IV.A. Instrument Flight

References: 14 CFR Part 61, Risk Management Handbook (FAA-H-8083-2), Instrument Flying Handbook (FAA-H-8083-15)

KNOWLEDGE

The applicant demonstrates understanding of:

1. **Elements Related to Attitude Instrument Flying and During Straight-and-Level, Climbs, Turns, and Descents While Conducting Various Instrument Flight Procedures**
   - A. Attitude Instrument Flying Concept
     - i. Aircraft performance is achieved by controlling the aircraft attitude and power (angle of attack and thrust to drag) to produce the desired performance
       - a. Pitch + Power = Performance
     - ii. The three general categories of instruments are control, performance, and navigation instruments
       - a. Control – Display immediate attitude and power indications and are permit precise adjustments
         - Control is determined by reference to the AI and power indicators
       - b. Performance – Indicate the aircraft's actual performance
         - Performance is determined by reference to the Altimeter, ASI, VSI, HI, and TC
       - c. Navigation - Indicate the position in relation to a selected navigation facility or fix
         - Determined by course indicators, range indicators, glide-slope indicators and bearing points
     - iii. Procedural Steps
       - a. *Establish* - an attitude/power setting on the control instruments resulting in the desired performance
         - Known or computed attitude changes and approximate power settings will help reduce workload
       - b. *Trim* - until control pressures are neutralized.
         - Trimming is essential for smooth, precise control and allows attention to be diverted elsewhere
       - c. *Crosscheck* – the performance instruments to determine if the desired performance is being obtained
         - Involves seeing and interpreting
         - If a deviation is noted, determine the magnitude and direction of correction necessary
       - d. *Adjust* – the attitude or power setting on the control instruments as necessary
   - B. Pitch Instruments
     - i. Attitude Indicator (A/I)
     - ii. Altimeter
     - iii. Vertical Speed Indicator (VSI)
     - iv. Airspeed Indicator
   - C. Bank Instruments
     - i. Attitude Indicator
     - ii. Directional Gyro (DG) or Heading Indicator
     - iii. Compass

iv. Turn Coordinator (T/C)

D. Power Instruments
   i. Engine Instruments
   ii. Airspeed Indicator

E. Instrument Crosscheck
   i. The continuous and logical observation of instruments for attitude and performance information
      a. The pilot maintains an attitude by reference to instruments that will give the desired performance
   ii. It is impossible to establish an attitude and have performance remain constant for a long period of time
      a. It is therefore necessary to constantly check the instruments and make appropriate changes
   iii. Different Crosschecks
      a. Select Radial Crosscheck
         - Based off the Attitude Indicator
            a Eyes never travel directly between the flight instruments, but move by way of the Attitude Indicator
         - Begin with the Attitude Indicator, scan an instrument and return to the Attitude Indicator before moving to another
      b. Inverted V Crosscheck
         - Moving your eyes from the Attitude Indicator to the Turn Coordinator, up to the Attitude Indicator, to the VSI, and back to the Attitude Indicator
      c. Rectangular Crosscheck
         - Move your eyes across the top three instruments and drop down to scan the bottom three
         - This gives equal weight to each instrument, regardless of its importance to the maneuver
         - But this method lengthens the time for your eyes to return to a maneuver's critical instrument
   iv. Crosscheck and Bank
      a. After establishing, check the Heading Indicator and Turn Coordinator to ensure the airplane is performing as desired
   v. Crosscheck and Pitch
      a. After establishing, check the Altimeter, VSI and Airspeed Indicator to ensure the airplane is performing as desired
   vi. Crosscheck Errors
      a. Fixation
         - Staring at a single instrument (Attitude Indicator is the most common)
         - This occurs for a variety of reasons and eliminates the crosscheck of other pertinent instruments
      b. Omission
         - Omitting an instrument from the crosscheck
         - May be caused by failure to anticipate major instrument indications following attitude changes
      c. Emphasis (VSI -chasing is common or emphasizing pitch or bank instruments)

