Maneuvering Speed (Va)

Maneuvering speed is the highest speed at which full deflection of the controls about any one axis are guaranteed not to overstress the airframe.

Maneuvering speed is stall speed multiplied by the square root of the limit load factor. Normal category limit is 3.8 Gs, the square root of which is 1.95. If, for example, the flaps-up stalling speed is 70, the maneuvering speed would be $70 \times 1.95 = 136.5$.

The maneuvering speed decreases as the aircraft's weight decreases from maximum takeoff weight because the effects of the aerodynamic forces become more pronounced as its weight decreases. That is because flying at a lower weight decreases the angle of attack and if the higher speed were maintained, excessive lift forces could cause structural damage at full deflection of the elevator.

The flight manuals for some aircraft (such as the Piper Cherokee) specify the design maneuvering speeds for weights below the maximum takeoff weight but sometimes it is left to the pilot to calculate. Using a "Rule of Thumb", the reduction in Va will be half the percentage reduction in aircraft weight.

- A 10% reduction of weight would result in a 5% decrease in Va
- A 30% reduction of weight would result in a 15% decrease in Va
Flight Instruments: Pitot-Static System – Types of Airspeed

**INDICATED (IAS)** = What you read on the AS Indicator

**CALIBRATED (CAS)** = INDICATED AS adjusted for installation errors.

**TRUE (TAS)** = CALIBRATED AS corrected for altitude and non-std temperature

**GROUND SPEED** – TRUE AS corrected for wind (actual speed moving across ground)

**HOW DO YOU FIND EACH OF THESE AIRSPEEDS?**
Flight Instruments: Pitot-Static System – What Affects Airspeed?

**POWER**
- Add Power (more trust) increases airspeed (pitch up tendency)
- Reduce Power (less trust) decreases airspeed (pitch down tendency)

**PITCH**
- Pitch DOWN (descend) will increase airspeed
- Pitch UP (climb) will decrease airspeed

**Transition to climb or descent from level flight**
Requires coordination of BOTH power and pitch.
Airspeed Errors

**Position Error:**
Caused by the static ports sensing erroneous static pressure; slipstream flow causes disturbance at the static port preventing actual atmospheric pressure measurement. (varies with airspeed, altitude and configuration)

**Density Error:**
Changes in altitude and temperature are not compensated for by this instrument.

**Compressibility Error:**
Caused by “packing” of air into the pitot tube at HIGH airscreeds, resulting in higher than normal indications. “Usually” not a factor at low airspeed.
Pitot-Static System – ALTIMETER

- Aneroid wafers
- 10,000 ft. pointer
- 100 ft. pointer
- 1,000 ft. pointer
- Static port
- Crosshatch flag: A crosshatched area appears on some altimeters when displaying an altitude below 10,000 feet MSL.
- Barometric scale adjustment knob
- Altimeter setting window
Flight Instruments: Pitot-Static System – ALTIMETER

- Altitude Indication Scale
- Altimeter Setting Adjustment Knob
- 10,000 ft Pointer
- 1,000 ft Pointer
- 100 ft Pointer
Flight Instruments: Pitot-Static System – 6 types of altitude

1. **Indicated** Altitude: Showing on altimeter

2. **Pressure** Altitude: Showing when set to standard pressure of 29.92” Formal definition is “the height above a standard datum plane (SDP),

3. **Density** Altitude is altitude adjusted for non-standard temperature. Less efficient in warmer whereas more efficient in cooler conditions.
Flight Instruments: Pitot-Static System – TYPES of altitude

4. **Calibrated** Altitude – correction to compensate for instrument error for your specific aircraft (see POH).

5. **True** Altitude – “MSL” (Measure Sea Level) “Height above seal level.”

6. **Absolute** Altitude – above ground level (AGL)
Limitations of Pressure Altitude

PRESSURE
Higher than standard pressure: Altimeter indicates lower than actual.
Lower than standard pressure: Altimeter indicates higher than actual.

