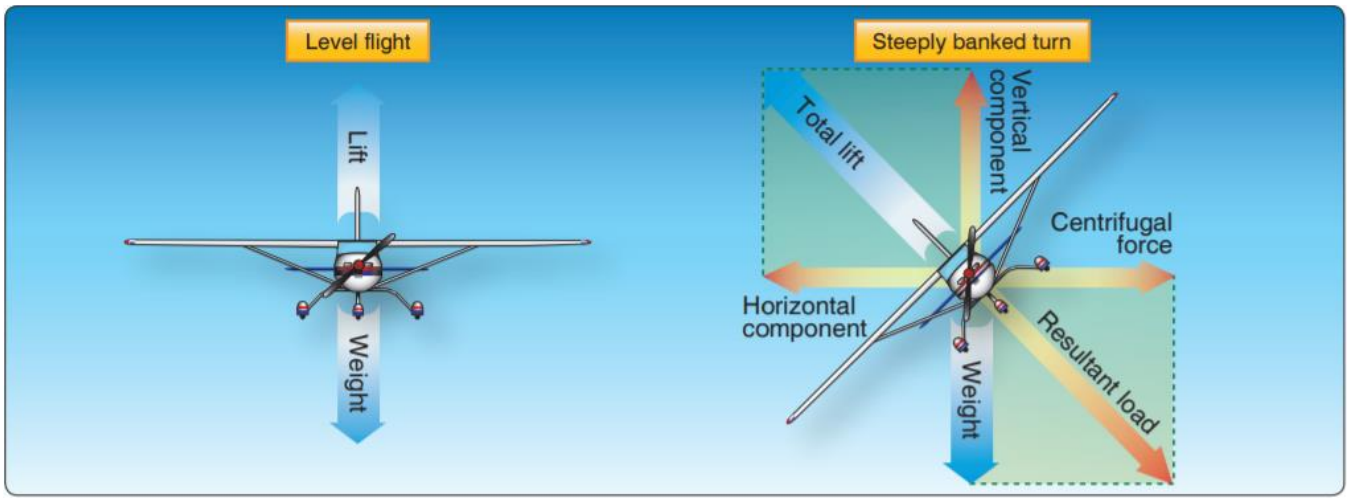
A level turn is a turn at a specified angle of bank in which altitude and airspeed are maintained.

Why

The ability to understand and fly a level turn is essential to the building of every pilot's skill set. Level turns are the building blocks to many more difficult maneuvers and will help the pilot in his or her control of the airplane.

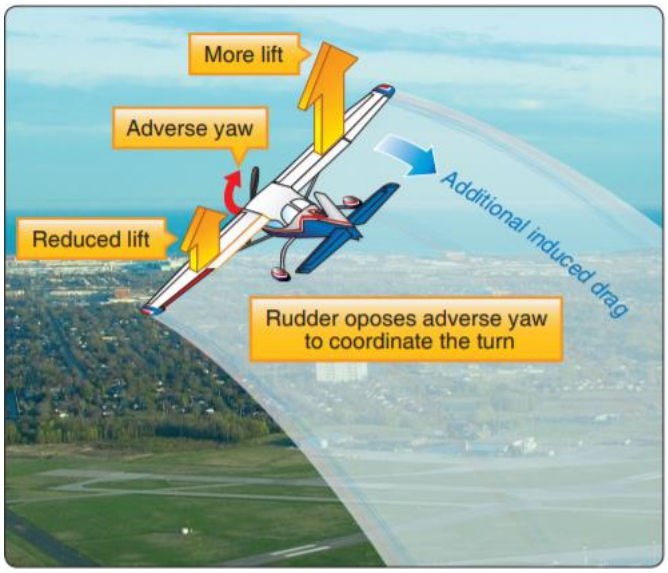
How:

1. **Flight Controls**
   - A. All four primary controls are used in coordination when making turns
     - i. Ailerons - Bank the wings and determine the rate of turn at a given airspeed
     - ii. Elevator - Moves the nose up or down in relation to the pilot, and perpendicular to the wings
       - a. It sets the pitch attitude in the turn and "pulls" the nose around the turn
     - iii. Rudder - Offsets yaw effects developed by the other controls (is not used to turn the airplane)
     - iv. Throttle - Provides thrust which may be used to maintain airspeed during a turn
2. **How the Turn Works**
   - A. Changing the direction of the wing's lift to either side causes the airplane to be pulled that direction
     - i. This is done by applying coordinated aileron and rudder to bank the airplane
   - B. Lift
     - i. In straight and level flight, the total lift is acting perpendicular to the wings and the Earth
       - a. As the plane is banked, lift becomes the resultant of two components:
         - Vertical Component (VC) - Continues to act perpendicular to Earth and opposes gravity, or the weight of the airplane
         - Horizontal Component (HC) - Acts parallel to the Earth's surface and opposes inertia (or Centrifugal Force)
       - b. The vertical and horizontal components act at right angles to each other (shown in the picture below); total lift acts perpendicular to the banked wings
         - The horizontal component of lift is what actually turns the airplane, not rudder



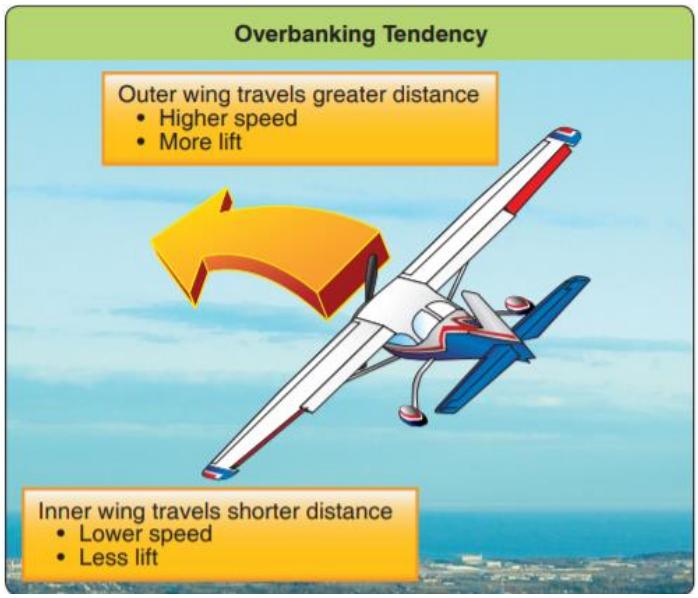
ii. Because a portion of the vertical lift has been transferred to horizontal lift, the angle of attack must be increased when turning in order to maintain altitude
   a. Total lift must be increased to compensate for the decreased vertical lift and maintain level flight
      - Total lift is perpendicular to the banked wings

C. Adverse Yaw
   i. When the pilot deflects the ailerons to bank the airplane, both lift and drag are increased on the rising wing, and simultaneously decreased on the lowering wing
      a. The aileron on the rising wing is deflected downward producing more lift and therefore more induced drag
   ii. The change in drag between the wings results in the airplane yawing opposite the direction of the turn (adverse yaw)
   iii. To counteract adverse yaw, rudder pressure is applied simultaneously with aileron in the direction of the turn



D. Overbanking Tendency

i. As the radius of a turn becomes smaller, a significant difference develops between the speed of the inside wing and the speed of the outside wing
   a. The wing on the outside of the turn travels a longer path than the inside wing, but both complete their respective paths in the same amount of time
      - Therefore, the outside wing must travel faster than the inside wing; as a result, it develops more lift
      - The difference in lift between the inside and outside wing tends to further increase the angle of bank



   b. In a shallow banked turn, the difference in lift between the two wings is generally overcome by the airplane's inherent lateral stability
      - The airplane will have a tendency to roll back to wings level unless the pilot holds aileron pressure in the direction of the turn
   c. In a medium bank, the lift differential generally matches the airplane's inherent lateral stability characteristics
      - The aileron can be left neutral and bank will neither increase or decrease
   d. At a high bank angle (generally > 45°), the difference in lift between the inner and outer wings outweighs the airplane's inherent lateral stability
      - The aircraft continues in the direction of the bank even with neutral flight controls
      - Aileron pressure is required in the direction opposite the turn in order to maintain the bank angle