- Putting emphasis on a single instrument, instead of the necessary combination of instruments
- You may naturally tend to rely on the instrument most understood

vii. Instrument Interpretation
   a. Understanding each instrument's construction and operating principles and applying this
   b. Tendency to chase the VSI thinking it's an instantaneous reading (remember, it's a lag instrument)
   c. As the performance capabilities of the aircraft are learned, the instrument indications will be interpreted appropriately in terms of the attitude of the aircraft
      - If the pitch is to be determined, the Airspeed Indicator, Alt, VSI and Attitude Indicator provide the necessary information
      - If the bank attitude is to be determined, the Heading Indicator, Turn Coordinator, and Attitude Indicator must be interpreted

viii. For each maneuver, you will learn what performance to expect and the combination of instruments to interpret to control the aircraft

F. Straight-and-Level Flight

Pitch + Power = Desired Performance
Nose on Horizon + Cruise Power = Straight and Level

Pitch		Bank	
A/I	On Horizon	A/I	Wings Level
Alt	Constant	DG	Constant
VSI	0	Compass	Constant
A/S	Constant Cruise AS	T/C	Level/Coordinated

i. Establish **-** Use the attitude indicator to establish a wings level, nose on the horizon attitude adjusting power as needed
ii. Trim – Trim to relieve the control pressures
iii. Crosscheck
iv. Adjust – Correct any performance errors as necessary and retrim the airplane, then crosscheck again

G. Constant Airspeed Climbs

Pitch + Power = Desired Performance
10° Nose Up + Full Power = Constant Airspeed Climb

Pitch		Bank	
A/I	10° Nose Up	A/I	Wings Level
Alt	Climbing	DG	Constant
VSI	Positive Climb	Compass	Constant
A/S	Constant Climb AS	T/C	Level/Coordinated

i. Establish – Raise the nose of the aircraft to the approximate pitch attitude for the desired climb speed
   a. As the airspeed approaches the desired climb speed, set the power to the climb setting (full)
ii. Trim – Trim to relieve the control pressures
iii. Crosscheck
iv. Adjust – Correct any performance errors as necessary and retrim the airplane, then crosscheck again
   - Adjust the pitch attitude to maintain the desired climb airspeed (1 bar or ½ bar width movements)

v. Leveling Off
    a. Lead the altitude by 10% of the vertical speed (EX: 500 fpm climb is led by 50')
    b. Use the same procedure to level off the plane
        - Establish – Reduce power and apply smooth steady elevator pressure toward a level attitude
        - Crosscheck – VSI, Altimeter and attitude indicator should show level flight
        - Then Trim the airplane and maintain straight and level flight

H. Constant Airspeed Descents

Pitch + Power = Desired Performance
3° Nose Down + Descent Power = Constant Airspeed Descent

Pitch		Bank	
A/I	3° Nose Down	A/I	Wings Level
Alt	Descending	DG	Constant
VSI	Negative Climb	Compass	Constant
A/S	Constant Descent AS	T/C	Level/Coordinated

i. Establish – Reduce power to a predetermined setting for the descent and maintain straight and level flight as airspeed decreases
    a. As the airspeed approaches the desired level, lower the nose with the attitude indicator to maintain a constant speed
ii. Trim – Trim to relieve the control pressures
iii. Crosscheck
iv. Adjust – Correct any performance errors as necessary and retrim the airplane, then crosscheck again
    a. Adjust the pitch attitude to maintain the desired climb airspeed
v. Leveling Off
    a. Lead the altitude by 10% of the vertical speed (EX: 500 fpm climb is led by 50')
    b. Use the same procedure to level off the plane
        - Establish – Introduce power and apply smooth steady elevator pressure toward a level attitude
        - Crosscheck – VSI, Altimeter and attitude indicator should show level flight
        - Then Trim the airplane and maintain straight and level flight

I. Turns to Headings

Pitch + Power = Desired Performance
Wings Banked/Nose Slightly High + Cruise Power = Turn to Heading

