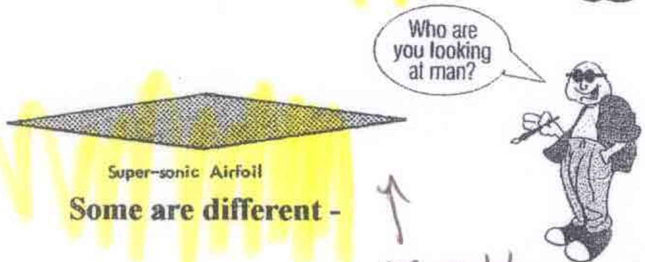
AN AIRFOIL -- Is any Surface Designed to Obtain a Useful Reaction, or LIFT, from Air Passing Over It.

PART I

IFFERENT AIRFOILS **Airfoils are a lot like people:**

Some, are just average -

Others are sleek & thin -



Some are different -

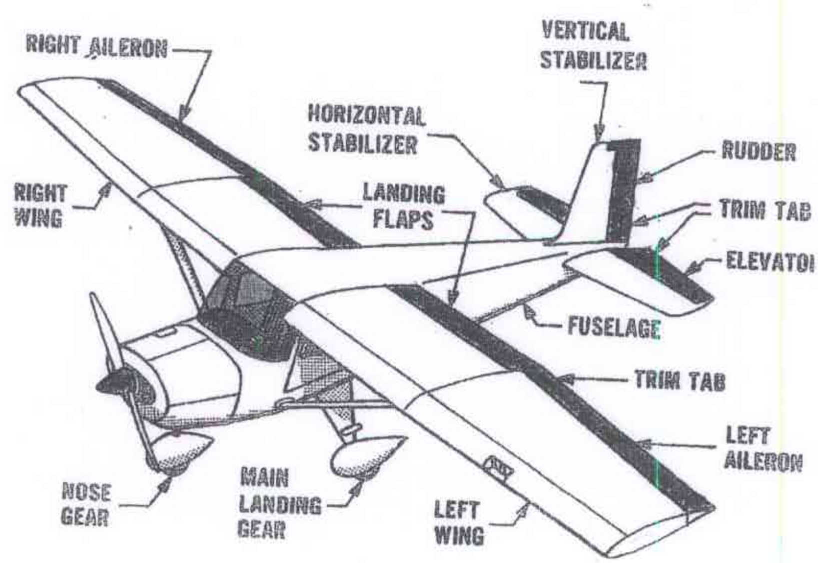
US Military

And others are built to hold couches down

commercial jets

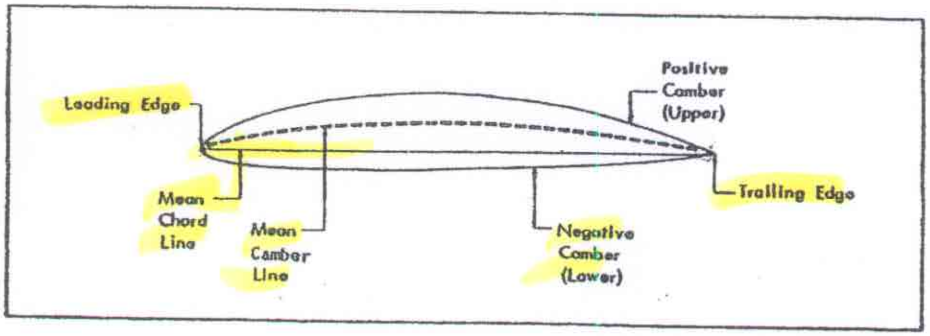
Other Examples Of Airfoils Are:

Wings
Horizontal Tail Surfaces
Vertical Tail Surfaces
Propellers



Parts of the Airplane

NEW TERMS

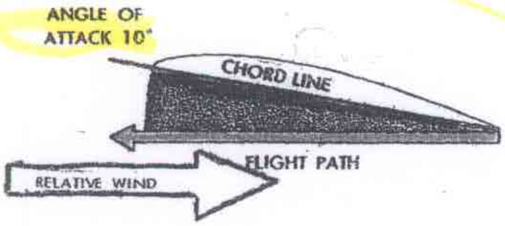


LEADING & TRAILING EDGE

CHORD LINE "Imaginary line" from L to T

MEAN CAMBER LINE

all points equidistant between top/bottom

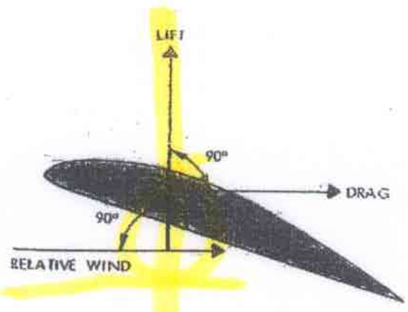


"created" wind by moving through Air

RELATIVE WIND

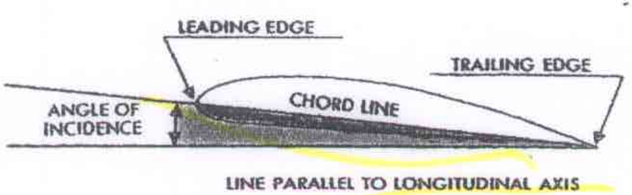
ANGLE OF ATTACK

chord line + relative wind



CENTER OF PRESSURE

where lift and relative wind meet.



ANGLE OF INCIDENCE

chord line + Longitudinal Axis

WING PLANFORM

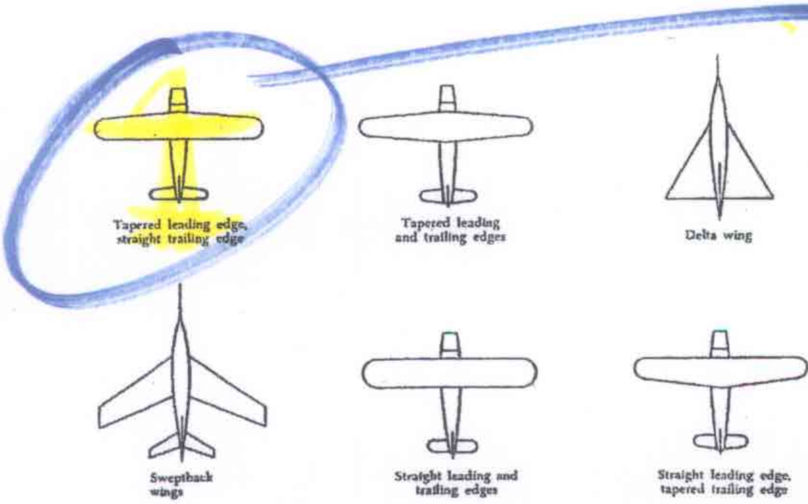
Surface from above

WING AREA

Ttl surface of wing Ft.²

WING SPAN

Distance

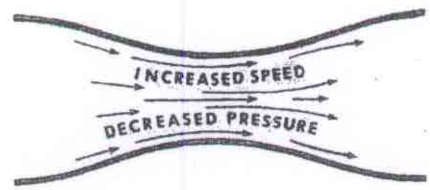


BERNOULLI'S PRINCIPLE

DANIEL BERNOULLI (1700 - 1782)

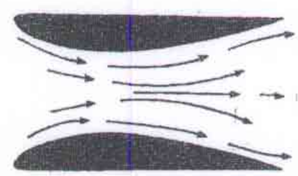
BERNOULLI WAS A SWISS MATHEMATICIAN WHO DABBLED IN PLUMBING.
HE MEASURED THE PRESSURE AND VELOCITY OF A FLUID TRAVELING THROUGH A VENTURI.

BERNOULLI DISCOVERED THAT,
WHEN AIR IS FORCED THROUGH A RESTRICTED OPENING,
IT ACCELERATES TO PASS THROUGH THE RESTRICTION.
FURTHER, HE FOUND THE ACCELERATED AIR
EXERTS LESS PRESSURE WHEN IT IS ACCELERATED.

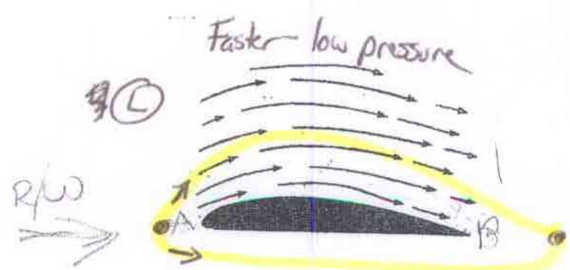


BERNOULLI'S PRINCIPLE STATES THAT THE AIR ~~TRAVELING~~
FASTER OVER THE CURVED UPPER SURFACE OF AN AIRFOIL
RESULTS IN LOWER PRESSURE ON THE TOP SURFACE.