E. Rate of Turn
   i. The rate of turn is dependent on airspeed and the horizontal component of lift (bank angle)
      a. Horizontal Component of Lift (bank angle)
         - The rate of turn at a given airspeed is dependent on the horizontal component of lift
            a The horizontal component of lift varies in proportion to the amount of bank
               1. As bank angle increases, the horizontal component of lift increases
               2. Therefore, the steeper the angle of bank, the higher the rate of turn
      b. Airspeed
         - As airspeed increases, the aircraft's rate of turn decreases due to inertia
            a The higher the airspeed of an aircraft, the greater the inertia
               1. The greater the inertia, the more the aircraft desires to continue straight ahead and therefore the slower the rate of turn
            b At a given angle of bank, a higher true airspeed will make the rate of turn slower, and the radius of the turn larger

F. Coordination
   i. The ball in the turn and slip indicator will be displaced whenever the airplane is skidding or slipping
   ii. In proper coordinated flight, there is no skidding or slipping

iii. Step on the ball to center it and maintain coordinated flight
   a. As discussed above, adverse yaw must be compensated for with rudder pressure in the direction of the turn. Anticipate and add rudder pressure with aileron
iv. Uncoordinated flight results in decreased performance (excess drag)
   a. Reduces airspeed, climb ability, etc.

3. Control Pressures and Over-Controlling

A. It is important to maintain a light grip on the flight controls
   i. Only grip with the fingertips
B. The control forces desired should be exerted lightly and just enough to produce the desired result
   i. Common Error - Application of control movements rather than pressures
      a. Use smooth, light pressure, not jerky movements
         - Small movements are much easier to control
      b. Large, jerky movements lead to large changes in pitch, bank, airspeed, etc., which leads to the pilot chasing the desired attitude
      c. Next time you drive, pay attention to the steering wheel corrections you use to maintain your lane on the freeway
         - Replicate this in the airplane to maintain the desired flight attitude – very small, smooth, and controlled pressures
   ii. The student should follow along with the instructor during the maneuver to feel the control pressures being used to maintain a level turn
      a. Demonstrates that little control movements are necessary
      b. The student becomes more confident through the procedures
      c. Show the student, then let the student fly
         - Continue to make corrections as necessary
C. Overcoming Tenseness/Over-controlling
   i. Signs of over-controlling
      a. Control movements rather than control pressures
         - Jolty, large movements of the flight controls
         - White knuckles (look for the death grip)
         - Overall nervousness
   ii. Prevention
      a. Point out the over-controlling and demonstrate the correct light, fingertip grip and the pressures desired
      b. If over-controlling is consistent, place a wooden pencil on top of the middle and ring finger and under the index and pointer finger of the hand the student uses to fly
         - If the student starts the death grip, the force of the pencil on his middle/ring finger will remind him/her to relax, if the student continues to tighten their grip the pencil will break

4. Trim Technique

A. Most airplanes are designed so that the primary flight controls (rudder, aileron, elevator) are streamlined with the non-movable airplane surfaces when the airplane is cruising straight-and-level, while at normal weight and loading
   i. If the airplane is out of the balanced condition (faster, slower, heavier, lighter, etc.), one or more of the control surfaces is going to have to be held out of its streamlined position by continuous control input

a. Trim tabs/control surfaces offset the constant flight control pressure inputs needed from the pilot
b. A properly trimmed aircraft is an indication of good piloting skills, and should allow the pilot to fly almost hands free
- Any control forces the pilot feels should be a result of deliberate flight control inputs, not forces being applied by the airplane

c. An improperly trimmed aircraft requires constant flight control pressures from the pilot, produces tension and fatigue, distracts the pilot from visual scanning, and contributes to abrupt and erratic airplane control inputs

B. Trimming the Airplane
i. Set the power
ii. Set the pitch
iii. Let the airspeed stabilize
iv. Trim the airplane for the current airspeed
a. Method
- Establish and hold the airplane in the desired attitude using the primary flight controls
  a Proper attitude should be established with reference to the horizon and then verified by reference to the flight instruments
- Apply trim to relieve the control pressure
  a The airplane attitude must be established and held first, then control pressures trimmed away so that the airplane will maintain the desired flight attitude in "hands off" flight
  b Most general aviation aircraft only have elevator trim, although some aircraft also have rudder and aileron trim
    1. In airplanes with multiple trim tabs, trim the rudder first, then elevator, then aileron
- As previously discussed, if power changes, the pitch attitude to maintain level flight will change, and the aircraft will have to be re-trimmed
  a On a longer flight, as the CG changes with decreasing fuel, adjustments may have to be made to maintain the proper trim

v. Common Error - Faulty trim technique
a. Trying to fly the airplane with trim is a common fault
- Establish the desired attitude, then trim the aircraft (establish first, trim second)
- Do not trim to establish the desired attitude (trim first, establish second)

b. There is no such thing as the perfect trim – with changing air, gusts, turbulence, fuel burn, etc. the airplane will have to be trimmed often
- Consistently make small adjustments to remain trimmed for level flight

