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.

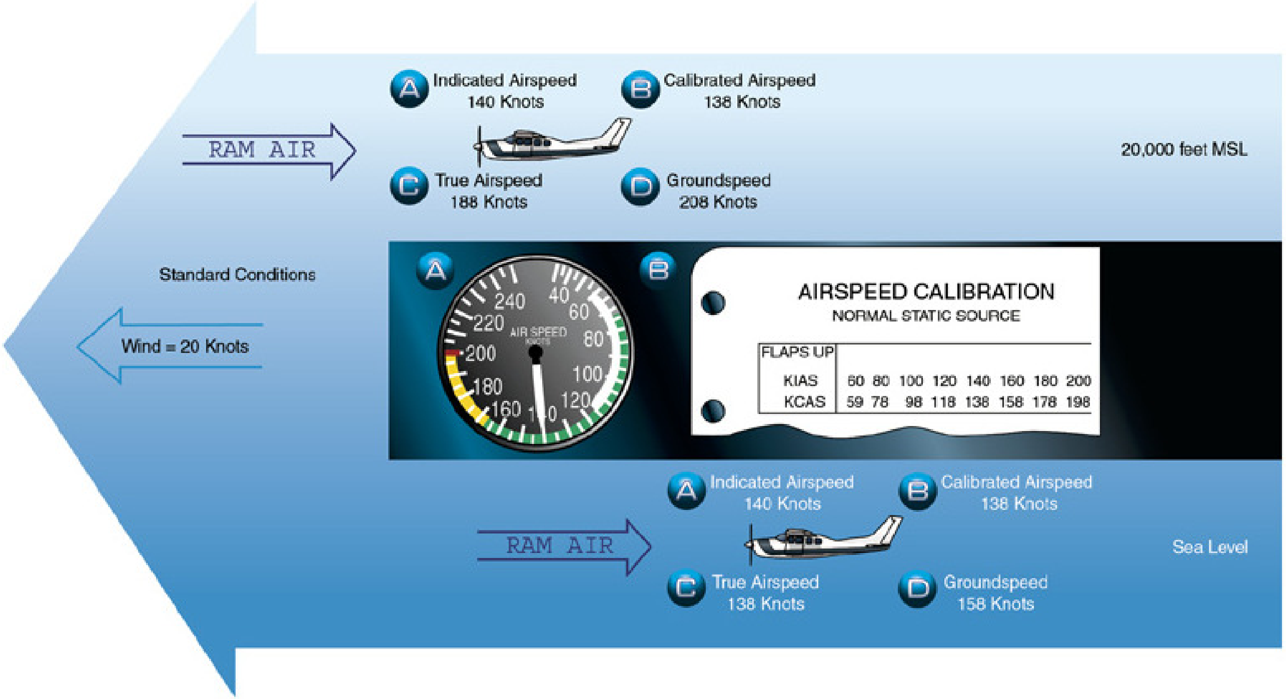
Maneuvering speed is stall speed multiplied by the square root of the limit load factor. Normal category limit is 3.8 Gs, the square root of which is **1.95**. If, for example, the **flaps-up stalling speed is 70**, the maneuvering speed would be **70 * 1.95 = 136.5**.

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



AIRSPEED CALIBRATION

NORMAL STATIC SOURCE

FLAPS UP								
KIAS	60	80	100	120	140	160	180	200
KCAS	59	78	98	118	138	158	178	198

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.

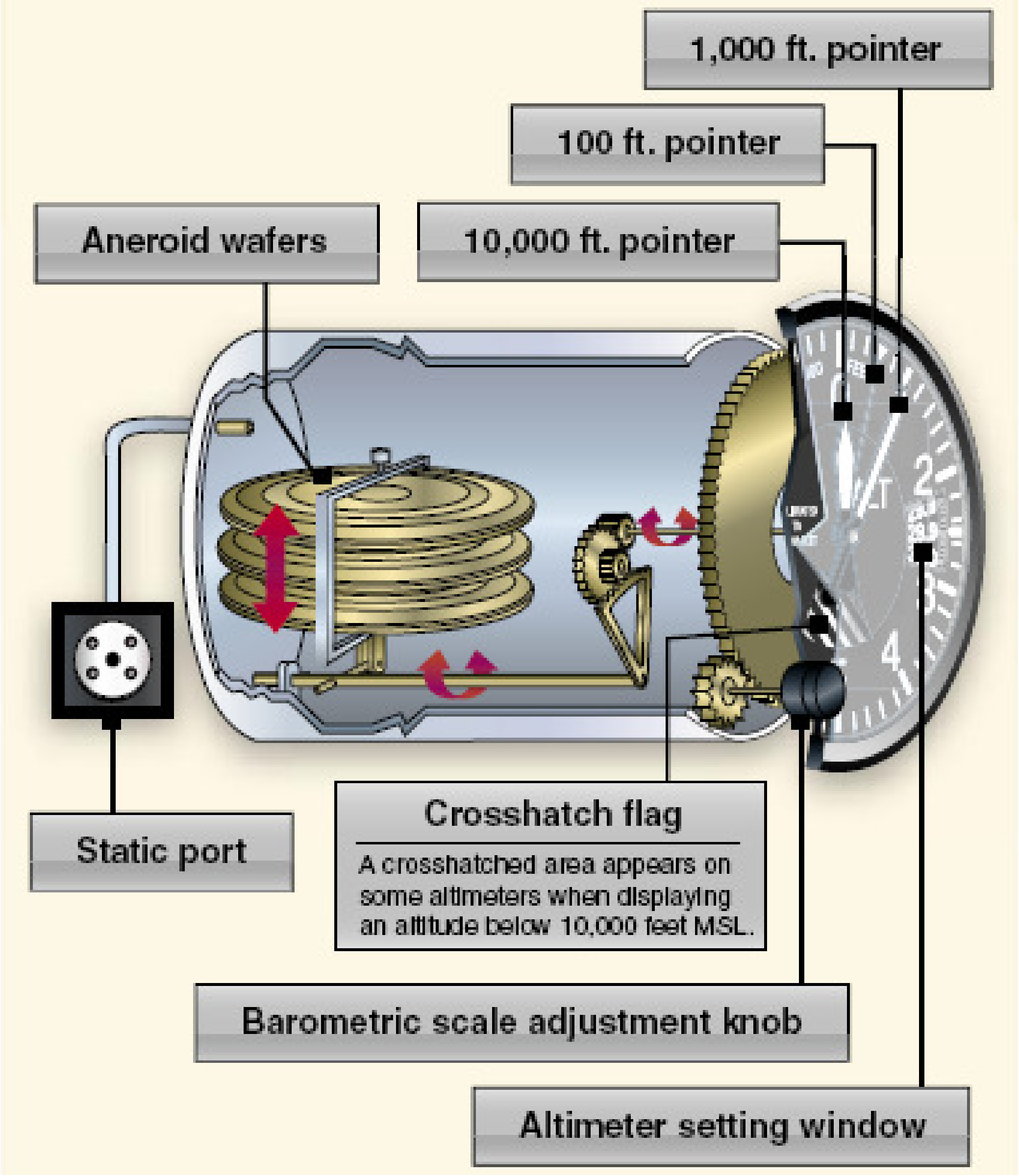
Airspeed Errors

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 airspeeds, resulting in higher than normal indications. “Usually” not a factor at low airspeed.

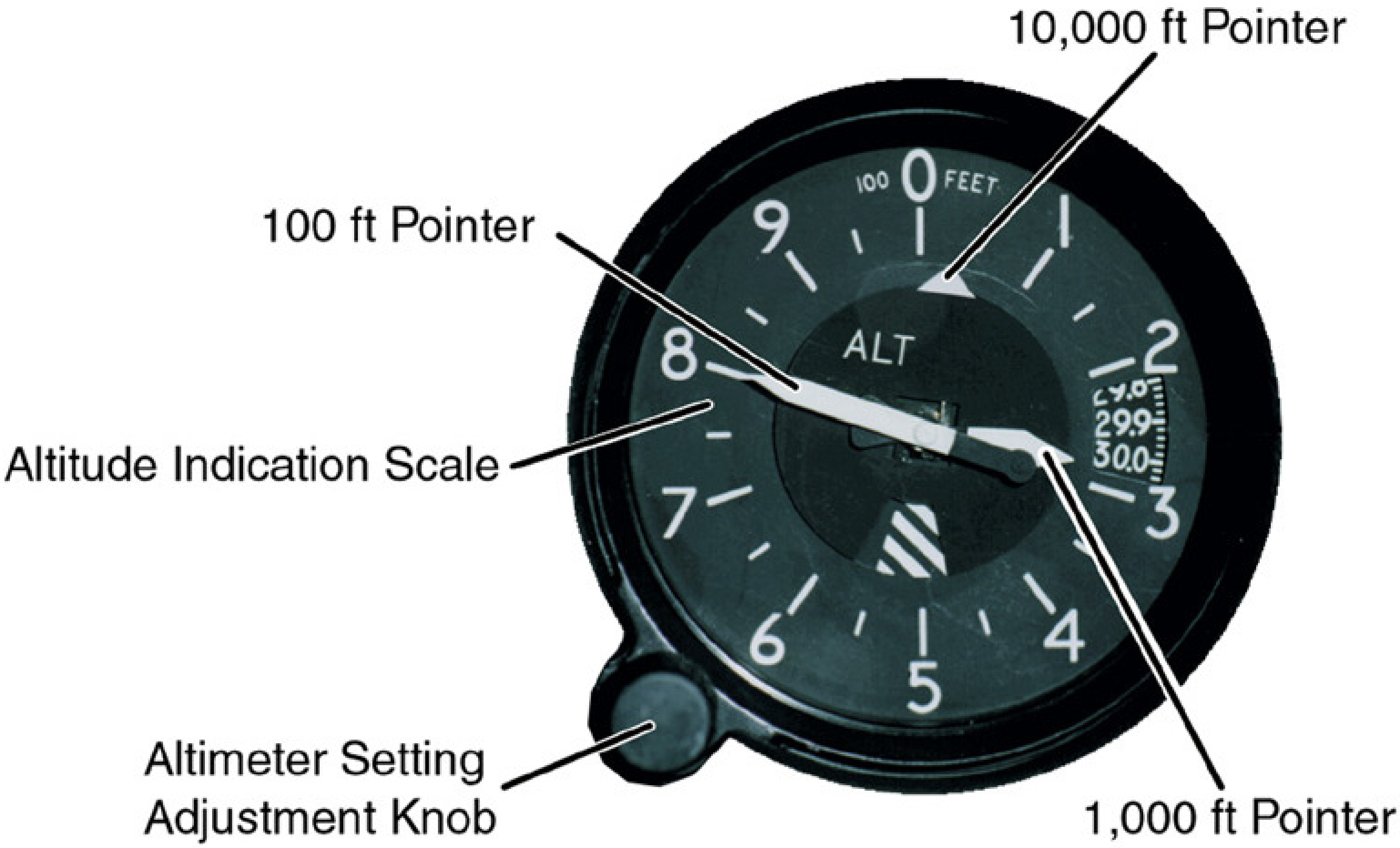
Pitot-Static System – ALTIMETER



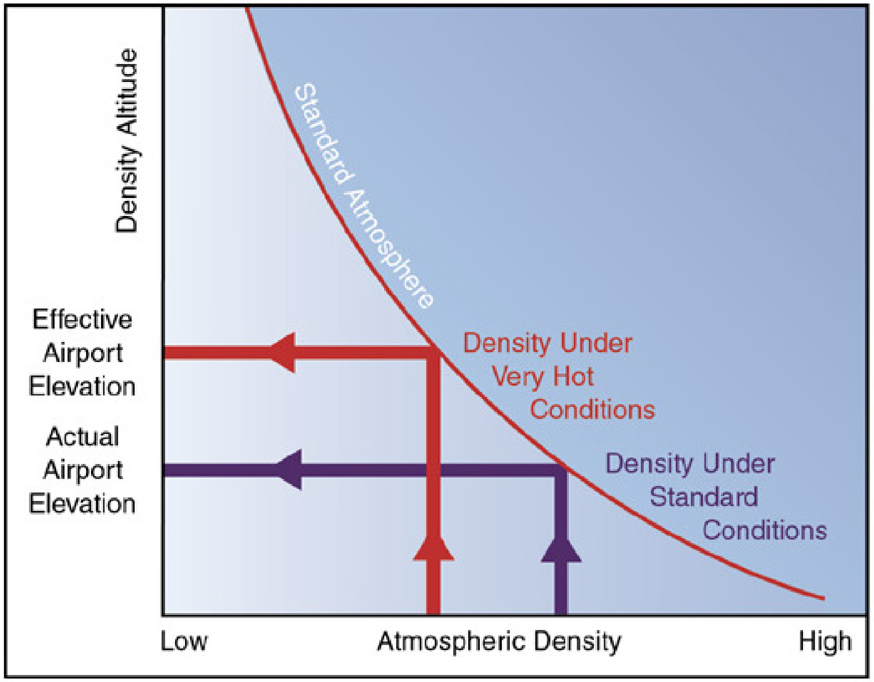
A crosshatched area appears on some altimeters when displaying an altitude below 10,000 feet MSL.