TEMPERATURE
On a Warm day: Pressure level is higher than on standard day – altimeter indicates lower than actual.
On a Cold day: Pressure level is lower than on a standard day – altimeter indicates higher than actual.
Pitot-Static System

If correct pressure not adjusted on altimeter, the indicated altitude will be **INCORRECT**.

“High to low – Look out below”
“Low to high – Look to the sky”

Flying from warm to cooler the altimeter will indicate lower indicated altitude than true altitude.

“FROM HOT TO COLD, LOOK OUT BELOW.”
“FROM COLD TO HOT LOOK TO THE TOP.”
Prior to each flight, a pilot should examine the altimeter for proper indications in order to verify its accuracy. To determine the condition of an altimeter, set the barometric scale to the current reported altimeter setting transmitted by the local automated flight service station (AFSS) or any other reliable source, such as ATIS, AWOS, or ASOS. The altimeter pointers should indicate the surveyed field elevation of the airport. If the indication is off more than 75 feet from the surveyed field elevation, the instrument should be referred to a certificated instrument repair station for recalibration.

**Altimeter Check**

![Figure 7-3. Effects of nonstandard temperature on an altimeter.](image)

![Figure 7-4. Look at the chart using a temperature of -10 °C and the aircraft altitude is 1,000 feet above the airport elevation. The chart shows that the reported current altimeter setting may place the aircraft as much as 100 feet below the altitude indicated by the altimeter.](image)
Since weather stations are located around the globe, all local barometric pressure readings are converted to a sea level pressure to provide a standard for records and reports. To achieve this, each station converts its barometric pressure by adding approximately 1 "Hg for every 1,000 feet of elevation. For example, a station at 5,000 feet above sea level, with a reading of 24.92 "Hg, reports a sea level pressure reading of 29.92 "Hg. [Figure 11-8] Using common sea level pressure readings helps ensure aircraft altimeters are set correctly, based on the current pressure readings.

**Figure 11-8. Station pressure is converted to and reported in sea level pressure.**
Altitude and Flight
Altitude affects every aspect of flight from aircraft performance to human performance. At higher altitudes, with a decreased atmospheric pressure, takeoff and landing distances are increased, as are climb rates. When an aircraft takes off, lift must be developed by the flow of air around the wings. If the air is thin, more speed is required to obtain enough lift for takeoff; therefore, the ground run is longer. An aircraft that requires 745 feet of ground run at sea level requires more than double that at a pressure altitude of 8,000 feet. [Figure 11-9]. It is also true that at higher altitudes, due to the decreased density of the air, aircraft engines and propellers are less efficient. This leads to reduced rates of climb and a greater ground run for obstacle clearance.
Flight Instruments: Pitot-Static System – Vertical Speed Indicator (VSI)

*TREND INFORMATION* ON CHANGE IN VERTICAL SPEED (rate of descent or climb in hundreds of feet per minute). Indicator not accurate until aircraft stabilized. There is a 6-9 second lag for stable pressure to give accurate reading. DON’T CHASE IT…
Flight Instruments: Gyroscopic

- **Attitude Indicator**
- **Heading Indicator (DG)**
- **Turn Coordinator**

The attitude indicator shows a right turn. The turn coordinator indicates a right turn. The heading moves from northerly to easterly direction indicating a right turn.
Flight Instruments: Gyroscopic Principles – Rigidity in Space and Precession

**Rigidity**: Tendency to remain in a constant position no matter what the orientation.

Precession: Small forces applied to a gyro will cause a resultant 90 degree force that is inversely proportional to the speed of the rotor and proportional to the deflective force.