5. Integrated Flight Instruction

A. The use of outside references and flight instruments to establish and maintain desired flight attitudes and airplane performance
i. Students who learn this way achieve a more precise and competent overall piloting ability
ii. The pilot should become familiar with the relationship between outside visual references and the corresponding instrument indications
a. Ex: A pitch adjustment may require a movement of several inches in relation to the natural horizon, but a seemingly insignificant movement on the attitude indicator

B. The Basic Elements

i. 90% outside, 10% inside
   a. At least 90% of the pilot's attention should be devoted to outside visual references and scanning for other traffic
ii. Validate the airplane's attitude on the flight instruments
   a. If the instruments display that the airplane's performance needs a correction, determine the correction and then apply it with reference to the natural horizon
   b. The airplane's attitude and performance are then rechecked by referring to the flight instruments
   c. Then maintain the corrected attitude by reference to the natural horizon
iii. Quick snap shots of the instruments
   a. No more than 10% of the pilot's attention should be inside the cockpit
   b. The pilot must learn to focus quickly on the appropriate flight instruments and then return immediately to the outside visual references

C. Common Error - Failure to crosscheck and correctly interpret outside and instrument references
   i. Ensure the student understands how to use visual and instrument references together to interpret the aircraft's attitude
   ii. Fixation, and making pitch/bank corrections while looking inside are common problems for new pilots
   iii. If necessary, cover the instruments for the first several hours to prevent fixation/reliance on the instruments

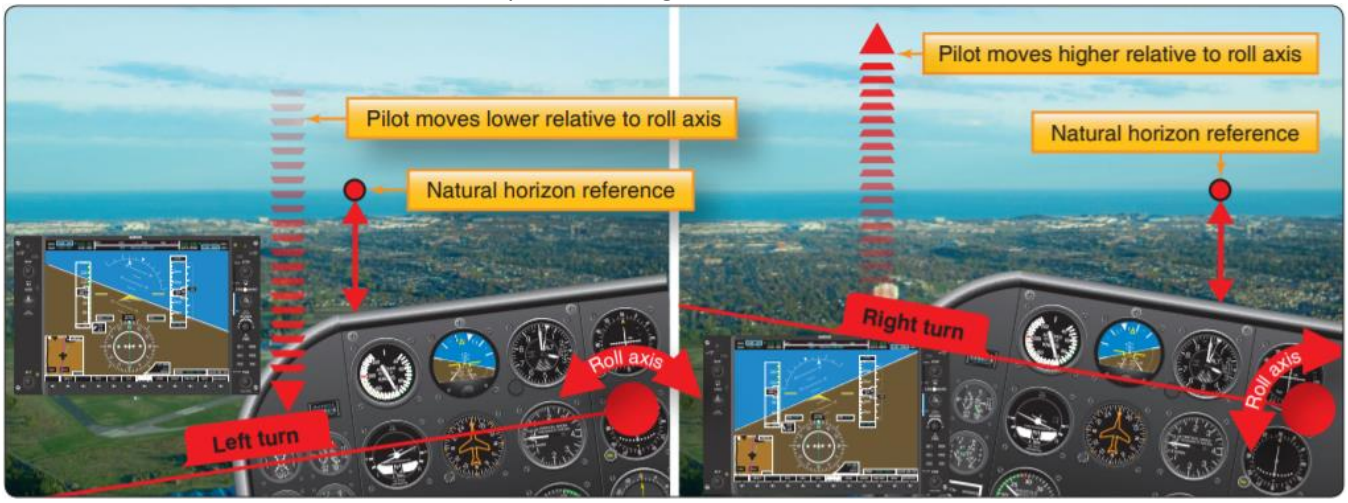
6. Level Turns

A. Before turning, clear the area in the direction of the turn and complete the pre maneuver checklist

B. Entering the Turn, Establishing the Bank Angle
   i. Outside References
      a. On most light single-engine airplanes, the top of the engine cowling is fairly flat, and its horizontal surface relative to the natural horizon provides a good indication for initially setting the bank angle and pitch attitude (the wings can also be used as a reference)
         - Use the position of the cowling and/or wings on the natural horizon as your attitude indicator to establish the turn, then crosscheck the turn with the instruments
         - With experience you will learn to associate the outside references with the bank angles and pitch attitudes required in the turn