Created by Steve Reisser

Flight Instruments: Pitot-Static System – ALTIMETER



Flight Instruments: Pitot-Static System – 6 types of altitude



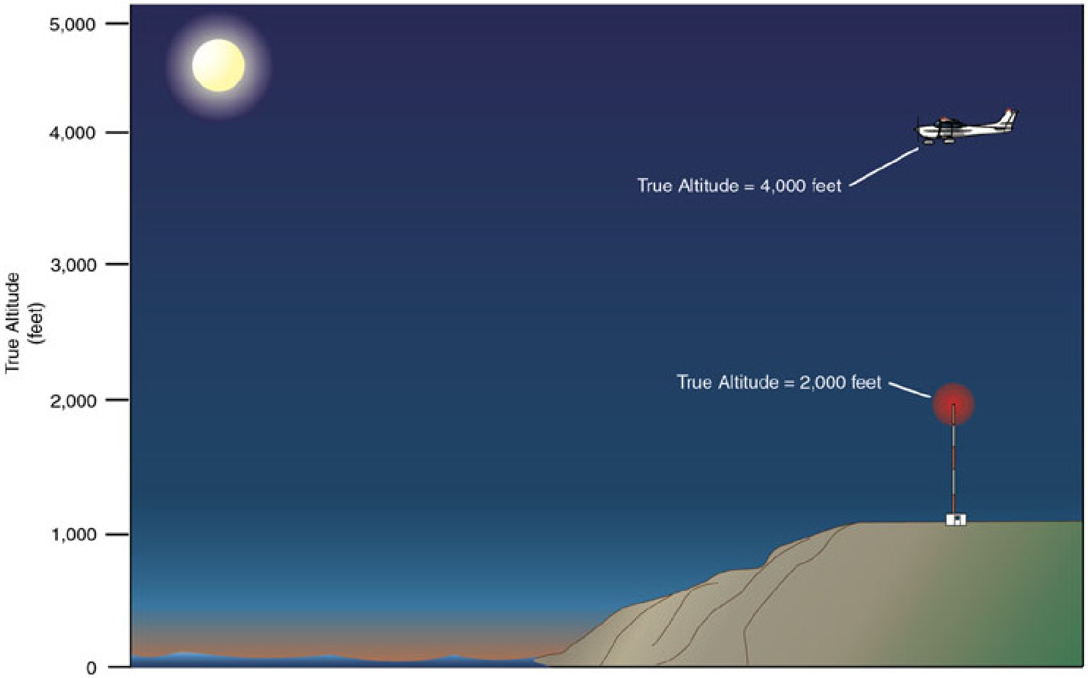
1. Indicated Altitude: Showing on altimeter

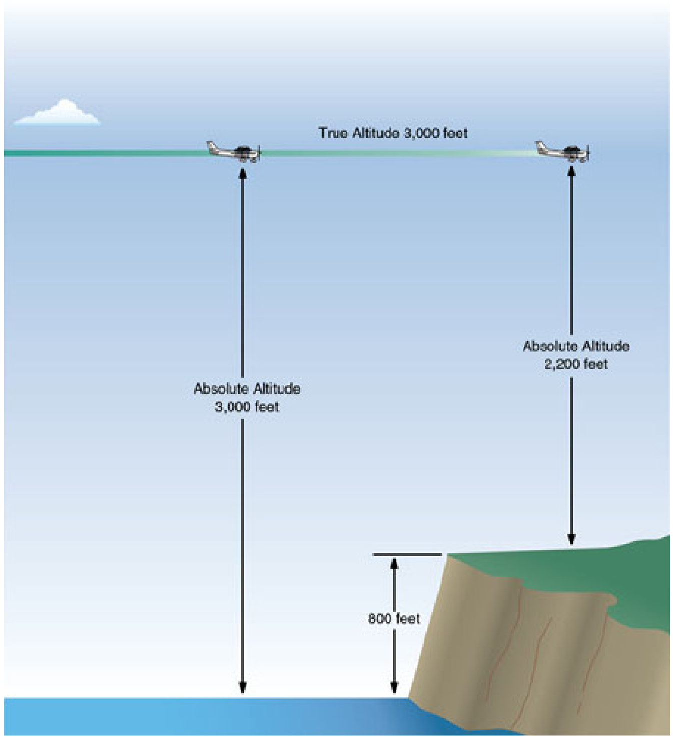
2. Pressure Altitude: Showing when set to standard pressure of 29.92" Formal definition is "the height above a standard datum plane (SDP),

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***.

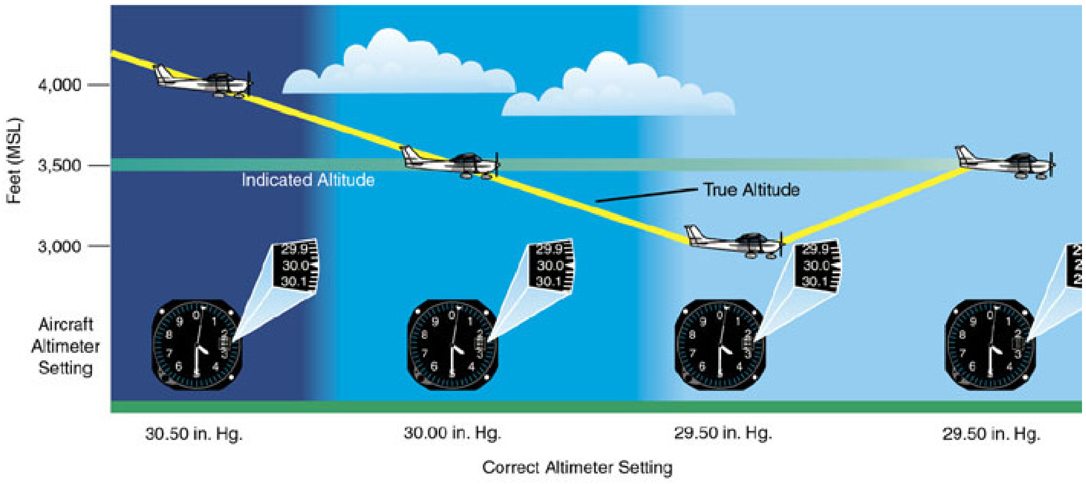
TEMPERATURE

On a Warm day: Pressure level is higher than on standard day – altimeter indicates ***lower than actual***.

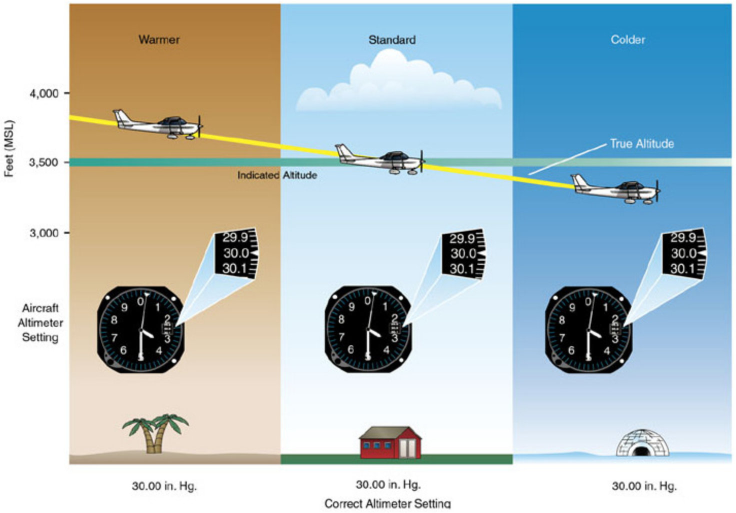
On a Cold day: Pressure level is lower than on a standard day – altimeter indicates ***higher than actual***.

Pitot-Static System

PRESSURE



TEMPERATURE



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.”

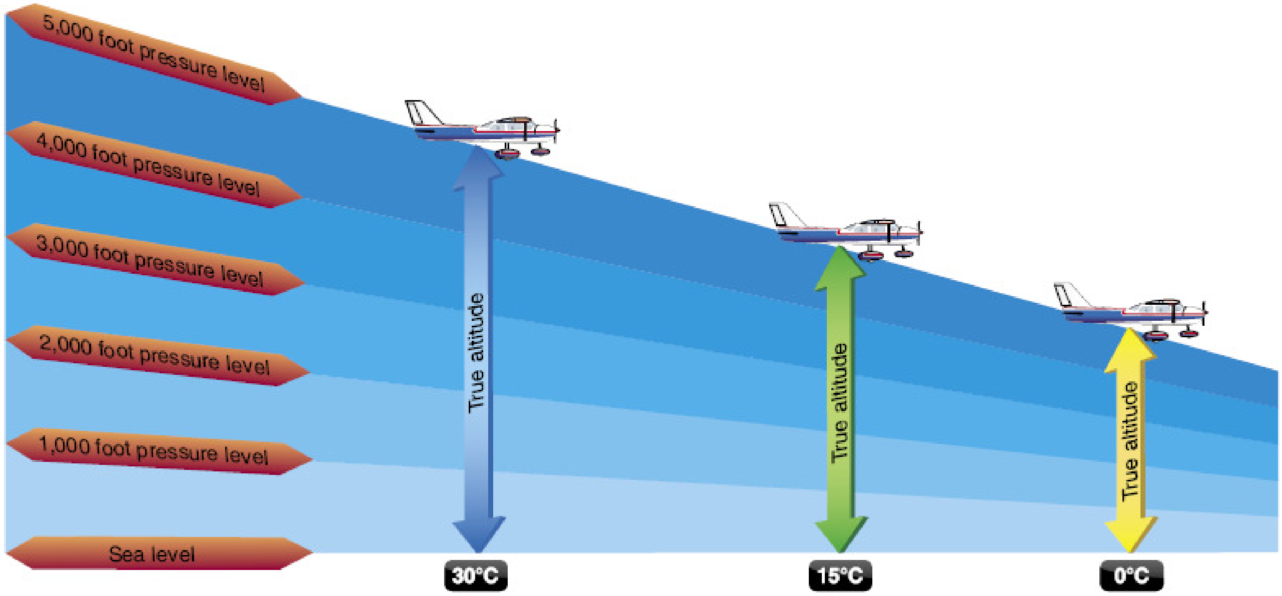
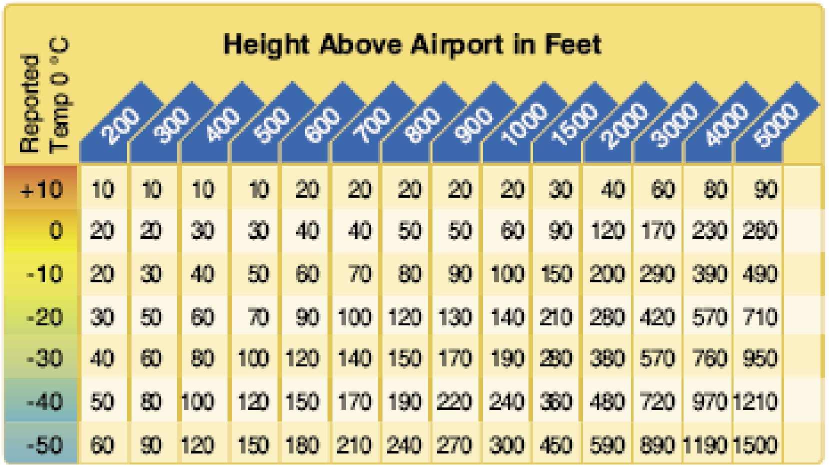


Figure 7-3. *Effects of nonstandard temperature on an altimeter.*



Reported Temp 0 °C	200	300	400	500	600	700	800	900	1000	1500	2000	3000	4000	5000
	Height Above Airport in Feet													
+10	10	10	10	10	20	20	20	20	20	30	40	60	80	90
0	20	20	30	30	40	40	50	50	60	90	120	170	230	280
-10	20	30	40	50	60	70	80	90	100	150	200	290	390	490
-20	30	50	60	70	90	100	120	130	140	210	280	420	570	710
-30	40	60	80	100	120	140	150	170	190	280	380	570	760	950
-40	50	80	100	120	150	170	190	220	240	360	480	720	970	1210
-50	60	90	120	150	180	210	240	270	300	450	590	890	1190	1500

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.*

Altimeter Check

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. <u>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</u>.

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.