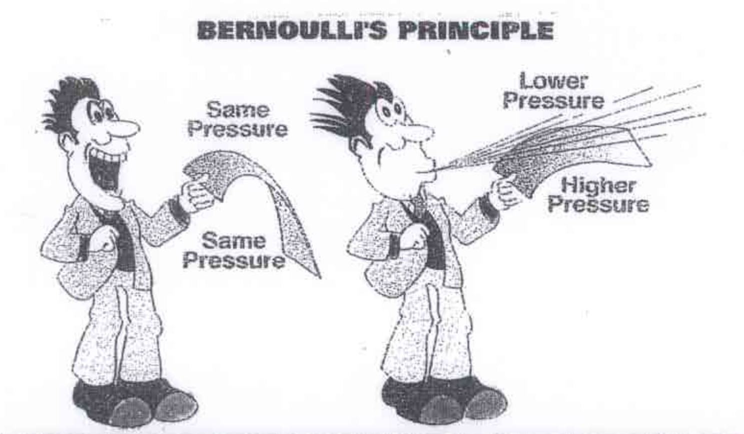
IN OTHER WORDS,
HIGH SPEED FLOW IS ASSOCIATED WITH LOW PRESSURE,
AND LOW SPEED FLOW WITH HIGH PRESSURE.



AIR ABOVE THE WING HAS TO TRAVEL A
GREATER DISTANCE IN THE SAME PERIOD OF TIME
THAN THE AIR FLOWING BELOW THE WING,
SO IT HAS TO TRAVEL FASTER OVER THE TOP.



SEE FOR YOURSELF



Blowing over the top of the paper creates higher velocity airflow which reduces pressure causing the paper to lift upward similar to a wing's lift.

NEWTON'S THIRD LAW OF MOTION

FOR EVERY ACTION THERE IS AN EQUAL AND OPPOSITE REACTION

THE REMAINDER OF LIFT IS CREATED WHEN AIR STRIKES THE BOTTOM OF THE WING AND IS DEFLECTED DOWNWARD.

THIS CREATES AN EQUAL AND OPPOSITE REACTION, THAT PUSHES THE WING UPWARD.