      b. Parallax Error
         - The airplane rolls on the longitudinal axis
         - Because most aircraft have side-by-side seating, each pilot sits to one side of the longitudinal axis

- For the pilot in the left seat, this results in the nose appearing to rise in a left turn (due to the pilot lowering in relation to the longitudinal axis) and appearing to descend in a right turn (due to the pilot rising in relation to the longitudinal axis).
    a Vice-versa for the pilot in the right seat



c. Another common problem is that a pilot may lean away from the turn in order to remain in an upright position in relation to the horizon
    - This should be avoided and corrected immediately in order to properly use visual references

ii. Control Inputs

a. Aileron and rudder pressure should be input together
    - Use small, smooth flight control inputs
        a Beginning pilots should not use large aileron and rudder control inputs which produce rapid roll rates and allow little time for the pilot to evaluate and make corrections
        b The faster and more firmly the aileron is applied, the faster the roll
        c The longer the aileron pressure is held, the greater the bank angle
        d Common Error - Application of control movements rather than pressures
    - Maintain Coordination
        a The ball of the turn coordinator should be centered
            1. "Step on the ball" to center it
        b Common Error - Uncoordinated use of the flight controls
            1. If the nose of the airplane starts to move before the bank starts, the rudder is being applied too soon
            2. If the bank starts before the nose starts turning, or the nose moves in the opposite direction, the rudder is being applied too late
            3. The nose should rotate on the horizon without leading or lagging the bank

b. Elevator Pressure
    - As the roll is being established, and vertical lift is divided into a vertical and horizontal component, gently increase back pressure to maintain level flight
        a The smaller the bank, the less elevator back pressure required, and vice-versa
        b When to apply the back pressure, and how much back pressure to apply will vary between aircraft
            1. Become familiar with the visual pitch references at different bank angles, and develop a feel for when the pitch input is required in the turn

- If desired, trim the aircraft to maintain hands free level flight, and reduce pilot workload

c. Power
- As lift is increased to maintain altitude in the turn, drag is also increased, reducing airspeed
  - a Usually not significant for small bank angles
- If necessary, increase power to maintain the desired airspeed
  - a Generally necessary above 30° of bank

iii. Crosscheck – 90% outside, 10% inside

a. Establish the turn with outside references
- Bank – Angle of the engine cowling and/or wings relative to the horizon
- Pitch – Height of the engine cowling or another point on the aircraft relative to the horizon

b. Crosscheck with the instruments
- Attitude indicator – Verify desired bank angle and pitch attitude
- Turn Coordinator – Coordinated flight
- Attitude Indicator – Should show level flight
- Vertical Speed Indicator – Should show zero climb. Check for trends
- Heading Indicator – Turning at a normal rate toward the desired heading
- Airspeed Indicator – Check for proper airspeed

C. In the Turn

i. Throughout the turn, the pilot should reference the natural horizon, scan for traffic, and occasionally crosscheck the flight instruments

ii. Outside References

a. Maintain the desired relationship between the cowling and/or wings with the natural horizon, while scanning for traffic

iii. Control Inputs

a. Aileron and Rudder (Maintaining Bank)
- After the bank has been established, all flight control pressures applied to the rudder and ailerons may be relaxed or adjusted, depending on the bank angle used
  - a As discussed, at low bank angles the pilot will have to maintain aileron and rudder pressure in the direction of the turn
  - b At medium bank angles, the pilot can relax the controls
  - c At high bank angles, the pilot will have to apply opposite aileron and rudder to maintain the bank angle and prevent bank from steepening
  - d Adjust as required using smooth, and controlled *pressures* throughout the turn
    1. It is common to have to add and remove aileron, rudder, and elevator pressure in order to maintain the desired bank
- Common Error - Uncoordinated use of the flight controls
  - a Keep the turn coordinator in your crosscheck and the ball centered

b. Elevator Pressure (Maintaining Altitude)
- Back pressure on the elevator should not be relaxed
  - a The vertical component of lift must be maintained if altitude is to be maintained
- Adjust trim as required to maintain hands free level flight

c. Power (Maintaining Airspeed)
- If properly set when the turn was established, the power should remain the same through the turn

