Attitude Instrument Flying and Aerodynamics

2.1 TURNS

1. An airplane requires a sideward force to make it turn.
    a. When the airplane is banked, lift (which acts perpendicular to the wingspan) acts not only upward but horizontally as well.
    b. The vertical component acts upward to oppose weight.
    c. The horizontal component acts sideward to turn the airplane, opposing centrifugal force.
    d. The rate of turn (at a given airspeed) depends on the magnitude of the horizontal lift component, which is determined by bank angle.
2. A turn is said to be coordinated when the horizontal lift component equals centrifugal force (the ball is centered).
    a. Centrifugal force is greater than horizontal lift in skidding turns (the ball is on the outside of the turn).
    b. Centrifugal force is less than horizontal lift in slipping turns (the ball is on the inside of the turn).
3. To coordinate a turn, you should center the ball on the turn-and-slip indicator or the turn coordinator.
    a. Center the ball by applying rudder pressure on the side where the ball is (e.g., if the ball is on the left, use left rudder).
4. A standard-rate turn is indicated when the needle is on the "doghouse" (Le., standard rate) mark on the turn-and-slip indicator.
5. The angle of attack must be increased in turns to maintain altitude because additional lift is required to maintain a constant amount of vertical lift.
    a. Thus, load factor always increases in turns (assuming level flight).
6. If airspeed is increased in a turn, the angle of bank must be increased and/or the angle of attack decreased to maintain level flight.
    a. Conversely, if airspeed is decreased in a turn, the angle of bank must be decreased and/or the angle of attack must be increased to maintain level flight.

2.2 TURN RATES

1. The standard-rate turn is 360° in 2 min., i.e., 3°/sec.
    a. A half-standard-rate turn is 360° in 4 min., i.e., 1.5° /sec.
    b. EXAMPLE: A 150° heading change using a standard-rate turn would take 50 sec. (150° ÷ 3°/sec. = 50 sec.)

2. A turn-and-slip indicator may be calibrated as 2-minute or 4-minute.
    a. On a 2-minute turn-and-slip indicator, a single width deflection of the needle indicates a turning rate of 3° per second, or a standard rate turn (i.e., 360° in 2 minutes).
    b. On a 4-minute turn-and-slip indicator, a single width deflection of the needle indicates a turning rate of 1.5° per second, or a half rate turn (i.e., 360° in 4 minutes). If the needle is on the doghouse, it is indicating a standard rate turn.

3. At a constant bank, an increase in airspeed decreases the rate of turn and increases the radius of the turn.
    a. The rate of turn can be increased and the radius of turn decreased by decreasing airspeed and/or increasing the bank.

2.3 CLIMBS AND DESCENTS

1. The three conditions which determine pitch attitude, i.e., angle of attack, required to maintain level flight are
    a. Airspeed
    b. Air density
    c. Airplane weight
2. When leveling off from a climb or descent to a specific altitude, you must start the level-off before reaching the desired altitude.
    a. Throughout the transition to level flight, the aircraft will continue to climb or descend at a decreasing rate.
    b. An effective practice is to lead the altitude by 10% of the indicated vertical speed.
        1) Since the last 1,000 ft. of a climb or descent should be made at 500 fpm, you will generally use a lead of 50 ft.
    c. To level off from a descent at a higher airspeed than descent speed, begin adding power 100 to 150 ft. above the desired altitude, assuming a descent rate of 500 fpm.
3. The pitch instruments are the attitude indicator, the altimeter, the vertical speed indicator, and the airspeed indicator.
    a. The attitude indicator should be used to make a pitch correction when you have deviated from your altitude; then the altimeter and vertical speed indicator are used to monitor the result.
    b. Altitude corrections of less than 100 ft. should be corrected by using a half-bar-width correction on the attitude indicator.
4. To enter a constant-airspeed descent from level cruise and maintain cruise airspeed, simultaneously reduce power and adjust the pitch using the attitude indicator as a reference to maintain cruise airspeed.
5. To enter a constant-airspeed climb from level cruise, increase the pitch such that the artificial horizon indicates an approximate nose-high attitude appropriate for the desired climb speed.
    a. Then apply the desired climb power setting.