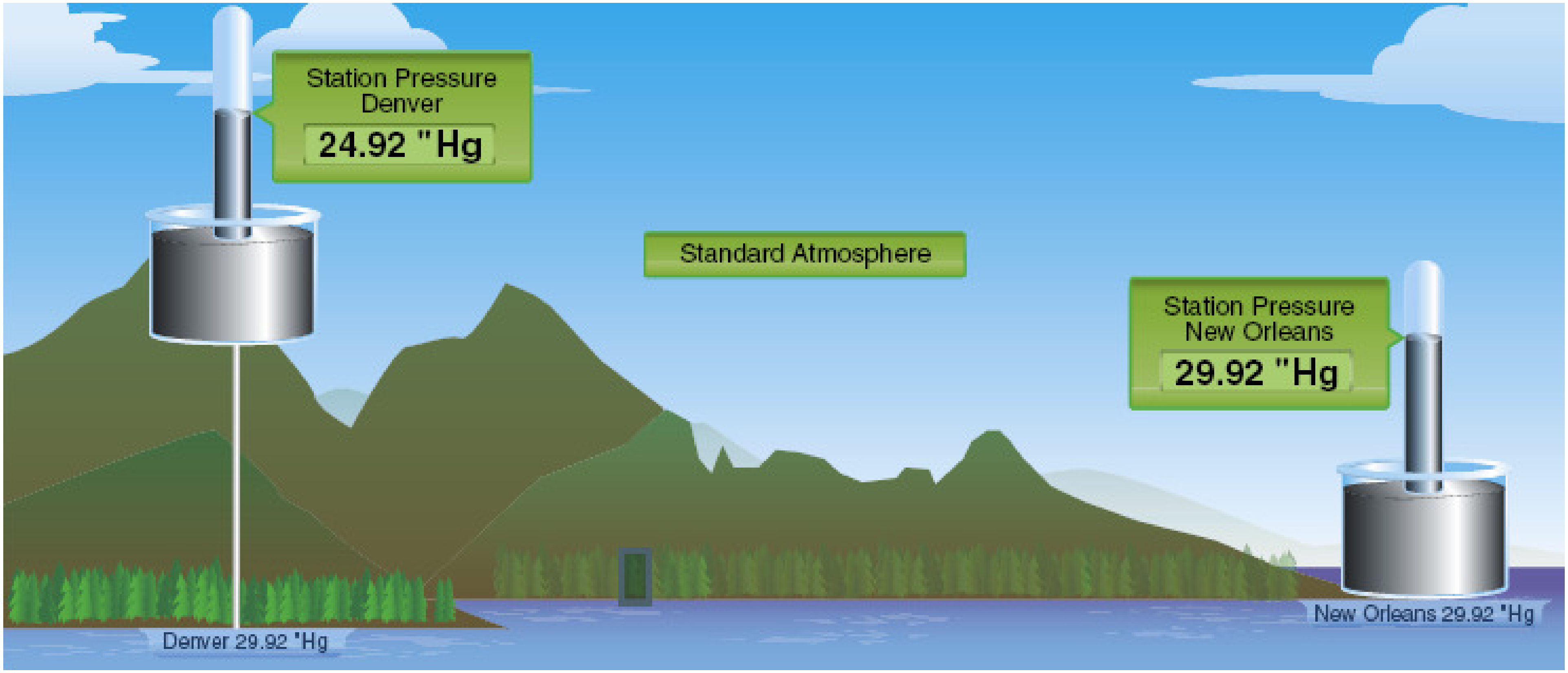
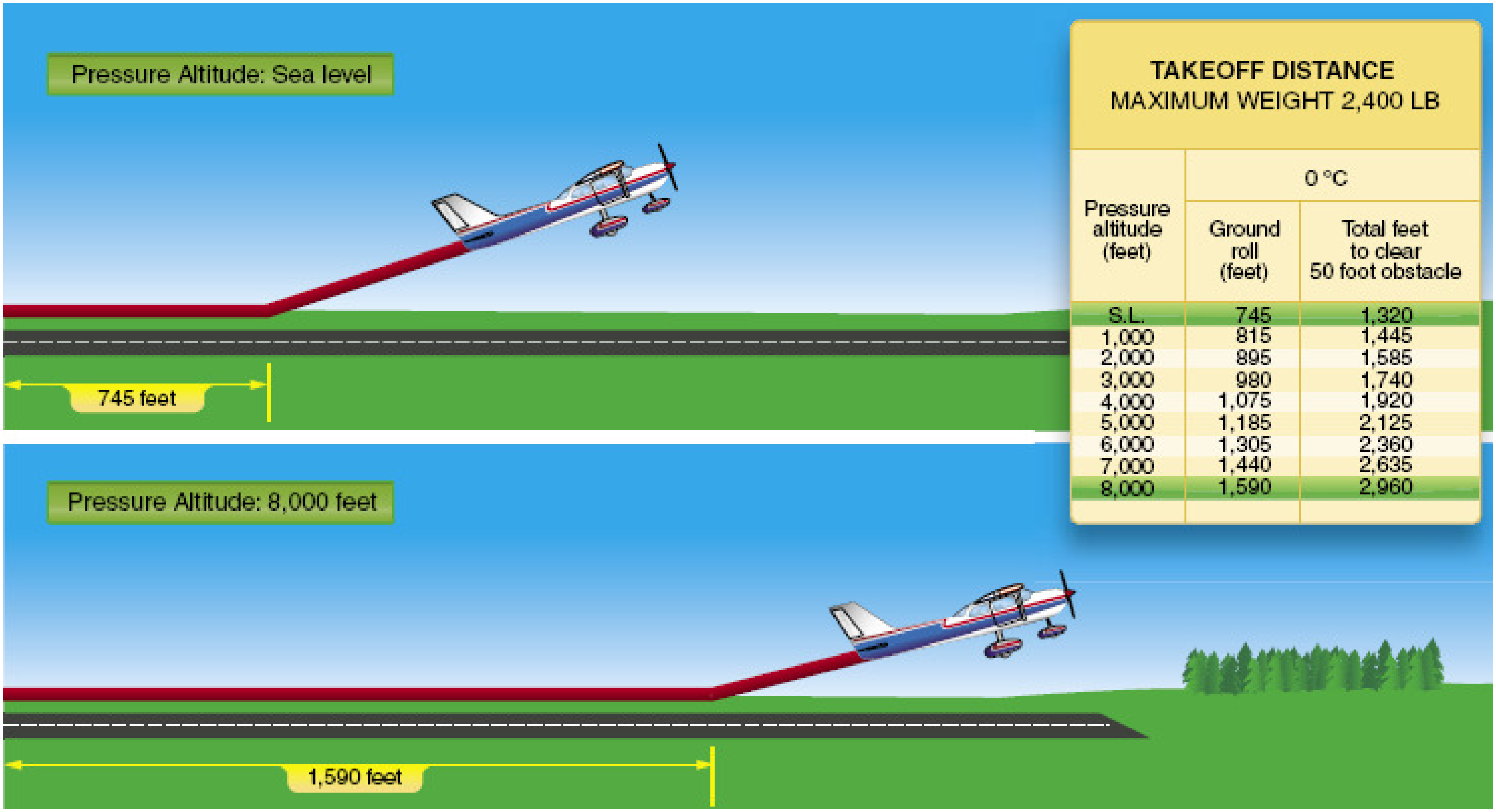


Figure 11-8. *Station pressure is converted to and reported in sea level pressure.*

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.

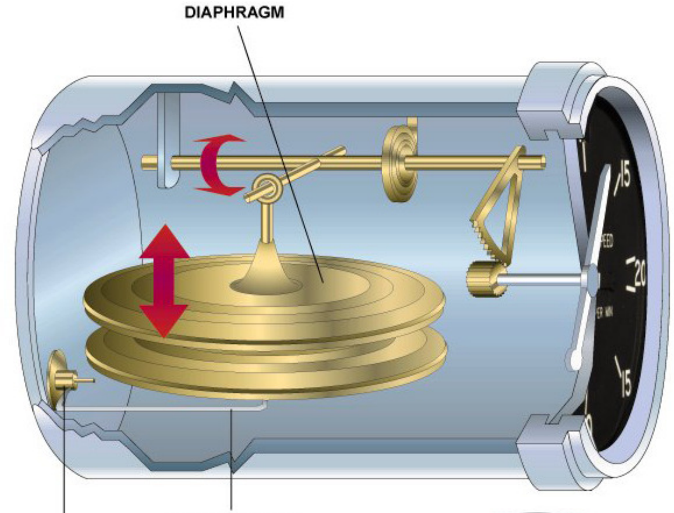
When an aircraft takes off, lift must be developed by the flow of air around the wings. If the air is thin, more speed is required to obtain enough lift for takeoff; therefore, the ground run is longer. An aircraft that requires 745 feet of ground run at sea level requires more than double that at a 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.



TAKEOFF DISTANCE
MAXIMUM WEIGHT 2,400 LB

Pressure altitude (feet)	0 °C	
	Ground roll (feet)	Total feet to clear 50 foot obstacle
S.L.	745	1,320
1,000	815	1,445
2,000	895	1,585
3,000	980	1,740
4,000	1,075	1,920
5,000	1,185	2,125
6,000	1,305	2,360
7,000	1,440	2,635
8,000	1,590	2,960

Flight Instruments: Pitot-Static System – Vertical Speed Indicator (VSI)



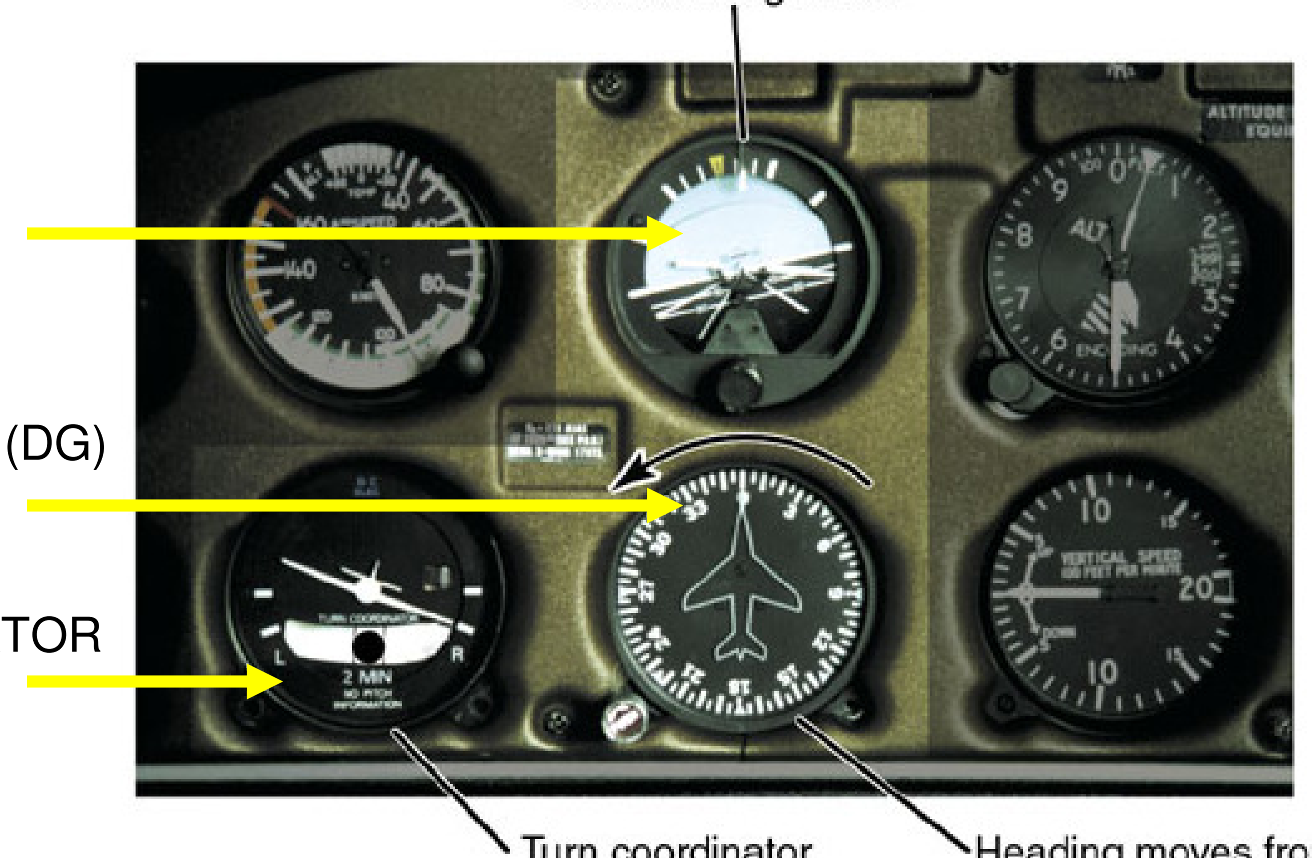
TREND INFORMATION ON CHANGE IN VERTICAL SPEED (rate of descent or climb in hundreds of feet per minute). Indicator not accurate until aircraft stabilized. There is a 6-9 second lag for stable pressure to give accurate reading. DON'T CHASE IT…