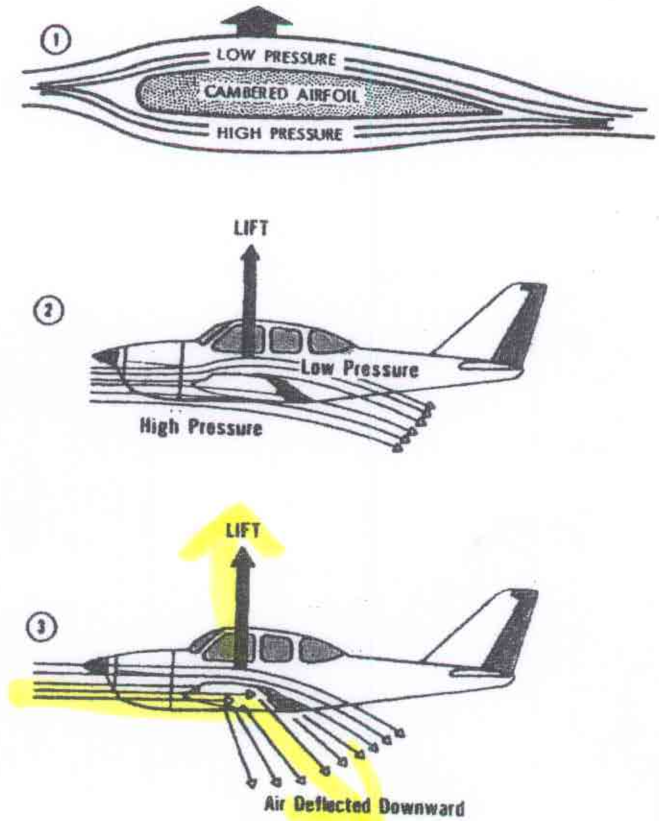


Figure 3-2 Forces Creating Lift

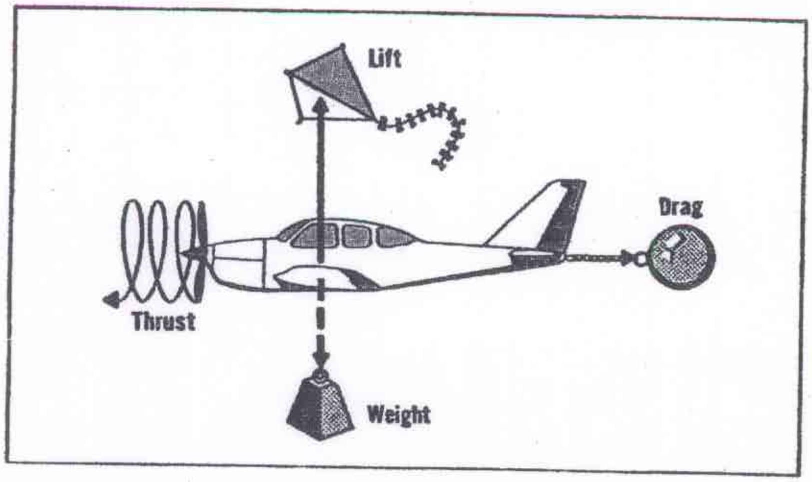
THUS BOTH THE DEVELOPMENT OF LOW PRESSURE ABOVE THE WING AND REACTION TO THE FORCE AND DIRECTION OF AIR AS IT IS DEFLECTED FROM THE WING'S LOWER SURFACE CONTRIBUTE TO THE TOTAL LIFT GENERATED.

→ Both Newton + Bernoulli contribute to t/l lift.

THE AMOUNT OF LIFT GENERATED BY THE WING DEPENDS UPON SEVERAL FACTORS: (1) SPEED OF THE WING THROUGH THE AIR, (2) ANGLE OF ATTACK, (3) PLANFORM OF THE WING, (4) WING AREA, AND (5) THE DENSITY OF THE AIR.

FOUR FORCES ACTING ON THE AIRPLANE

LIFT IS THE UPWARD FORCE CREATED BY AN AIRFOIL WHEN IT IS MOVED THROUGH THE AIR.



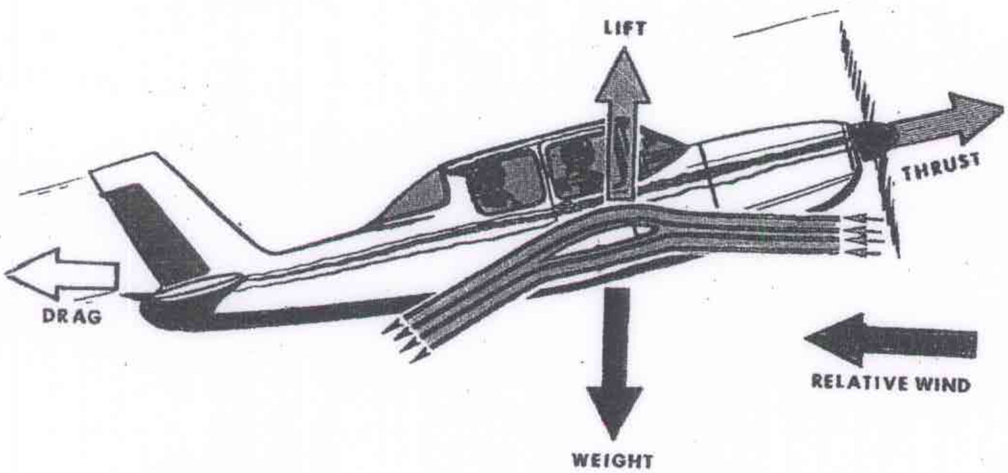
WEIGHT

IS GRAVITY THE DOWNWARD FORCE WHICH TENDS TO DRAW ALL BODIES VERTICALLY TOWARDS THE CENTER OF THE EARTH.

THRUST

THE PROPELLER, ACTING AS AN AIRFOIL, PRODUCES THE THRUST, OR FORWARD FORCE THAT DRIVES THE A/C THROUGH THE AIR. IT RECEIVES ITS POWER DIRECTLY FM THE ENGINE.

DRAG IS THE REARWARD FORCE WHICH RESISTS THE FORWARD MOVEMENT OF THE AIRPLANE THROUGH THE AIR.