Powered by electrically driven **VACUUM** system.
Flight Instruments: Gyroscopic

TURN COORDINATOR

Gyro driven by electrical or vacuum (pressure)

Standard rate turn-2 minutes
Flight Instruments: Gyroscopic

TURN COORDINATOR

Rate of turn too slow for angle of bank. 😞 Too much bank (roll)

Rate of turn too great for angle of bank. 😞 Too little bank (roll)

Rate of turn and angle of bank just right 😊

Vary rate of turn or “Step On the Ball”
AERODYNAMICS OF SLIPS AND SKID

1. Normal Turn: Centrifugal Force Equals Horizontal Lift.
2. Slipping Turn: Centrifugal Force Less Than Horizontal Lift.
3. Skidding Turn: Centrifugal Force Greater Than Horizontal Lift.

Don’t let this confuse you... The turn and bank indicators show what the pilot observes → Slip (slipping down to right) Skid (skipping out to left)
Standard Rate Turns

- Two Minute Turn (3 degrees per second)
- **Always use Turn and Bank Indicator as your “primary” reference for standard rate turns!!**
- You can determine the angle on the “Attitude Indicator” by a mental calculation of

  \[
  \text{Airspeed} / 10 \times 1.5
  \]

  \[
  \begin{align*}
  \text{TAS} \ 80 / 10 &= 8 \times 1.5 = 12 \text{ degrees} \\
  \text{TAS} \ 100 / 10 &= 10 \times 1.5 = 15 \text{ degrees} \\
  \text{TAS} \ 120 / 10 &= 12 \times 1.5 = 18 \text{ degrees} \\
  \text{TAS} \ 160 / 10 &= 16 \times 1.5 = 24 \text{ degrees}
  \end{align*}
  \]
ATTITUDE INDICATOR
Flight Instruments: Gyroscopic Attitude Indicator Mechanics

LIMITS:

- **Roll** = 60-70 degrees and **Pitch** = 100-110 degrees after which the gyro will become **caged** and require service to unseat the gyros.
- Might be a “slight” nose-up indication in rapid acceleration or nose-down indication on rapid deceleration.
- There is a slight chance of a small bank or pitch error following a 180 degree turn that will correct itself after about a minute of straight and level flight.
Flight Instruments: HEADING INDICATORS

NON-GYROSCOPIC: **Magnetic Compass**. Accurate in straight and level, non-accelerated flight.

GYROSCOPIC: **Heading Indicator** also referred to as the Directional Gyro. Adjust with Magnetic Compass every 15 minutes during flight.
Limitations of Gyroscopic Heading Indicator (Directional Gyro)

• On SOME older heading indicators, the limits are approximately 55 degrees of pitch and 55 degrees of bank.
• When exceeded the instrument “tumbles” or “spills” and no longer gives correct indication until reset.
• Many modern DGs will not tumble
• MUST re-align to COMPASS during straight and level flight because precession caused by friction may cause as much as 15 degree error every hour.
Magnetic Compass

Floats in a solution of white kerosene
Flight Instruments: Magnetic Variation & Deviation

Variation: difference in True North and Magnetic North

Deviation: Instrument error displayed on Magnetic Compass and aircraft documents (POH)

<table>
<thead>
<tr>
<th>FOR (MH)</th>
<th>0°</th>
<th>30°</th>
<th>60°</th>
<th>90°</th>
<th>120°</th>
<th>150°</th>
<th>180°</th>
<th>210°</th>
<th>240°</th>
<th>270°</th>
<th>300°</th>
<th>330°</th>
</tr>
</thead>
<tbody>
<tr>
<td>STEER (CH)</td>
<td>359°</td>
<td>30°</td>
<td>60°</td>
<td>88°</td>
<td>120°</td>
<td>152°</td>
<td>183°</td>
<td>212°</td>
<td>240°</td>
<td>268°</td>
<td>300°</td>
<td>329°</td>
</tr>
</tbody>
</table>

RADIO ON [✓]  RADIO OFF [ ]
Flight Instruments: **Magnetic Compass Errors**

Magnetic dip is the result of the vertical component of the Earth’s magnetic field. This dip is virtually non-existent at the magnetic equator. The vertical component increases at higher latitudes. **DIP ERRORS** are responsible for compass errors in **acceleration**, **deceleration** and **turns**. Magnetic bar is weighted to reduce dipping that is strongest at the poles and least at equator.