Flight Instruments: Gyroscopic

ATTITUDE
INDICATOR

HEADING
INDICATOR (DG)

TURN
COORDINATOR



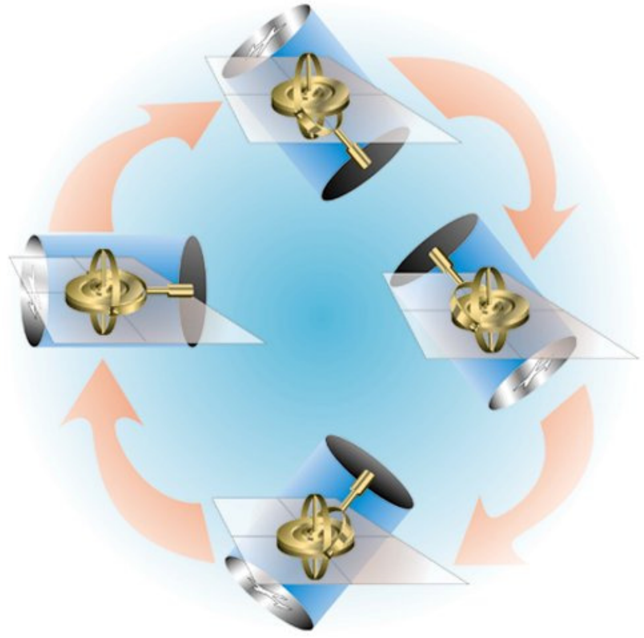
Attitude indicator
shows a right turn

Turn coordinator
indicates a right turn

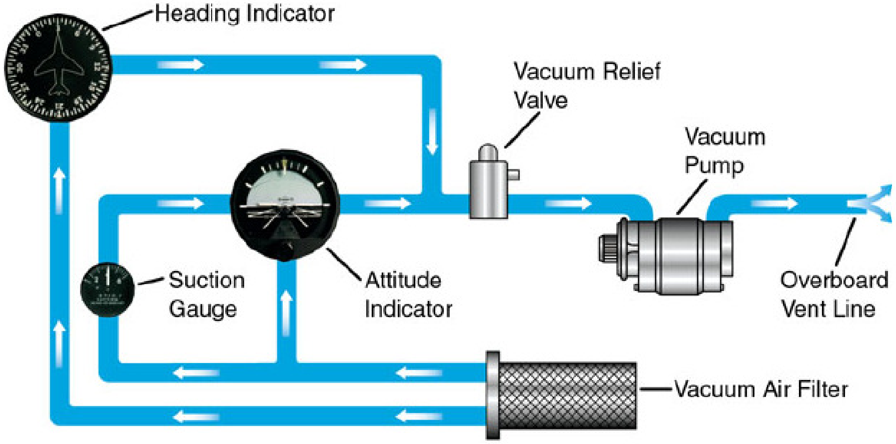
Heading moves from
northerly to easterly direction
indicating a right turn

Flight Instruments: Gyroscopic Principles – Rigidity in Space and Precession

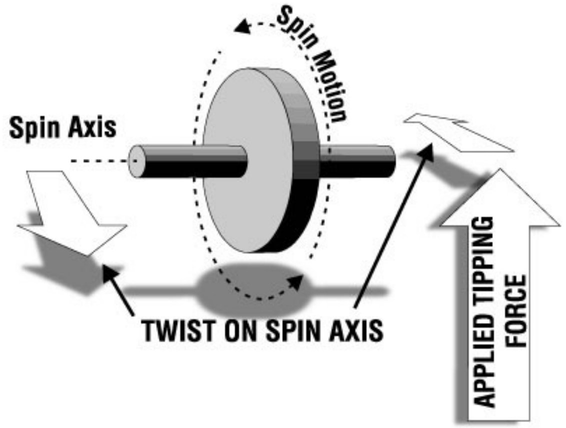
Rigidity: Tendency to remain in a constant position no mater what the orientation.



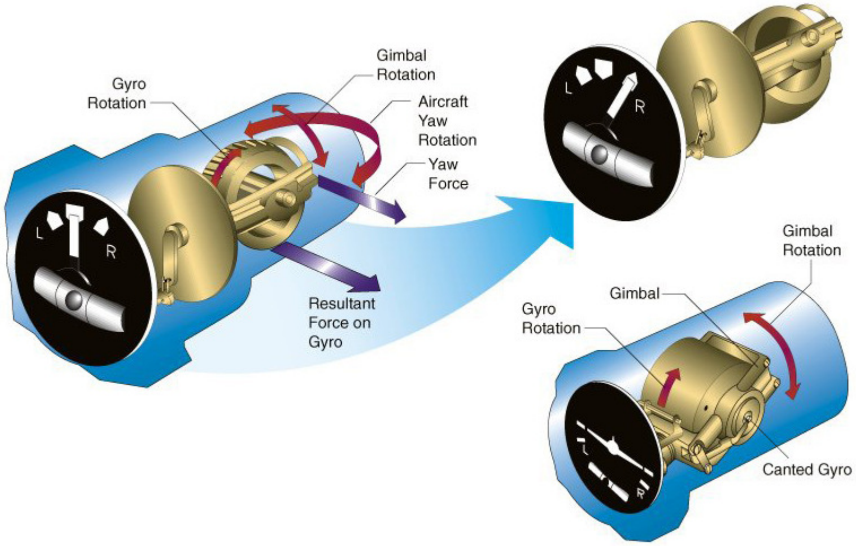
Powered by electrically driven **VACUUM** system



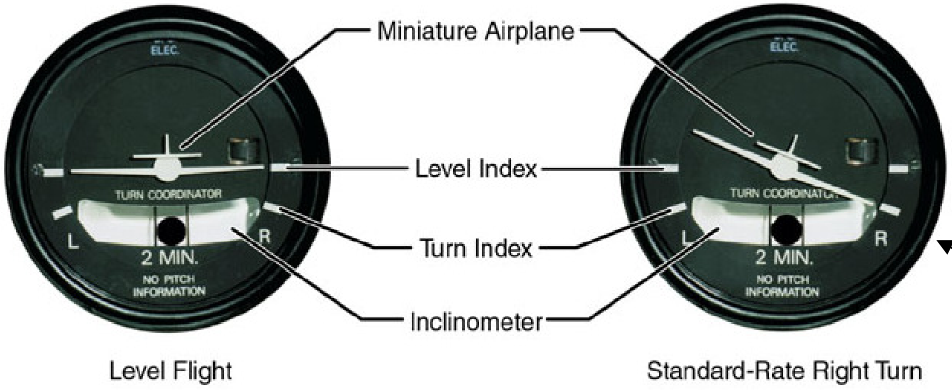
Precession: Small forces applied to a gyro will cause a resultant 90 degree force that is Inversely proportional to the speed of the rotor and proportional to the deflective force.



Flight Instruments: Gyroscopic
TURN COORDINATOR



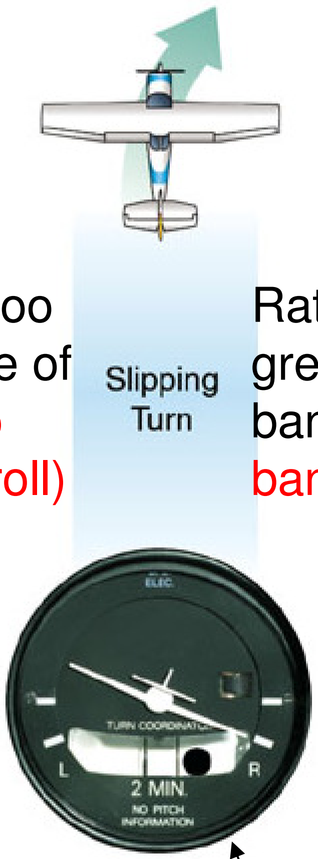
Gyro driven by electrical or vacuum (pressure)



Standard rate turn-2 minutes

Flight Instruments: Gyroscopic
TURN COORDINATOR

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

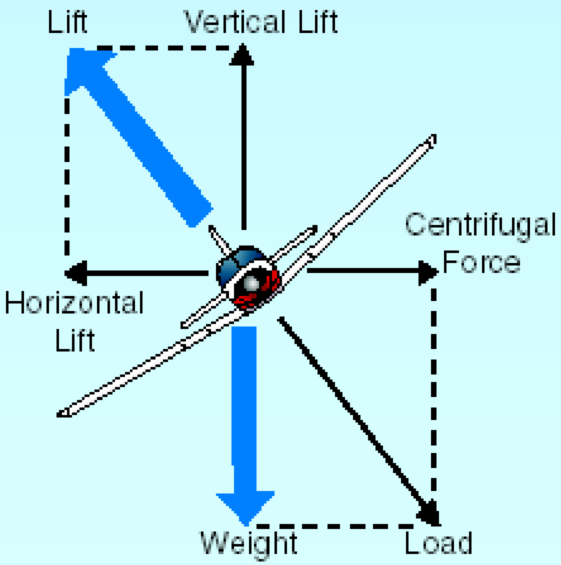


Rate of turn too great for angle of bank. ☹ Too little bank (roll)

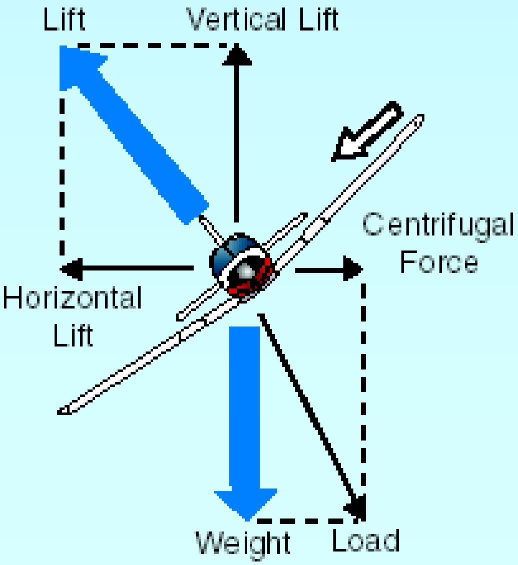
Rate of turn and angle of bank just right ☺

Vary rate of turn or “Step On the Ball”

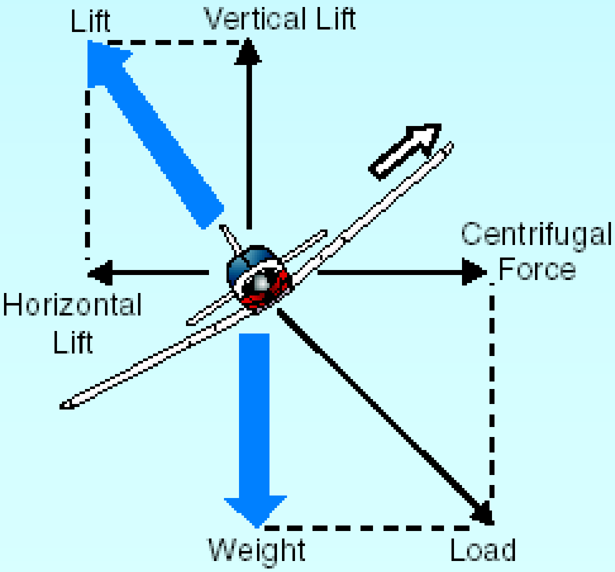
AERODYNAMICS OF SLIPS AND SKID



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)