EXCESS THRUST

Unaccellerated flight = Sum of all upward forces = Sum of all downward forces

DURING UNACCELERATED FLIGHT (WHICH INCLUDES CONSTANT RATE CLIMBS AND DESCENTS) THE SUM OF ALL UPWARD FORCES EQUALS THE SUM OF ALL DOWNWARD FORES.

WHAT IF THRUST IS > DRAG
WHAT IF THRUST IS < DRAG

WHAT IF LIFT IS > WEIGHT
WHAT IF LIFT IS < WEIGHT

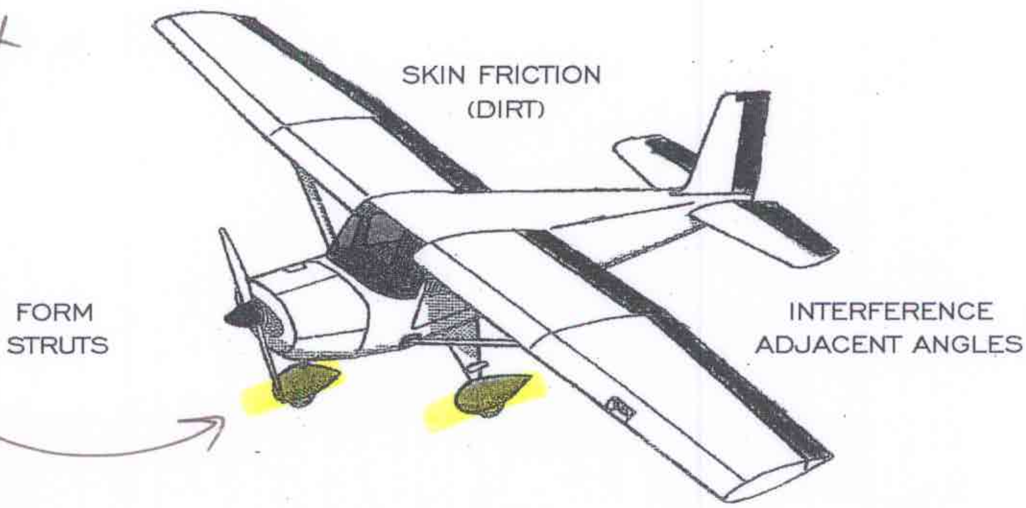
go into Drag in detail (next)

DRAG

THE REARWARD ACTING FORCE WHICH RESISTS THE FORWARD MOVEMENT OF THE AIRPLANE THROUGH THE AIR.

PARASITE DRAG IS CAUSED BY FRICTION BETWEEN THE AIR AND THE SURFACE OVER WHICH IT IS FLOWING.

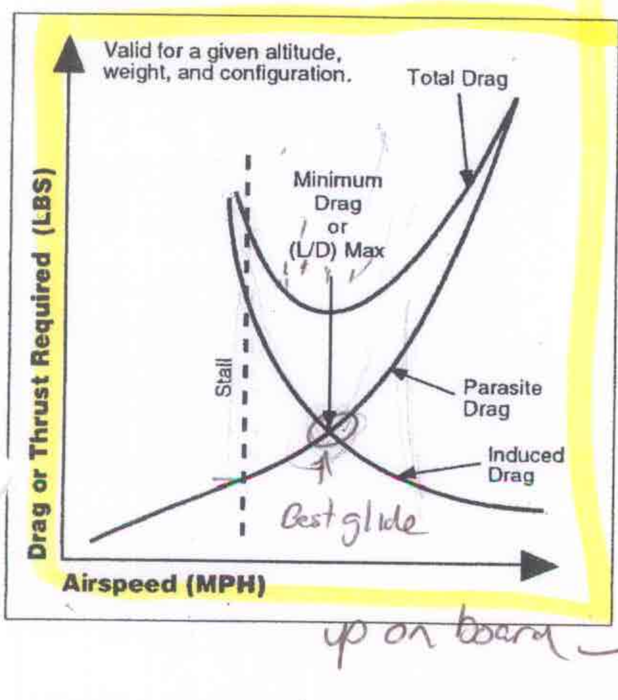
sticking head out of window



WHEEL COVERS & FAIRINGS
OR
WINGLETS
REDUCE DRAG

INDUCED DRAG IS THE RESULT OF THE WING BEING INCLINED INTO THE WIND AND REDUCING LIFT.

into the wind



up on board

INDUCED DRAG INCREASES W/ AOA & IS GREATEST AT SLOW A/S.