Deviation turning **FROM North or South Heading** (Undershoot North, Overshoots South … UNOS)

Deviation turning **FROM North or South Heading** (Undershoot North, Overshoots South … UNOS)

**Variation:** Difference in Magnetic / True North

**Deviation:** Electrical interference from aircraft

**Oscillation:** Rough handling or turbulence

Deviates NORTH when accelerating, and Deviates SOUTH when decelerating. On EASTERLY or WESTERLY HEADINGS. **“ANDS”** (Accelerate North Decelerate South)
Flight Instruments: Turning Errors

**UNOS** – Undershoot North, Overshoot South [Turn rates > 7 ½ degrees]

When making a turn a turn from a northerly heading, the compass LAGS (initially starts a deviation in the OPPOSITE direction then moves behind your actual turn) so you must rollout BEFORE the desired heading (you need to **UNDERSHOOT**). --- **UN** part of acronym.

When making a turn from a southerly heading, the compass gives an indication of a turn in the correct direction, but leads the actual heading (you need to **OVERSHOOT**). This error also disappears as the airplane approaches an east or west heading. The **OS** part of the acronym.

The amount of lead or lag is approximately equal to the latitude of the airplane. For example, turning from a heading of south to a heading of west while flying at 40° north latitude, the compass rapidly turns to a heading of 220° (180° + 40°). At the midpoint of the turn, the lead decreases to approximately half (20°), and upon reaching a heading of west, it is zero. Actual calculations are important for an INSTRUMENT RATING. For your Private/Sport certification, It is important that you understand that the dip error will have impact on turns from North and South.
Digital Based Instrument Systems

Instrumentation changes are in process to digital based information and displays.

- Electronic Flight Information Systems / Primary Flight Displays (EFIS-PFD)
- Engine Monitoring Systems (EMS)
- Synthetic Vision Systems (SV)
- Automatic Dependent Surveillance Broadcast (ADS-B)
- Global Positioning Systems (GPS)
Example 1

“Six-pack”

Equivalent
Digital
EFIS/PFD/MFD/GDU
Electronic Flight Information Systems / Primary Flight Displays / Multi-Function Displays/Graphic Display Units
Garmin 1000 PFD/MFD
Prices range from $495 on bottom row to $30,000 above (2009 pricing)
EMS
Engine Monitoring System
Synthetic Vision Systems

Primary Flight Display OVERLAYED with real time graphic of outside conditions regardless of visibility. Can be panel mounted or used with Tablet Personal Computer OR projected onto the back of the spinning propeller so directly viewed by pilot looking out the windshield.
ADS-B (NextGen-2013)

**Automatic** - Periodically transmits information with no pilot or operator input required.

**Dependent** - Position and velocity vector are derived from the GPS or a Flight Management System (FMS)

**Surveillance** - A method of determining position of aircraft, vehicles, or other asset

**Broadcast** - Transmitted information available to anyone with the appropriate receiving equipment

**INITIAL SERVICE**
- Surveillance Broadcast Services (En Route, Terminal, Surface)
- Traffic/Flight Information Broadcast Services
- Enhanced Visual Acquisition
- Enhanced Visual Approaches (1)
- Final Approach and Runway Occupancy Awareness
- Airport Surface Situational Awareness
- Conflict Detection
What instruments are required to fly daytime VFR

Tachometer for each engine
Oil pressure gauge for each engine
Manifold Pressure gauge
    for each attitude engine
Altimeter
Temperature gauge
    for each liquid cooled engine
Oil temperature gauge
    for each air-cooled engine

Fuel Gauge for each tank
Floatation Gear for each occupant if beyond gliding distance from shore.
Landing gear position indicator if gear retractable
Airspeed Indicator
Anti-collision lighting system for aircraft certified after 3/11/96
Magnetic Direction Indicator
ELT (Emergency Locator Transmitter)
Safety Belts (and shoulder harnesses from front seat if manufactured after 1978)
What instruments are required to fly night VFR

All daytime PLUS..