Pitch		Bank	
A/I	Nose Slightly High	A/I	Wings Banked
Alt	Constant	DG	Turning to Heading
VSI	0	Compass	Turning to Heading
A/S	Constant Cruise AS	T/C	Banked/Coordinated

i. Prior to entering, determine which direction the turn should be made and the angle of bank required
    a. Use an angle of bank equal to the number of degrees to turn, not to exceed 30 degrees
ii. Establish – coordinated aileron and rudder pressure to establish the desired bank angle on the attitude indicator
    a. If standard rate, use the turn coordinator to check
    b. Adjust pitch as necessary (probably increase) to maintain level flight
iii. Trim – Trim the airplane

iv. Crosscheck
v. Adjust – Correct any performance errors as necessary and go through the process again
vi. Rolling Out
    a. Apply coordinated rudder and aileron pressure to level the wings on the attitude indicator
        - Depending on the amount of turn, rollout about 10 degrees before the desired heading
            a Or use ½ the bank angle or less for small turns
vii. Adjust the pitch to maintain level flight

2. Interpretation, Operation, and Limitations of Pitch, Bank, and Power Instruments

A. Pitch Instruments
    i. Attitude Indicator
    ii. Altimeter
    iii. Vertical Speed Indicator
    iv. Airspeed Indicator
B. Bank Instruments
    i. Attitude Indicator
    ii. Heading Indicator
    iii. Compass
    iv. Turn Coordinator
C. Power Instruments
    i. Airspeed Indicator
    ii. Engine Instruments
D. See II.B. Aircraft Flight Instruments for Operation and Limitations

3. Normal and Abnormal Instrument Indications

A. Normal Instrument Indications
    i. Normal instrument indications occur when the internal components of the instrument are functioning properly and there are no abnormal external influences affecting the instrument (ice, for example)
    ii. Normal indications should be checked while on the ground during the preflight, taxi, run-up, takeoff and airborne to ensure there are no potential problems
        a. During the preflight, normal indications can be found in the flight manual
        b. During taxi, normal indications include:
            - Attitude Indicator – no more than 5 degrees of bank or pitch while taxiing
                a Refer to the flight manual for more specific requirements. 5 degrees is a generic attitude indicator check
            - Turn Coordinator – The Ball swings in the opposite direction of the turn
            - Heading Indicator – The heading indicator turns appropriately with the turn
                a Right turn = increasing numbers; Left turn = decreasing numbers
            - Altimeter – once set to the current pressure the altimeter should indicate within 75’ of elevation
            - Navigation Instruments – Should indicate as set. Verify VOR operation with a VOR check on the taxi out, if available
            - Power Instruments – Verify normal operation and instruments in the green ranges (once the engine is warm)
        c. During the run-up, follow the flight manual instructions and verify normal operation accordingly

d. During takeoff
    - Airspeed Indicator – Verify the airspeed comes alive as the aircraft accelerates
    - Engine Instruments – Verify they are still in the green and the engine is operating as expected
e. Airborne
    - Pitch (and Bank) + Power = Performance
    - Although conditions may change from day to day the general pitch and power settings will equate to roughly the same performance from the aircraft
        a. The aircraft should perform as expected with known pitch and power settings

B. Abnormal Instrument Indications
i. Abnormal instrument indications occur when there is an internal problem with the instrument or an outside influence affecting the instrument's operation
a. For example:
    - A pitot static cover left on will prevent the airspeed indicator from operating
    - An excessive pitch attitude can cause an attitude indicator to tumble and display abnormal indications
    - Non-Standard Temperatures can cause abnormal instrument indications
        a. Even though the altimeter is functioning properly, the indications are not correct (this is explained in Lesson II.B. Aircraft Flight Instruments and Navigation Equipment)
    - Frozen pitot or static ports can result in abnormal indications
    - Faulty mechanisms can also cause abnormal indications

ii. Abnormal instrument indications can be seen anytime (from preflight to airborne and landing)
a. Reference the flight manual for expected operation and operating tolerances