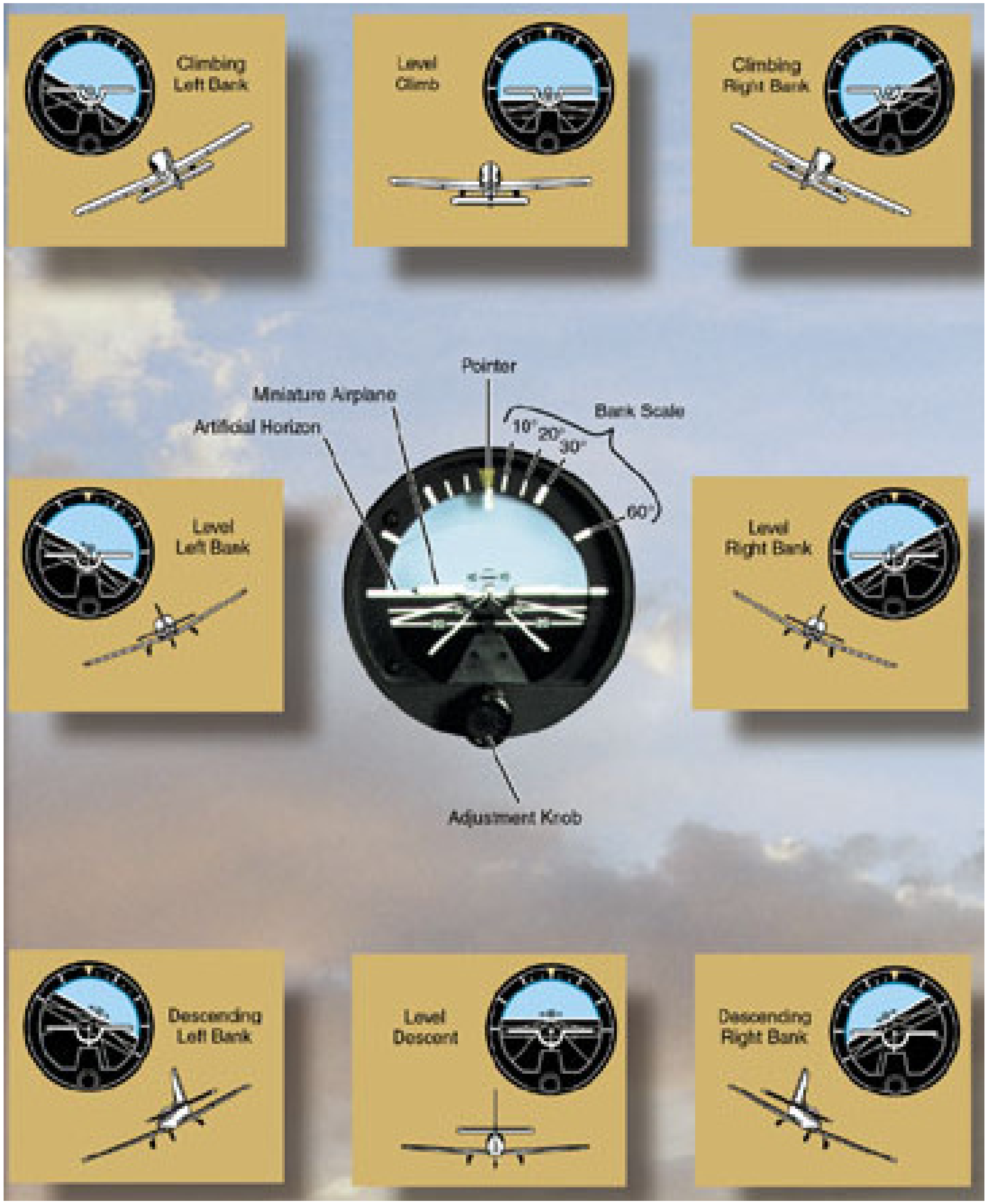
Standard Rate Turns

- 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

Airspeed / 10 * 1.5

TAS 80/10 = 8*1.5= 12 degrees
TAS 100 /10 = 10*1.5= 15 degrees
TAS 120 /10 = 12*1.5= 18 degrees
TAS 160 /10 = 16*1.5= 24 degrees

ATTITUDE INDICATOR



Flight Instruments: Gyroscopic Attitude Indicator Mechanics

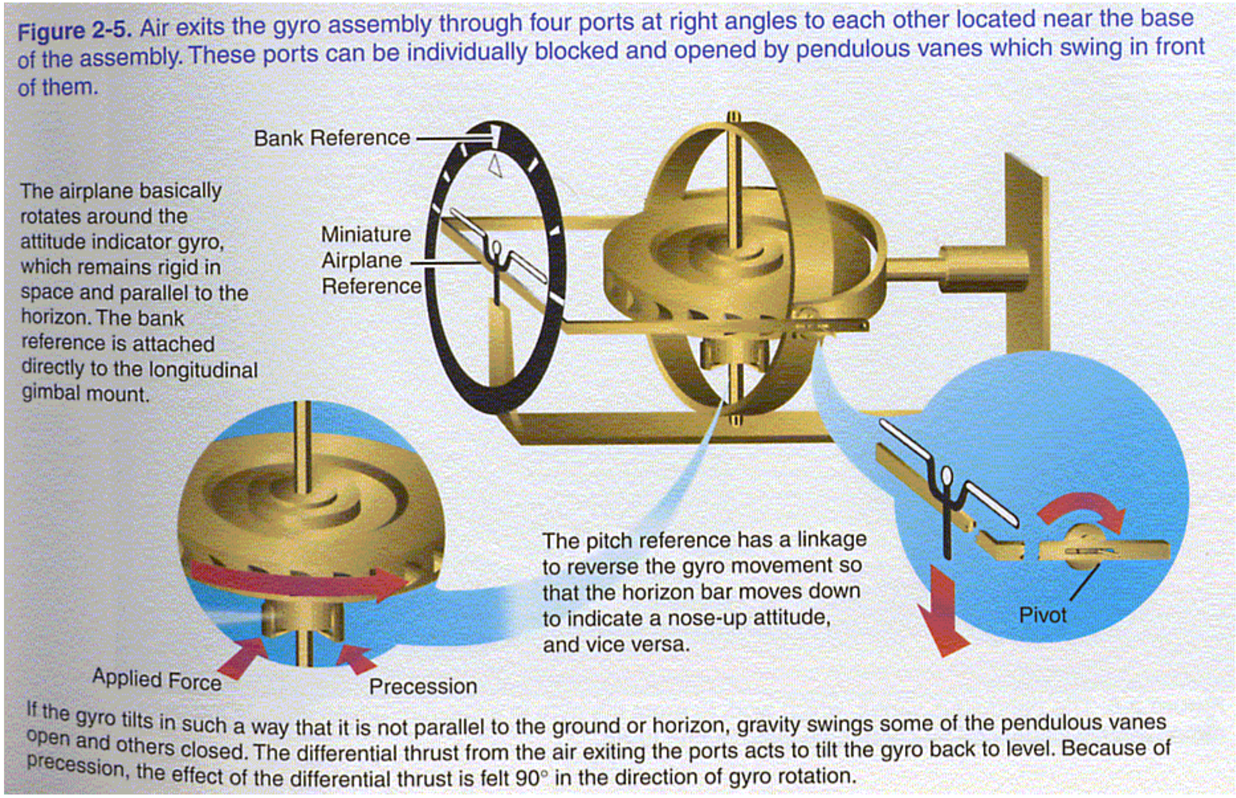


Figure 2-5. Air exits the gyro assembly through four ports at right angles to each other located near the base of the assembly. These ports can be individually blocked and opened by pendulous vanes which swing in front of them.

The airplane basically rotates around the attitude indicator gyro, which remains rigid in space and parallel to the horizon. The bank reference is attached directly to the longitudinal gimbal mount.

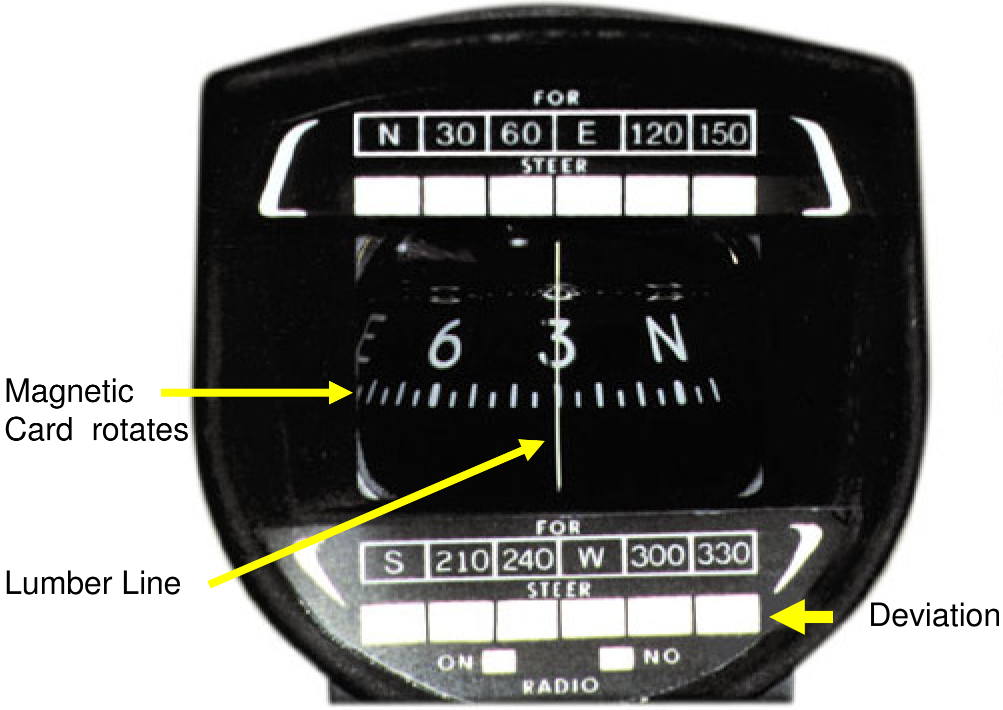
The pitch reference has a linkage to reverse the gyro movement so that the horizon bar moves down to indicate a nose-up attitude, and vice versa.

If the gyro tilts in such a way that it is not parallel to the ground or horizon, gravity swings some of the pendulous vanes open and others closed. The differential thrust from the air exiting the ports acts to tilt the gyro back to level. Because of precession, the effect of the differential thrust is felt 90° in the direction of gyro rotation.

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



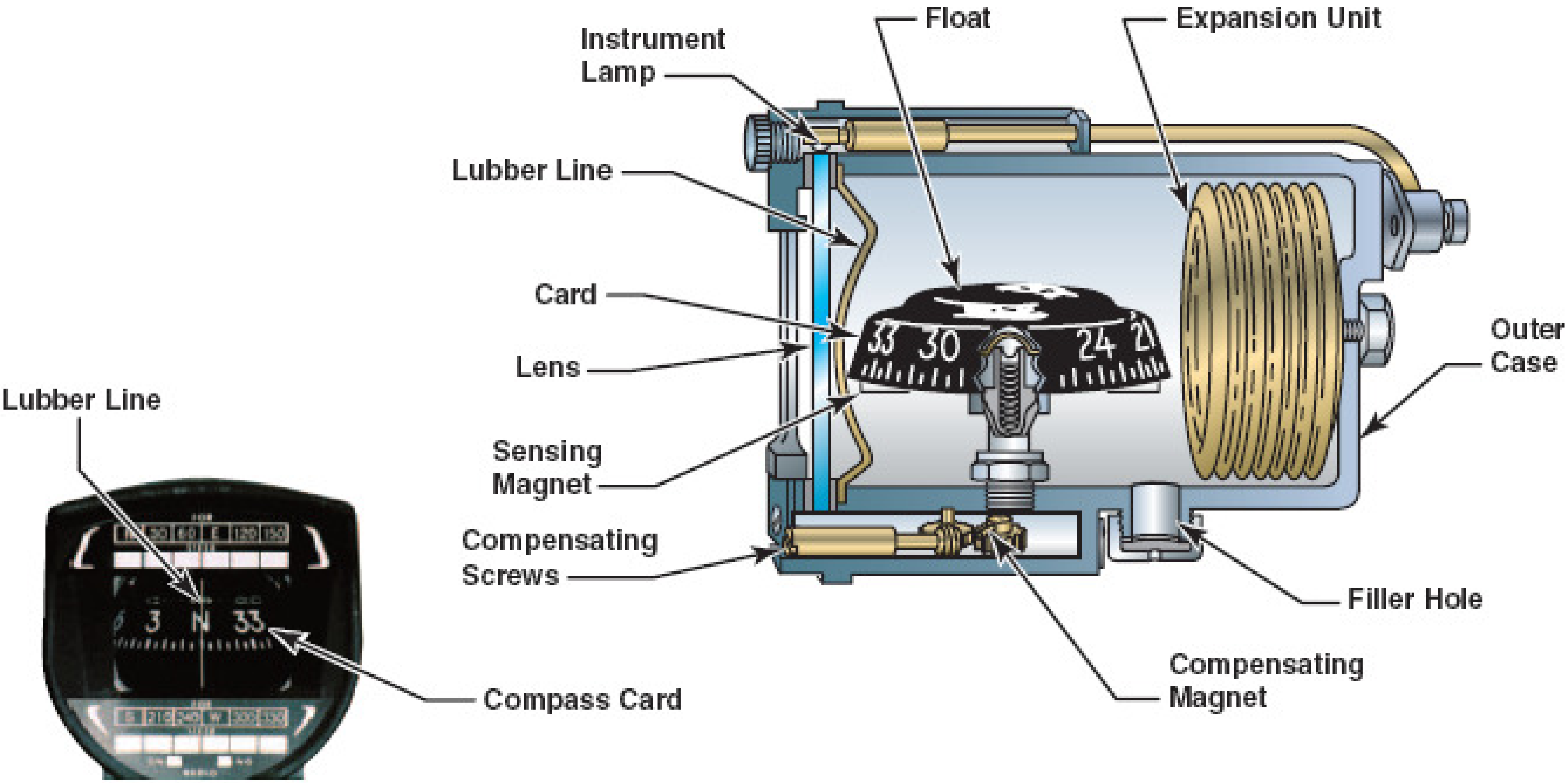
NON-GYROSCOPIC: **Magnetic Compass**. Accurate in **straight and level, non-accelerated flight.**