**Fuses**: 1 spare set of 3 of each type

**Landing Light**: IF aircraft is operated for hire

**Anti-collision lighting**: approved red/white

**Position lighting**: navigation lights

**Source of electrical energy**: for all electrical and communications equipment
AERODYNAMICS

Video
The Four Forces of Flight

In steady-state straight and level unaccelerated flight, the sum of the opposing forces is equal to zero. Opposing forces cancel one another.
Aerodynamics: LIFT Principles

Works because of Newton’s Laws of Motion and Bernoulli’s Principle … Plus

Three Laws of physics help explain: 1. If at rest-stays at rest, if in motion-stays in motion
2. $F=ma$, and 3. For every action there is an equal and opposite reaction.

Bernoulli’s Law that attempts to account for negative pressure above the wing producing Lift as a result in the curve along the upper part of the wing (camber).
Aerodynamics: LIFT
AIRFOILS

Airflow across wing

Angle of attack (angle between relative wind and chord line = greater lift .... To a point above which too much angle of attack is very bad (stalls). Stalls/Spins occur when “CRITICAL ANGLE OF ATTACK EXCEEDED.”

Anything that interferes with the flow of air over the surface of the wing negatively effects lift, such as frost (always clear). Cleaning, waxing helps!
Aerodynamics: LIFT
ANGLE OF ATTACK (AOA)
Aerodynamics: LIFT

OTHER FACTORS

WING Shape, Area, Aspect Ratio, Angle of Attack, Velocity of air, & Density

Wing Area = 100 sq ft
Aspect Ratio = 25

Wing Area = 180 sq ft
Aspect Ratio = 7.2

5 ft Average Chord

36 ft Span

2 ft Average Chord

50 ft Span

Pilot control of lift: – Increase thrust or airspeed and angle of attack increase lift. POWER, ELEVATOR, FLAPS

Flow turning at trailing edge is very important.

Higher Turning = Greater Lift

This effect is used for stability and control of the airplane.

Included in Lift Coefficient

Lift is directly related to surface area.

$L = \text{Constant} \times A$

Double the Area --> Double the Lift

Aerodynamic Forces depend on Re and M

For a valid experiment, Reynolds Number and Mach Number must match flight conditions.

Viscosity

Characteristic

"Stickiness"

Reynolds (Re)

Compressibility

"Springiness"

Mach (M)

Definition

density x velocity x length

viscosity coefficient

Equation

$r \times \frac{V \times L}{\mu}$

flow velocity

speed of sound

$\frac{V}{a}$

Ground School 2011 Created by Steve Reisser
Aerodynamics: LIFT

FLAPS

Flaps allow for more lift (by increasing effective camber), to enable a *steeper descent angle without an increase in airspeed.*

- **PLAIN**
- **SPLIT**
- **SLOTTED**
- **FOWLER-Most effective**
Aerodynamics: WEIGHT & THRUST & DRAG

WEIGHT – DOWNWARD FORCE OPPOSED BY LIFT
THRUST – FOREWARD FORCE OPPOSED BY DRAG
DRAG – BACKWARD (SLOWING) FORCE OPPOSED BY THRUST – FORM, INTERFERENCE, AND SKIN FRICTION
Types of Drag

*Parasite Drag* – all forces working to slow the aircrafts movement and increases as the square of the airspeed.

*Form Drag* – due to shape and airflow around aircraft

*Induced Drag* – a byproduct of lift. The greater the lift, the greater the induced drag. It increases inversely with the square of the airspeed. Illustrated on next slide.

*Interference Drag* – the intersections of airstreams create eddy currents, turbulence, or restrictions to smooth airflow.

*Skin Friction Drag* – due to aerodynamic resistance due to contact of moving air with the surface of the aircraft.