4. Normal and Abnormal Instrument Operations

A. Normal Instrument Operation
i. Normal instrument operation occurs when there is no outside influence affecting the operation of the instrument
a. The instrument operates as designed and as discussed in Lesson II.B. Aircraft Flight Instruments and Navigation Equipment

B. Abnormal Instrument Operation
i. Abnormal instrument operation occurs when an outside influence affects instrument operation
a. Altimeter
    - If the static port becomes blocked the trapped static pressure causes the altimeter to freeze at the altitude where the blockage occurred
b. Airspeed Indicator
    - If the pitot system becomes blocked, dynamic pressure cannot enter the system and the airspeed indicator no longer operates
        a. If the drain hole is open, the pressure drains and airspeed decreases to zero
        b. If the drain hole is also blocked, the airspeed indicator will operate similar to an altimeter
            1. As altitude increases, the airspeed will increase and as altitude decreases, the airspeed will decrease
    - If the static system is blocked, but not the pitot port, the airspeed indicator continues to operate but is not accurate

        a. When the aircraft is operated above the altitude at which the blockage occurred, the airspeed indicates lower than the actual airspeed since the trapped pressure is higher than normal for the altitude
        b. When the aircraft is operated below the altitude at which the blockage occurred, the airspeed indicates higher than the actual airspeed since the trapped pressure is lower than normal for the altitude
    c. Vertical Speed Indicator
        - In the case of a blocked static system, the VSI produces a continuous zero indication
iii. Reference the flight manual for expected operation and operating tolerances

RISK MANAGEMENT

The applicant demonstrates the ability to identify, assess, and mitigate risks, encompassing:

1. Situations that can Affect Physiology and Degrade Instrument Cross-check

A. Various situations can degrade a pilot's instrument cross-check

i. Examples include busy, task saturated parts of the flight (approach and arrival), outside distractions (other aircraft, the view), other people (whether in the cockpit or on the radio), systems and instruments on board the aircraft (G1000, iPads, phones, instrumentation), etc.

ii. Physiological Factors

a. Drugs/Medication
- Drugs and medication can degrade cognitive abilities
- Even drugs that have little or no effect on the ground, can have an effect at altitude
- Don't fly on drugs or medication. Check with an AME as to what is safe and unsafe to fly on

b. Sleep/Fatigue
- A lack of sleep can degrade an instrument crosscheck
- Be well rested prior to flight

c. Stamina/Food
- A lack of energy from too little food can degrade the pilot's crosscheck
- A lack of energy from too much food can also degrade a pilot's crosscheck
- Be properly nourished prior to flight

d. Sickness
- Don't fly sick

e. Illusions
- Various physiological illusions (as mentioned above) can degrade or confuse a pilot's crosscheck
- Trust the instruments, maintain your crosscheck and attempt to ignore or suppress the illusion you are experiencing

iii. Fixation

a. Staring at one instrument
- Often times a pilot will fixate on an instrument based on the current situation. For example, a constant airspeed climb may result in the pilot focusing on maintaining airspeed while neglecting the other instruments

b. Always keep your eyes moving

iv. Omission

a. Omitting and instrument from the crosscheck

- This may occur for various reasons. One may be a lack of understanding of the instrument and thus a neglect of the information, another may be the position of the instrument

b. Keep all instruments in your scan
- If you don't understand something, ask for clarification or look it up

v. Emphasis
a. Placing emphasis on a single instrument is very common and can become a habit if not corrected
b. When the importance of a single instrument is elevated above another, the pilot begins to rely solely on that instrument for guidance

B. The pilot needs to ensure that his or her attention is always divided between flying the aircraft and whatever else needs to be taken care of
i. If you need more time, ask for it. Inform ATC that you'd like delayed vectors or ask for a hold to catch back up
ii. If something- or someone is distracting you, remove that thing (phone, etc.) or kindly inform the person that you need to focus on something else
iii. Remember, Aviate, Navigate, Communicate. Flying (especially when in the weather) is your number one priority