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

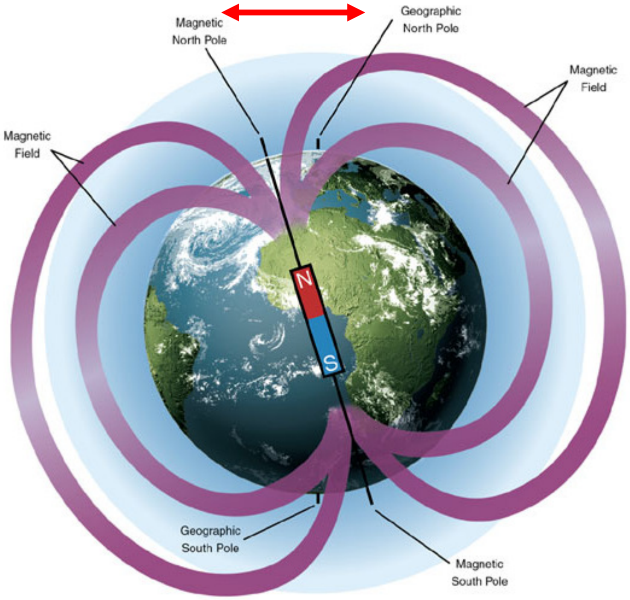


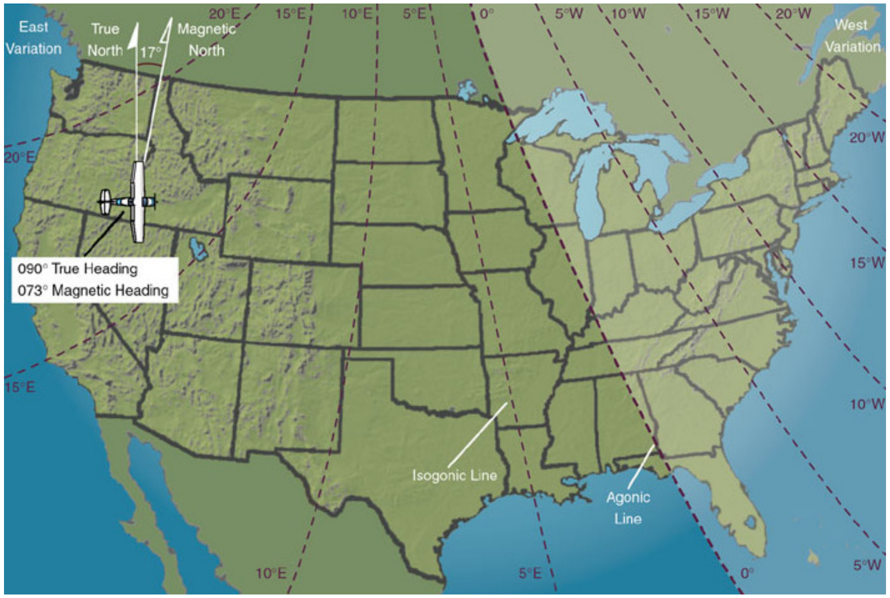
Floats in a solution of white kerosene

Flight Instruments:

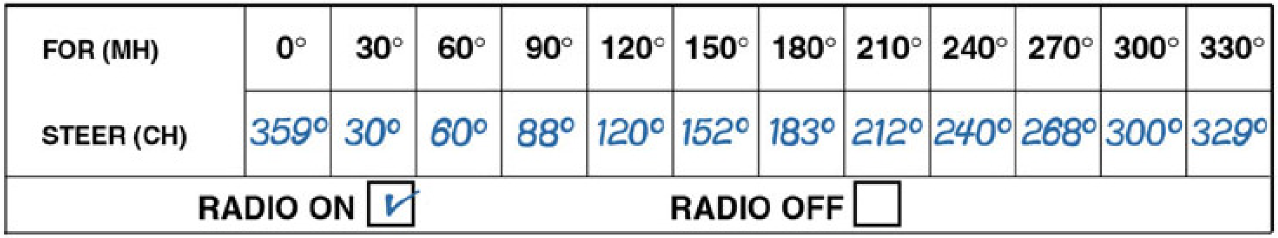
Magnetic Variation & Deviation

Variation: difference in True North and Magnetic North





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



FOR (MH)	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°
STEER (CH)	359°	30°	60°	88°	120°	152°	183°	212°	240°	268°	300°	329°

RADIO ON ☑ RADIO OFF ☐

Flight Instruments: **Magnetic Compass Errors**

Variation, Deviation, Oscillation

Variation: Difference in Magnetic / True North
Deviation: Electrical interference from aircraft
Oscillation: Rough handling or turbulence

Magnetic dip

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.

Acceleration - Deceleration

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

Turning Errors

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

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

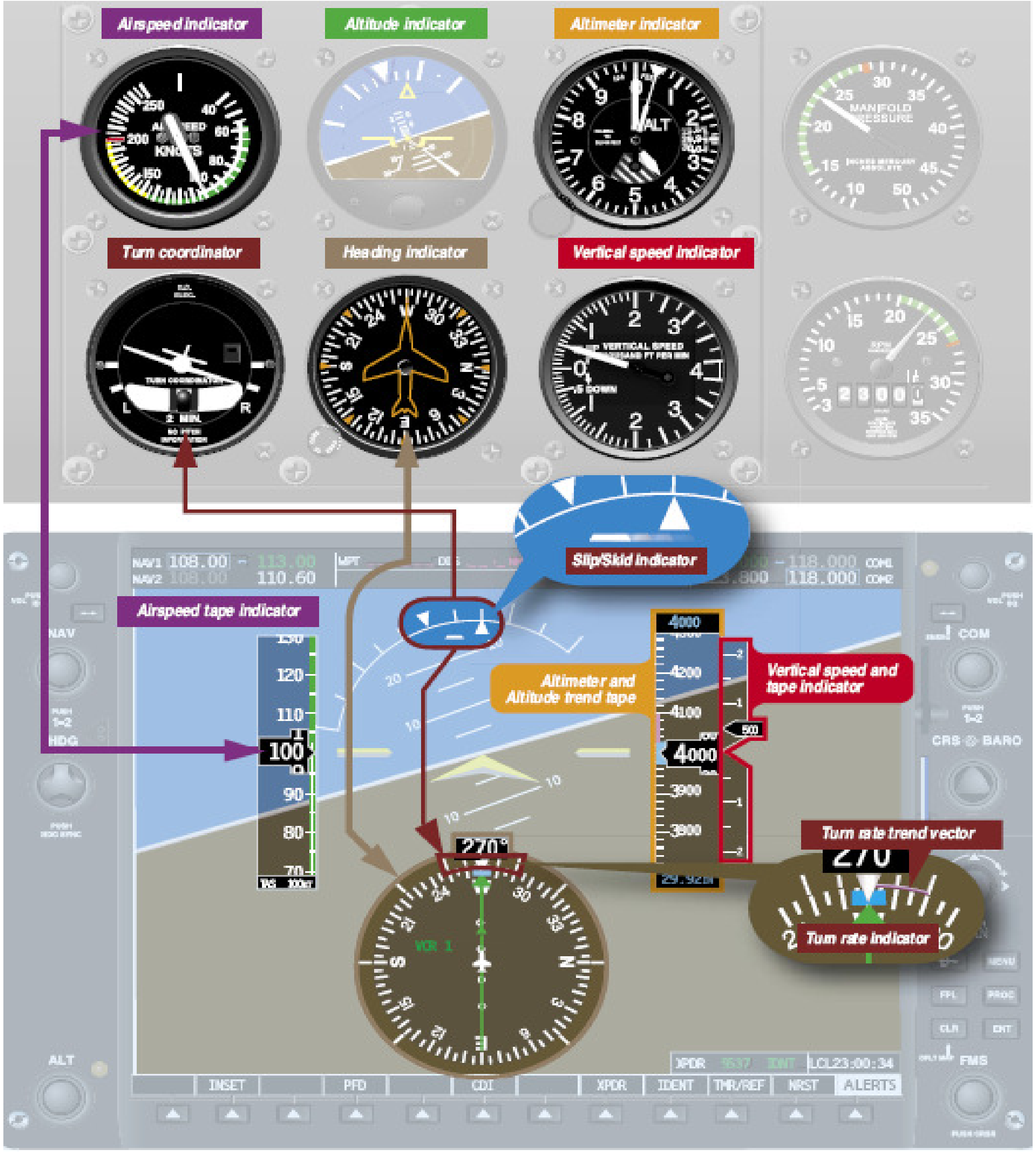
Instrumentation changes are in process to digital based information and displays.

- 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)

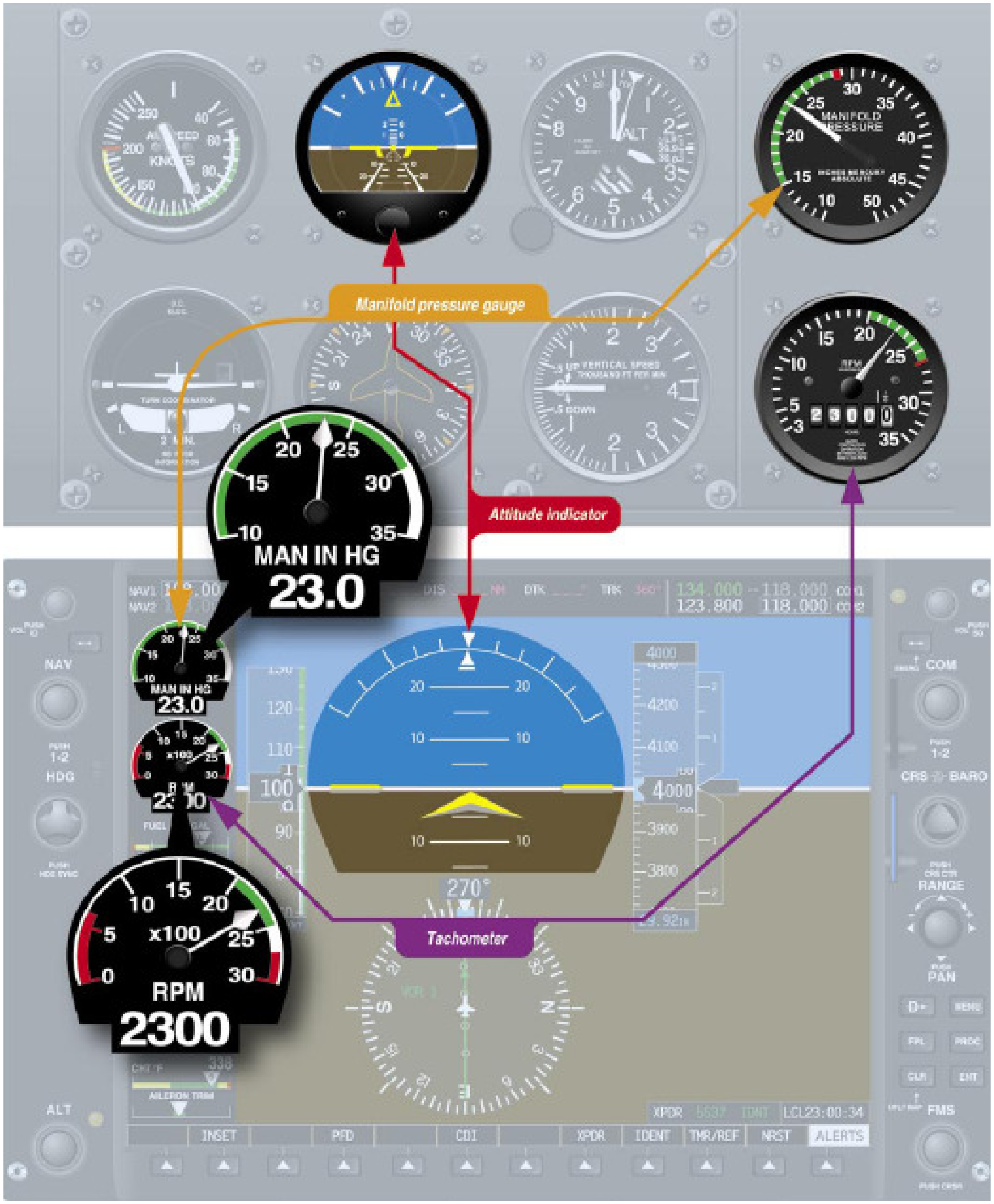
Example 1

“Six-pack”