- If the airspeed has increased/decreased 5 knots, adjust the power

iv. Crosscheck and Adjust – 90% outside, 10% inside
   a. Same as above - backup the outside references with the instruments and ensure the desired bank angle, altitude, and airspeed are being maintained, as well as coordinated flight
   b. Adjustments
      - If bank angle is too high or low, reestablish the desired bank using the ailerons
         a Adjust rudder as required to maintain coordination
         b If climbing/descending, adjust the pitch attitude in relation to the horizon, then recheck the altimeter/VSI to determine if altitude is being maintained
         c Once an attitude is established that maintains the altitude, maintain the attitude in relation to the horizon
      - Once the necessary adjustments have been made, re-trim the airplane
   c. Common Error - Faulty attitude and bank control
      - Use smooth controlled, pressures to make small adjustments in order to maintain the desired bank angle and pitch attitude
      - Understand the relationship between bank and pitch
         a Increased bank necessitates increased pitch to maintain altitude
         b Decreased bank requires less pitch to maintain altitude
   d. Common Error - Failure to cross-check and correctly interpret outside and instrument references
      - Become familiar with the visual references associated with your aircraft
      - Maintain 90% outside, 10% inside
      - Understand what the instruments mean and what corrections are required based on the instrument indications
v. Summary
   a. During all turns, the ailerons, rudder and elevator are used to correct minor variations in pitch and bank, just as they are in straight-and-level flight

D. Rolling Out
   i. General/Control Inputs
      a. Similar to a roll in except control pressures are used in the opposite direction
         - Aileron and rudder are applied toward the high wing
      b. Since the airplane continues to turn as long as there is any bank, the rollout must be started prior to reaching the desired heading
         - As a general rule, lead the rollout by approximately ½ the bank angle (this is a very slow roll out)
            a In a 30° bank turn, start the rollout 15° before your desired heading
      c. As the angle of bank decreases, elevator pressure should be gently relaxed to maintain altitude
         - As bank is rolled out, the horizontal component of lift is decreasing and the vertical component of lift is increasing
      d. Power should be reduced to maintain the desired airspeed in straight flight
      e. As the wings become level, the control pressures should be smoothly relaxed so that the controls are neutralized as the airplane returns to straight-and-level flight
      f. Remove trim, if necessary
      g. Attention should be directed to visual references, as well as the flight instruments to determine that the wings are leveled and the turn stopped

ii. Outside References
    a. The aircraft should be returned to the straight-and-level flight references
iii. Crosscheck – 90% outside, 10% inside
    a. As straight-and-level flight is reestablished, continue to reference the natural horizon, scan for traffic, and occasionally crosscheck the flight instruments

Common Errors:

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

Conclusion:
Brief review of the main points
In a level turn, we establish and maintain our bank angle and pitch attitude in relation to the horizon. The airplane's attitude is confirmed by referring to flight instruments and its performance. If the airplane performance, as indicated by flight instruments, indicates a need for correction, a specified amount of correction should be applied with reference to the horizon. Then the airplane's attitude and performance are rechecked by referring to the flight instruments.

PTS Requirements:

To determine that the applicant:

1. Exhibits instructional knowledge of the elements of level turns by describing:
    a. Effect and use of flight controls.
    b. The Integrated Flight Instruction method.
    c. Outside and instrument references used for pitch, bank, yaw, and power control; the crosscheck and interpretation of those references; and the control procedure used.
    d. Trim procedure.
    e. Methods that can be used to overcome tenseness and over controlling.
2. Exhibits instructional knowledge of common errors related to level turns by describing:
    a. Failure to cross-check and correctly interpret outside and instrument references.
    b. Application of control movements rather than pressures.
    c. Uncoordinated use of flight controls.
    d. Faulty altitude and bank control.
3. Demonstrates and simultaneously explains level turns from an instructional standpoint.
4. Analyzes and corrects simulated common errors related to level turns.