2. Spatial Disorientation and Optical Illusions

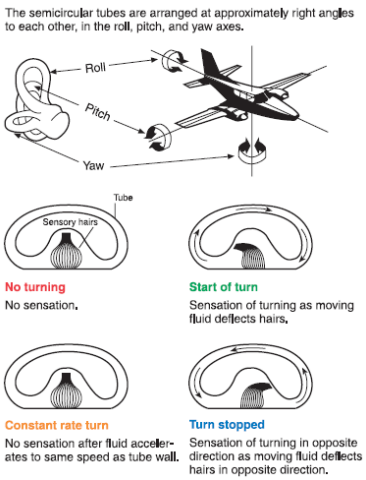
A. Spatial Disorientation
i. Explanation
a. Orientation is the awareness of the position of the aircraft and of oneself in relation to a specific reference point
b. Disorientation is the lack of orientation
c. Spatial Disorientation refers to the lack of orientation with regard to the position, attitude, or movement of the airplane in space
d. The body uses three systems to ascertain orientation and movement in space
- Visual: The eye, by far the largest source of information
- Postural: The sensation of position, movement, and tension perceived through nerves, muscles, and tendons
- Vestibular System: A very sensitive motion sensing system located in the inner ears. It reports head position, orientation, and movement in three-dimensional space

e. All of this info comes together in the brain, and most of the time, the three streams of information agree, giving a clear idea of where and how the body is moving

ii. Relation to flight
a. Flying can result in conflicting information being sent to the brain, leading to disorientation
b. Visual System (eyes)
- Flight in VMC
  a The eyes are the major orientation system and usually prevail over false sensations from the other systems when outside references are available
- Flight in IMC
  a When visual cues are taken away, the eyes cannot correct for the false sensations, and a pilot can become disoriented

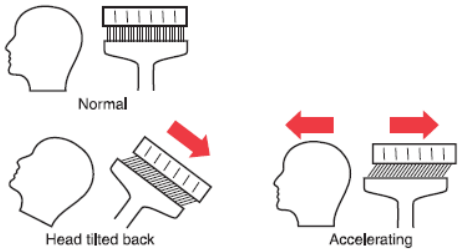
c. Vestibular System (ears)
- The vestibular system in the inner ear allows the pilot to sense movement and determine orientation in the surrounding environment

- Two major parts: Semicircular Canals and Otolith Organs
- Semicircular Canals
  - a Explanation
    1. Detect angular acceleration
    2. Three tubes at right angles to each other
       a. One on each of the three axes; pitch, roll, and yaw
    3. Each canal is filled with a fluid, called Endolymph Fluid
    4. In the center of the canal is the cupola, a gelatinous structure that rests upon sensory hairs located at the end of the vestibular nerves
  - b How they work: In a Turn
    1. When the ear canal is moved in its plane (a turn is started), the relative motion of the fluid moves the cupola, which stimulates the sensory hairs to provide the sensation of turning
       a. Glass of water illustration: wall is moving but water is not
    2. The ear only detects turns of a short duration
       a. After approximately 20 seconds, the fluid accelerates and moves at the same speed as the ear canal
       b. At the same speed, the hairs detect no relative movement and the sensation of turning ceases (it feels like straight and level flight)
          i. Glass of water illustration: water matches the speed of the glass
       c. When the turning stops, the ear canal stops moving but the fluid does not
          i. This moves the sensory hairs in the opposite direction, creating the sensation of a turn in the opposite direction even though the aircraft is flying straight
    3. This can be demonstrated: Establish a 30° bank turn, tell the student to close their eyes and let you know when the aircraft is flying straight. Maintain the turn, after about 20 seconds the student should feel as though the aircraft is out of the turn, have them open their eyes. Try it again, but this time once they believe the aircraft is straight, roll out of the bank. The student will feel like the aircraft is turning in the opposite direction.