2.4 FUNDAMENTAL INSTRUMENT SKILLS

1. The three fundamental skills for attitude instrument flying are (in order)

    a. **Instrument cross-check** -- the continuous and logical observation of instruments for attitude and performance information

    b. **Instrument interpretation** -- the understanding of each instrument's construction, operating principle, and relationship to the performance of the airplane

    c. **Airplane control** -- includes the following elements:

        1) Pitch control
        2) Bank control.
        3) Power control

2.5 APPROPRIATE INSTRUMENTS FOR IFR

1. Flight instruments are divided into the following three categories:

    a. Pitch instruments

        1) Attitude indicator (AI)
        2) Altimeter (AL T)
        3) Airspeed indicator (ASI)
        4) Vertical speed indicator (VSI)

    b. Bank instruments

        1) Attitude indicator (AI)
        2) Heading indicator (HI)
        3) Turn coordinator (TC) or turn-and-slip indicator (T&SI)
        4) Magnetic compass

    c. Power instruments

        1) Manifold pressure gauge (MP)
        2) Tachometer (RPM)
        3) Airspeed,indicator (ASI)

2. For any maneuver or condition of flight, the pitch, bank, and power control requirements are most clearly indicated by certain key instruments. Those instruments which provide the most pertinent and essential information will be referred to as primary instruments. Supporting instruments back up and supplement the information shown on the primary instruments.

		PITCH	BANK	POWER
a.	Straight and level			
	Primary	ALT	HI	ASI
	Supporting	AI"VSI	AI,	MP and/or RPM
b.	Airspeed changes in straight and level			
	Primary	ALT	HI	MP and/or RPM initially
	Supporting	AI, VSI	AI, TC	ASI as desired air- speed is approached
c.	Establishing a level standard-rate turn			
	Primary	ALT	AI	ASI
	Supporting	AI,	TC	MP and/or RPM
d.	Stabilized standard-rate turn			
	Primary	ALT	TC	ASI
	Supporting	AI,	AI	MP and/or RPM
e.	Change of airspeed in level turn			
	Primary	ALT	TC	MP and/or RPM
	Supporting	AI,	AI	ASI
f.	Transitioning from straight and level to constant airspeed climb			
	Primary	AI	HI	MP and/or RPM
	Supporting	ASI,	AI,	ASI
g.	Straight constant airspeed climb			
	Primary	ASI	HI	MP and/or RPM
	Supporting	AI,	AI,	ASI
h.	As power is increased to enter a straight, constant-rate climb			
	Primary	ASI	HI	MP and/or RPM
	Supporting	AI,	AI,	
i.	Straight, constant-rate, stabilized climb			
	Primary	VSI	HI	ASI
	Supporting	AI	AI,	MP and/or RPM

3. For straight-and-Ievel flight, the magnetic compass replaces the HI as the primary bank instrument if the HI is inoperative.

4. The ball of the turn coordinator or turn-and-slip instrument indicates the quality of the turn.

2.6 UNUSUAL ATTITUDES

1. For recovery from nose-low unusual attitudes (negative VSI, increasing airspeed, decreasing altitude, airplane below horizon on attitude indicator):
   a. Reduce power to prevent excess airspeed and loss of altitude.
   b. Level the wings with coordinated rudder and aileron. c. Gently raise the nose to level flight attitude.
2. For recovery from nose-high unusual attitudes (positive VSI, decreasing airspeed, increasing altitude, airplane above horizon on attitude indicator):
   a. Add power.
   b. Lower the nose.
   c. Level the wings.
   d. Return to the original altitude and heading.
3. When recovering without the aid of the attitude indicator, level flight attitude is reached when the altimeter and the airspeed indicator stop prior to reversing their direction of movement and the vertical speed indicator reverses trend.
4. If the attitude indicator has exceeded its limits in an unusual attitude, nose-low or nose-high attitude can be determined by the airspeed indicator and the altimeter.
   a. The vertical speed indicator is also useful but is not as reliable in turbulent air.

2.7 INOPERATIVE INSTRUMENTS

1. To determine an inoperative instrument, analyze each instrument to determine what it is indicating, and determine which instrument is in conflict with the others.
2. Also, consider grouping the instruments by the systems which power them.
   a. The heading indicator and the attitude indicator are vacuum-driven.
   b. The turn coordinator is usually electric.
   c. The airspeed indicator, altimeter, and VSI rely on the static source.
      1) The airspeed indicator also relies on the pitot tube.
         a) Remember that, if the pitot tube's ram air and drain hole are clogged, the airspeed indicator acts as an altimeter; i.e., lower altitudes result in lower airspeeds and vice versa.
         b) Also remember that, if only the ram air hole is clogged, the pressure in the line will vent out the drain hole, causing the airspeed indication to drop to zero.

2.8 TURBULENCE AND WIND SHEAR

1. In severe turbulence, set power for the design maneuvering speed (VA)' and maintain a level flight attitude.
   a. Attempting to turn or maintain altitude or airspeed may impose excessive load on the wings.
2. Flight at or below VA means the airplane will stall before excessive loads can be imposed on the wings.
3. When climbing or descending through an inversion or wind-shear zone, you should be alert for any sudden change in airspeed.