Equivalent Digital



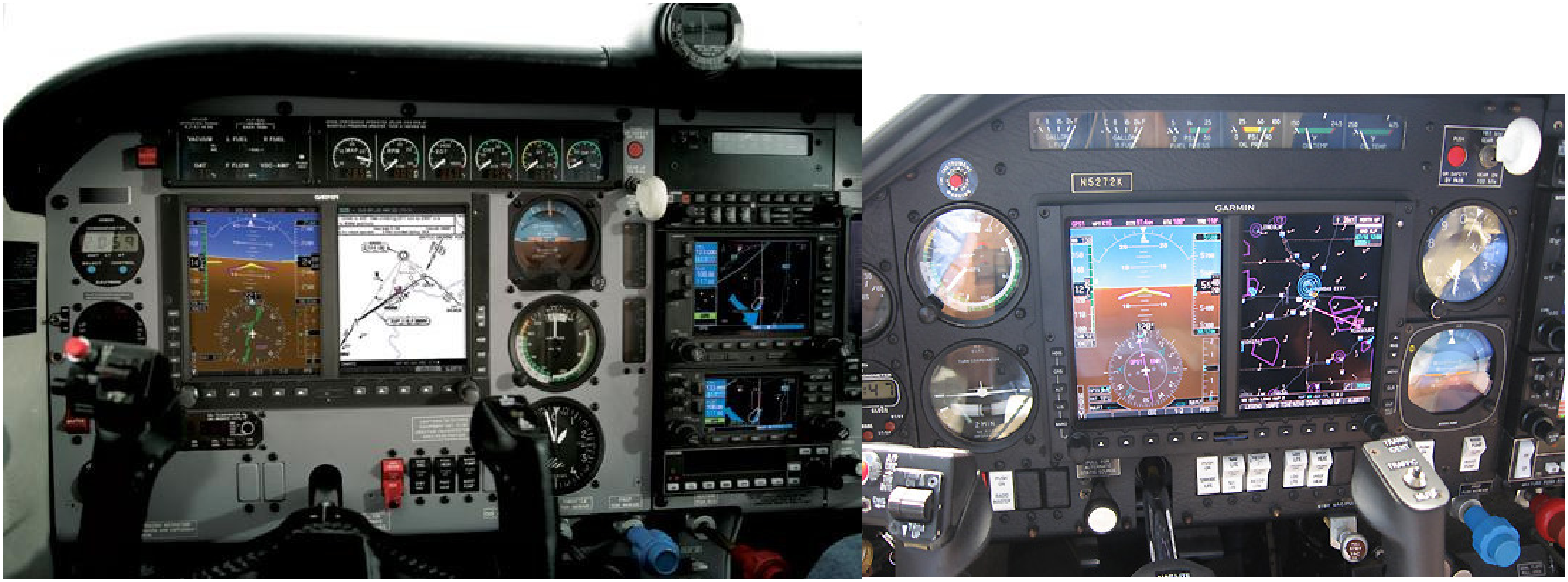
Example 2


Manifold pressure gauge
Attitude indicator
Tachometer
MAN IN HG
23.0
RPM
2300
x100

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

MSG In front of KOGD D

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

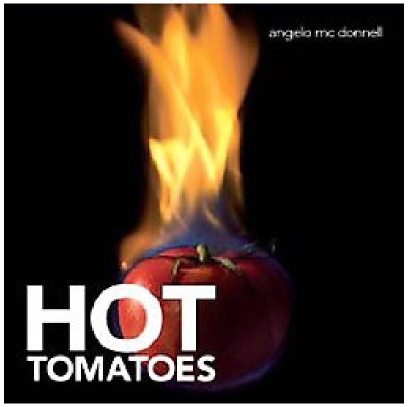
Airspeed Indicator

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 <u>night</u> <u>VFR</u>

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

Ground School 2011

Created by Steve Reisser

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.

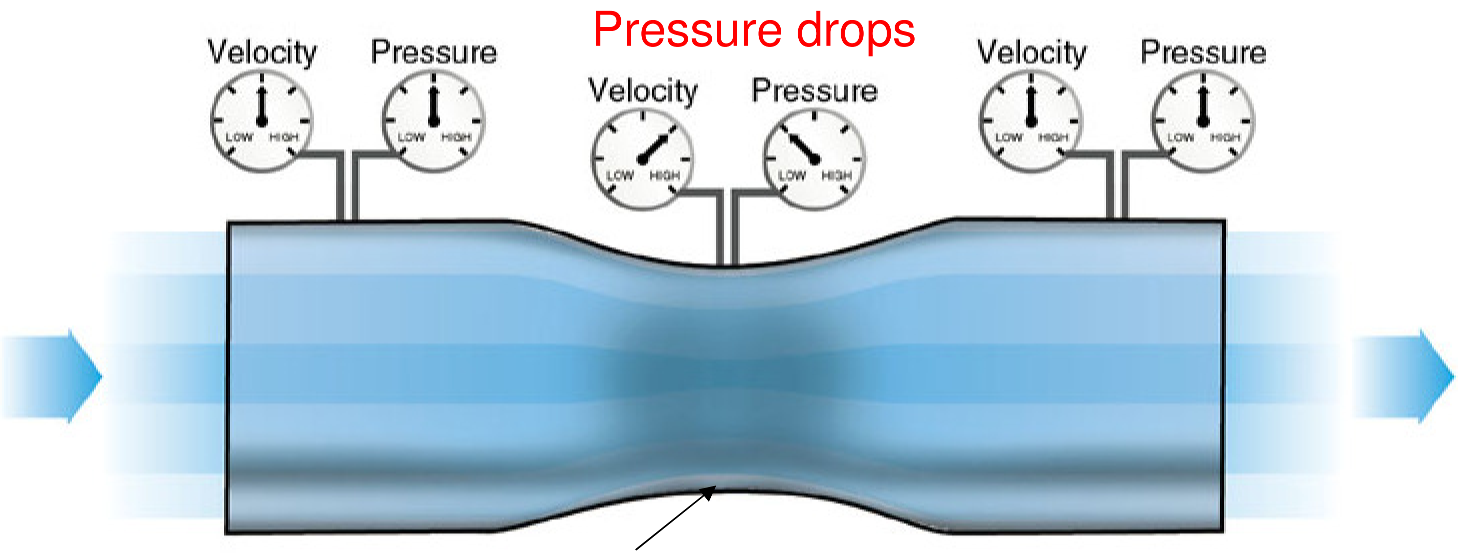
Aerodynamics: LIFT

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).



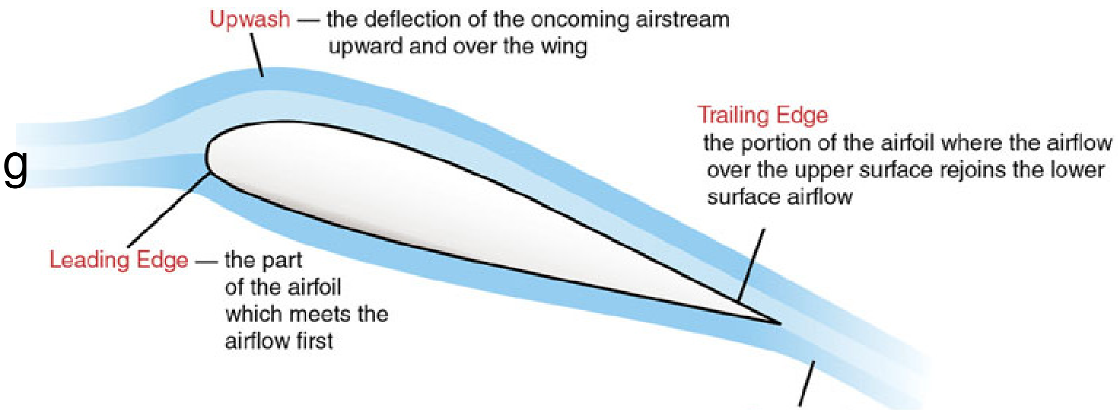
Pressure drops

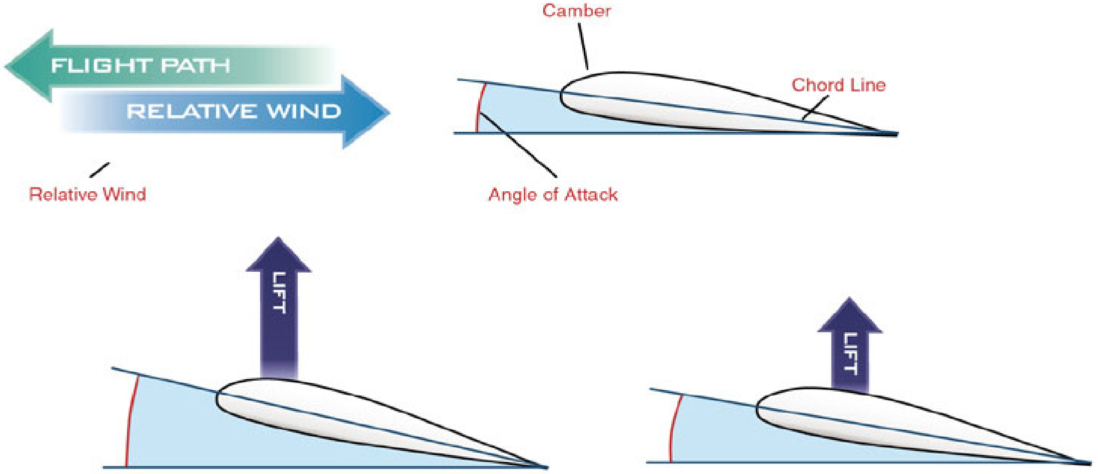
Shape (camber) of wing

Aerodynamics: LIFT

AIRFOILS

Airflow across wing



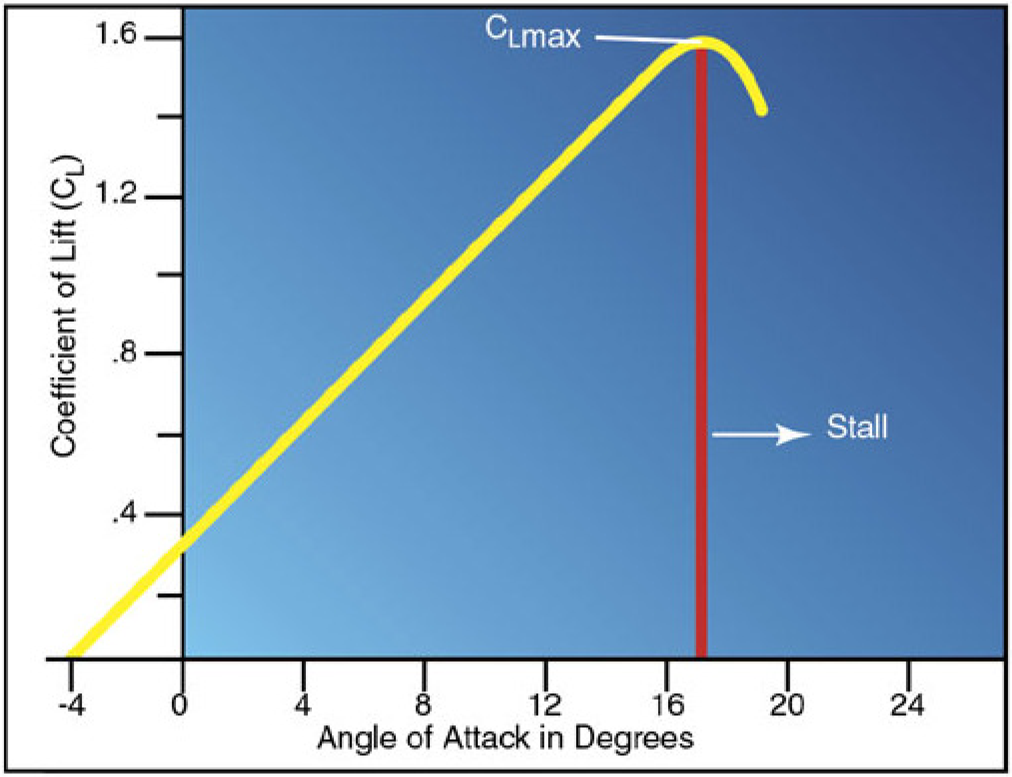


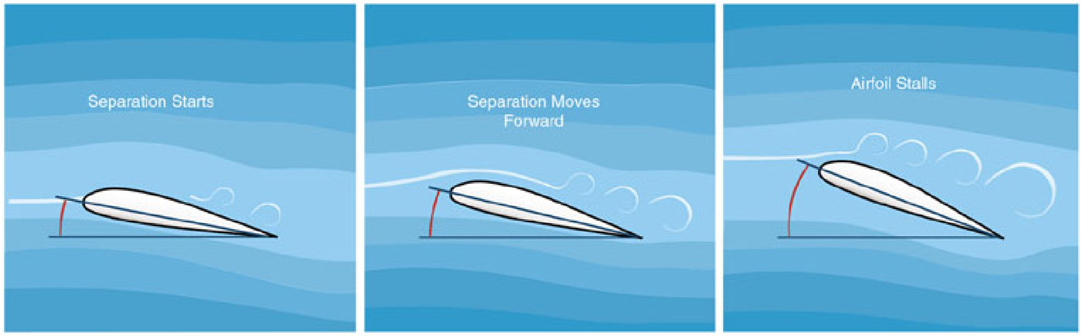
Anything that interferes with the flow of air over the surface of the wing negatively effects lift, such as frost (always clear). Cleaning, waxing helps !