- Otolith Organs
  - a Explanation
    1. Detect linear acceleration/gravity
    2. A gelatinous membrane containing chalk like crystals covers the sensory hairs

3. When you tilt your head, the weight of the crystals cause the membrane to shift due to gravity and the sensory hairs detect the shift



b Acceleration
1. Forward acceleration gives the illusion of the head tilting backward and deceleration gives the illusion of the head tilting forward

d. Postural System (nerves)
- Nerves in the body's skin, muscles, and joints constantly send signals to the brain, which signals the body's relation to gravity
- Acceleration will be felt as the pilot is pushed back into the seat
- False Sensations
  a Forces created in turns can lead to false sensations of the direction of gravity, and may give the pilot a false sense of which way is up
    1. The brain has no way of differentiating between the forces of a turn (coordinated or uncoordinated) and the force of gravity
  b Turbulence can create motions that confuse the brain
  c Fatigue or illness can exacerbate these sensations

iii. Countering the sensations
a. Recognize the problem, disregard the false sensations, and rely totally on the flight instruments

iv. The pilot must have an understanding of the problem and the self-confidence to control the aircraft using only instrument indications (do not trust the feelings, trust the instruments)

B. Optical Illusions

i. When visual contact with the horizon is lost, the vestibular system becomes unreliable
a. Without visual references outside the aircraft, there are many situations in which combinations of normal motions and forces create convincing illusions that are difficult to overcome
b. Prevention is usually the best remedy, but if that's not an option, a pilot can reduce susceptibility to disorienting illusions through training and awareness and learning to rely totally on flight instruments

ii. Illusions
a. The Leans
- A sudden return to level flight following a prolonged turn that went unnoticed by the pilot
- Leveling the wings may cause an illusion that the aircraft is banked in the opposite direction causing the pilot to lean in the direction of the original turn

b. Coriolis Illusion
- Occurs when a pilot has been in a turn long enough for the fluid in the ear canal to move at the same speed as the canal
- A movement of the head in a different plane may set the fluid moving, creating the illusion of turning or accelerating on a different axis. The pilot may try to correct this imaginary position putting the aircraft in a potentially dangerous condition

c. Graveyard Spiral

- Like in the Coriolis illusion, a pilot in a long turn may lose the sensation or turning. During the recovery to level flight, the pilot will experience the sensation of turning in the opposite direction causing the pilot to return the original turn
- Because an aircraft tends to lose altitude in turns the pilot may notice a loss of altitude
- The absence of any sensation of turning creates the illusion of being in a level descent, the pilot may pull back on the controls in an attempt to climb or stop the descent
    a. This action tightens the spiral and increases the loss of altitude and can lead to a loss of aircraft control

d. Somatogravic Illusion
- A rapid acceleration, can create the illusion of being in a nose up attitude. The pilot may push the aircraft into a dive attitude
- A rapid deceleration can have the opposite effect

e. Inversion Illusion
- An abrupt change from climb to straight and level flight can create the illusion of tumbling backwards. The pilot may push the aircraft into a nose low attitude which can intensify the illusion

f. Elevator Illusion
- An abrupt vertical acceleration (like in an updraft) can create the illusion of being in a climb. The pilot may push the aircraft into a nose low attitude
- The opposite is true for a downward vertical acceleration

3. Flying with Unfamiliar Flight Display Systems and Avionics

A. Learning a new crosscheck can take time, new and unfamiliar flight displays often have instrumentation and information not only in different places, but displayed in entirely different formats
    i. Take time to learn the system
        a. Fly with an instructor, fly during day VMC conditions, take your time to become more comfortable with the new system

B. Even though the new system may present more information in a more user friendly and safety-oriented way, if you don't know how to use it properly it can quickly become a hazard, degrading safety in the aircraft

SKILLS

The applicant demonstrates the ability to:

1. Maintain altitude ±100 feet during level flight, selected headings ±10°, airspeed ±10 knots, and bank angles ±5° during turns.
2. Use proper instrument cross-check and interpretation, and apply the appropriate pitch, bank, power, and trim corrections when applicable.