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.”

Aerodynamics: LIFT

ANGLE OF ATTACK (AOA)



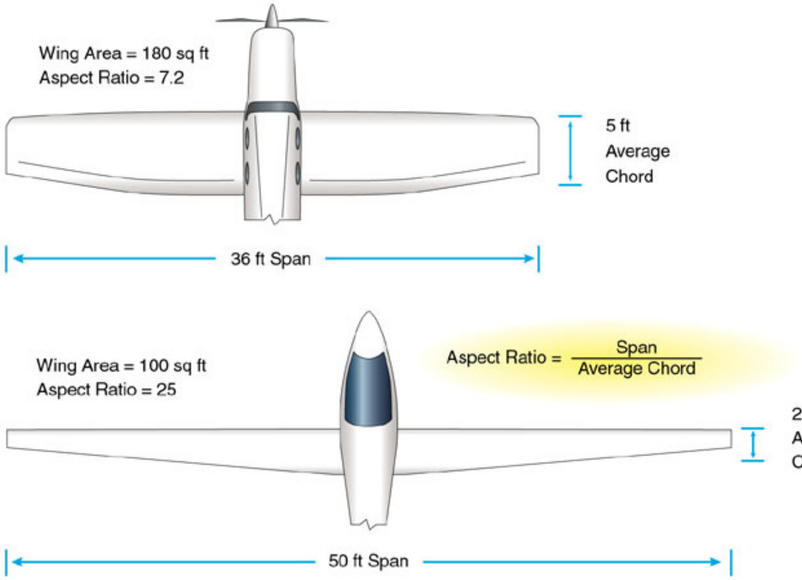


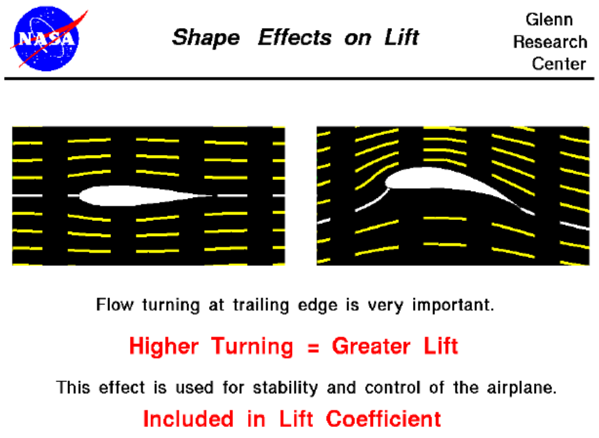
Created by Steve Reisser

Aerodynamics: LIFT

OTHER FACTORS

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





Shape Effects on Lift

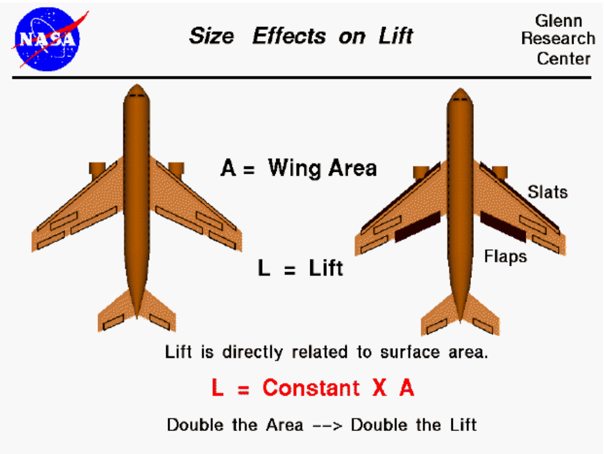
Glenn
Research
Center

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



Size Effects on Lift

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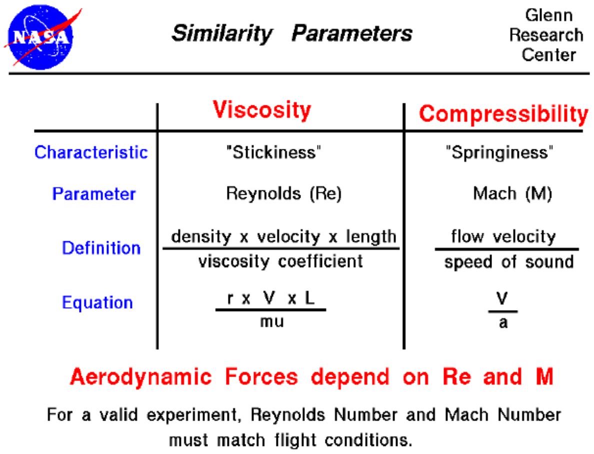
Lift is directly related to surface area.

L = Constant X A

Double the Area --> Double the Lift



Similarity Parameters

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	Viscosity	Compressibility
Characteristic	"Stickiness"	"Springiness"
Parameter	Reynolds (Re)	Mach (M)
Definition	$\frac{\text{density x velocity x length}}{\text{viscosity coefficient}}$	$\frac{\text{flow velocity}}{\text{speed of sound}}$
Equation	$\frac{\text{r x V x L}}{\text{mu}}$	$\frac{V}{a}$

Aerodynamic Forces depend on Re and M

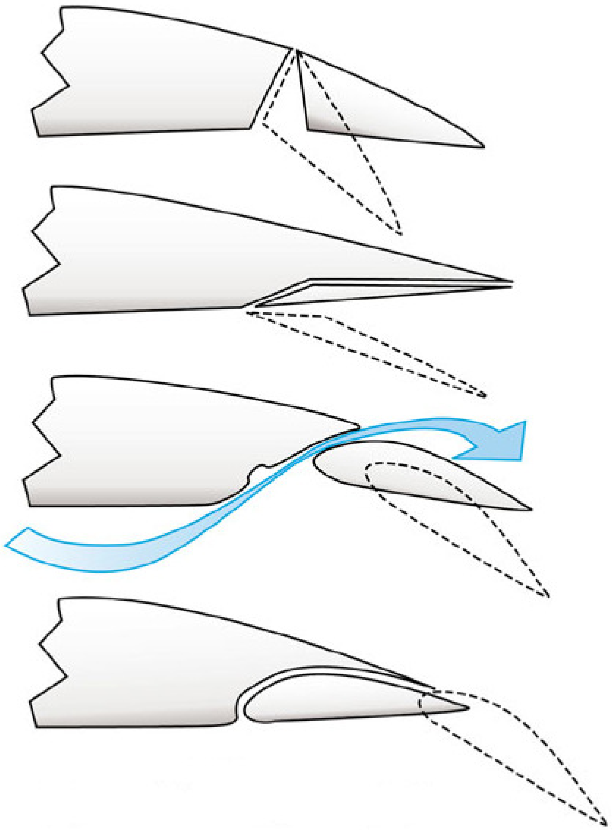
For a valid experiment, Reynolds Number and Mach Number must match flight conditions.

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

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

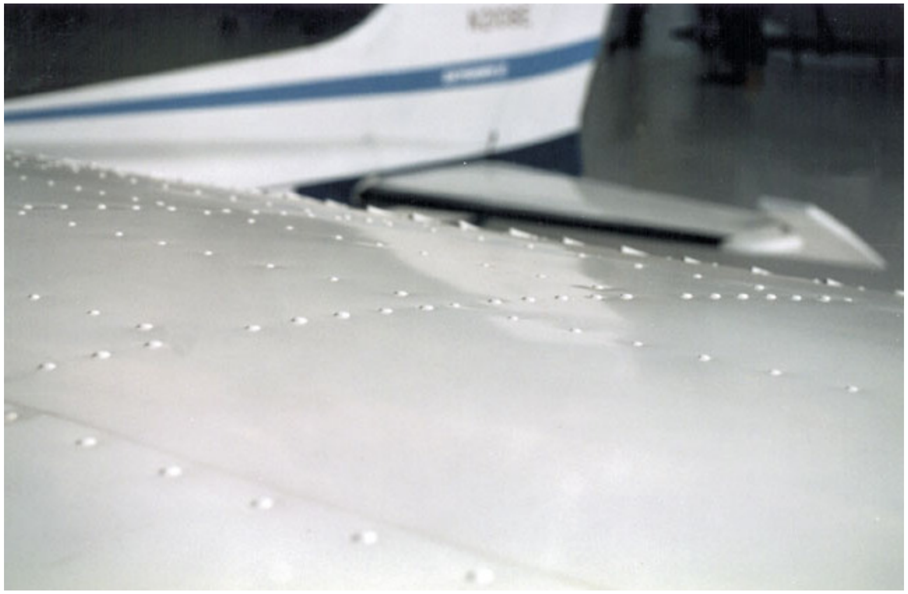
FOWLER-Most effective

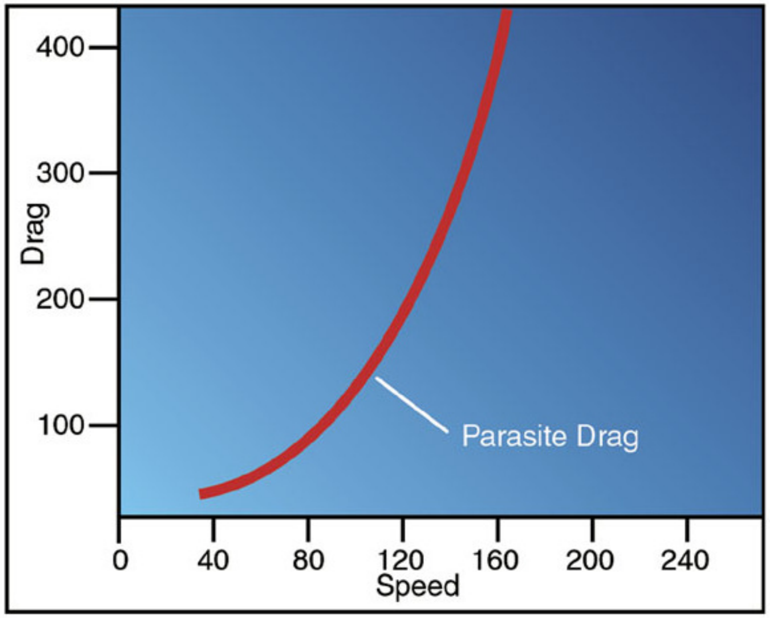
Aerodynamics: WEIGHT & THRUST & DRAG

WEIGHT – DOWNWARD FORCE OPPOSED BY LIFT

THRUST – FOREWARD FORCE OPPOSED BY DRAG

DRAG - BACKWARD (SLOWING) FORCE OPPOSED BY THRUST – FORM, INTERFERENCE, AND SKIN FRICTION

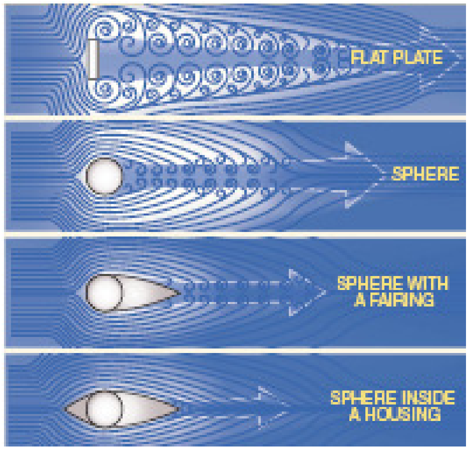




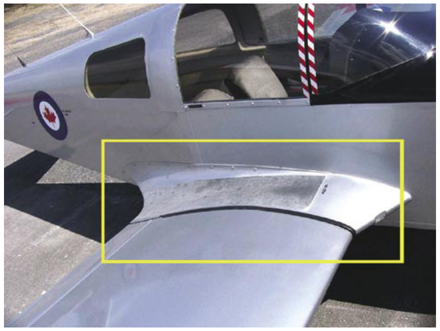
Types of Drag

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



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



Skin Friction Drag-due to aerodynamic resistance du to contact of moving air with the surface of the 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.