Angle of Attack

PARASITE DRAG INCREASES WITH THE SQUARE OF THE A/S.

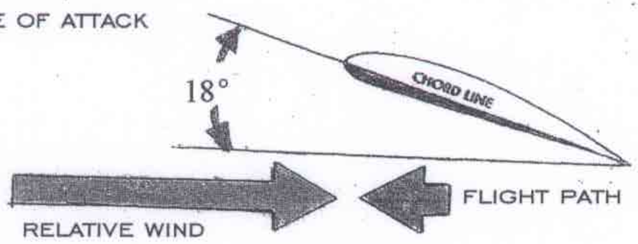
IT'S WHY IT TAKES A LOT OF POWER TO ACHIEVE HIGH SPEEDS.

THE POINT WHERE THE SUM OF THE INDUCED AND PARASITE DRAG IS AT ITS MINIMUM, OR L/D MAX. IS WHERE BEST GLIDE RANGE OCCURS.

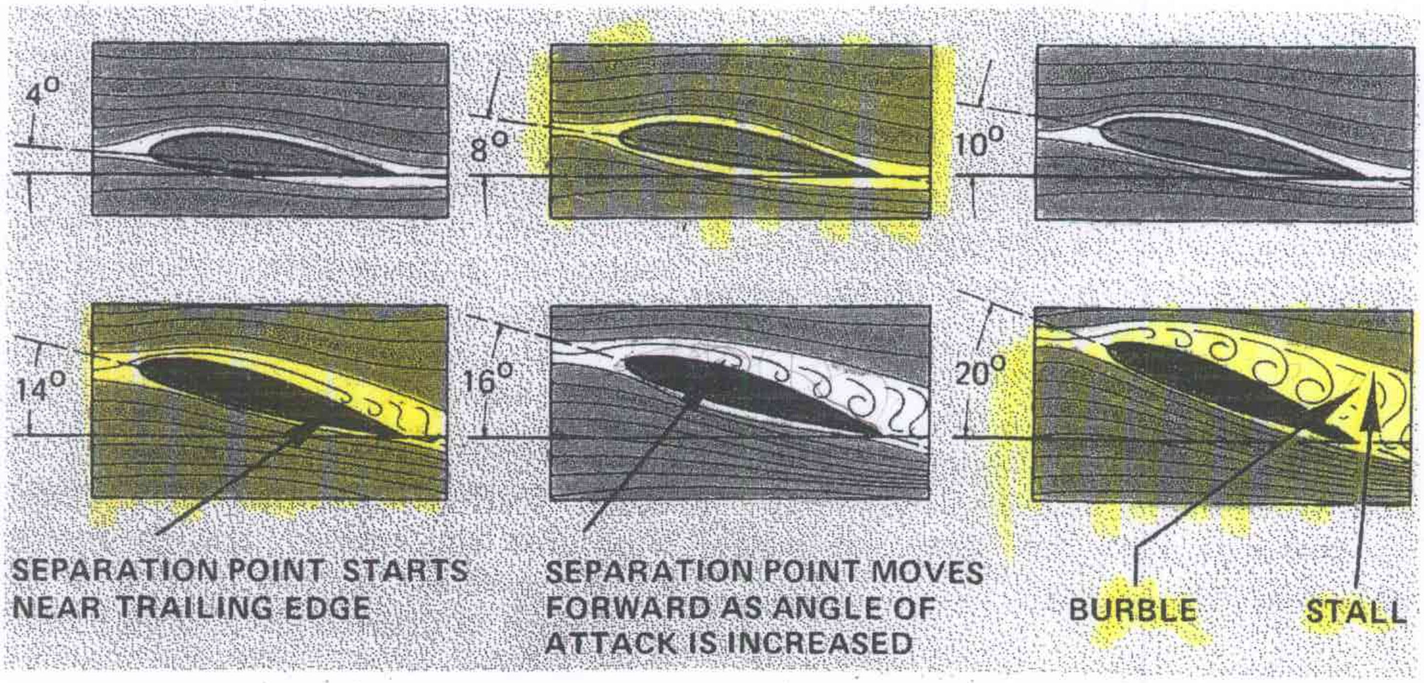
AIRFLOW AROUND A WING

REMEMBER:

ANGLE OF ATTACK



up on board



AT SMALL AOA LIFT OF THE WING COMES FROM PRESSURE DIFFERENCES BETWEEN THE UPPER AND LOWER SURFACES (BERNOULLI'S PRINCIPLE), AND AIR BEING DEFLECTED DOWNWARD FROM THE WING (NEWTON'S LAW). BY CHANGELING THE AOA THE PILOT CAN CONTROL LIFT, AIRSPEED, AND DRAG. ← on board

STALL

HOWEVER, [WHEN THE AOA GETS TO GRATE THE AIR SEPARATES FROM THE SURFACE OF THE WING AND BACKFILL, BURBLES, AND EDDIES. LIFT IS DESTROYED AND THE AIRCRAFT IS SAID TO HAVE STALLED. (1) AN AIRPLANE STALLS WHEN YOU EXCEED THE CRITICAL AOA.] AND THE CRITICAL AOA THAT THE AIRPLANE STALLS IS DEPENDENT ON THE DESIGN OF THE WING. THE ONLY THING A PILOT CAN DO TO CHANGE THAT IS TO CHANGE THE SHAPE OF THE WING (WHICH CAN BE DONE WITH FLAPS).

CRITICAL AOA IS THE HIGHEST AOA AT WHICH AIR WILL FLOW OVER AN AIRFOIL IN A SMOOTH FLOW.

THE CRITICAL ANGLE OF ATTACK ON MOST AIRFOILS IS ≈ 18–20°

THE CRITICAL AOA REMAINS CONSTANT REGARDLESS OF WEIGHT, DYNAMIC PRESSURE, BANK ANGLE, OR PITCH ATTITUDE. THESE FACTORS CERTAINLY WILL AFFECT THE SPEED AT WHICH THE STALL OCCURS, BUT NOT THE ANGLE.

(2) Stall: a loss of lift and increase of drag that occurs when an aircraft is flown at an angle of attack greater than the angle for maximum lift.

(on Board)

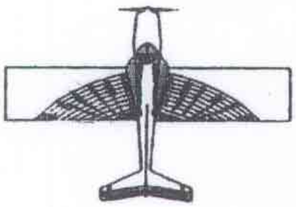
WING PLANFORM

THE SHAPE OF THE WING AS SEEN FROM ABOVE

SWEEPTBACK AND DELTA WINGS:

GENERALLY FOR HIGH SPEED A/C THAT FLY NEAR THE SEED OF SOUND;
STALL CHARACTERISTICS ARE MORE CRITICAL DUE TO THE HIGH ANGLES OF ATTACK REQUIRED.
REQUIRE VERY PRECISE FLYING TECHNIQUES, ESPECIALLY AT SLOW SPEEDS.

DISADVANTAGES: INCREASED DUTCH ROLL TENDENCIES;



STRAIGHT WING

EXCELLENT STALL CHARACTERISTICS;
STALLING AT THE WING ROOT FIRST;
PROVIDES ADEQUATE AILERON EFFECT
USUALLY QUITE STABLE;
FAVORED DESIGN FOR LOW-COST, LOW

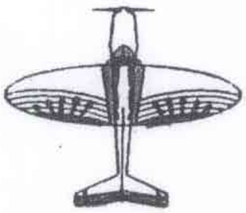
TWIST IN THE WING

SLATS

SLOTS

STALL STRIPS

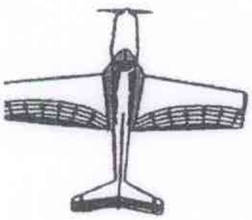
Why the wing STALLS @ ROOT FIRST



ELLIPTICAL WING

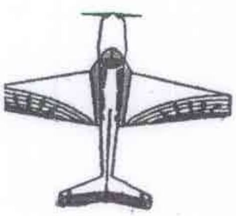
PROVIDES A MINIMUM OF INDUCED DRA
PRODUCES THE BEST LIFT COEFFICIEN
LITTLE ADVANCE WARNING OF A COMPL ... T
BECAUSE OF POOR AILERON EFFECTIV

THE DISADVANTAGES ARE ITS HIGH CO
ITS LACK OF AILERON EFFECTIVENESS



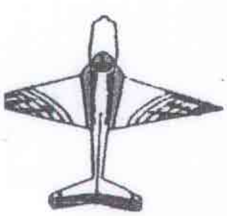
TAPERED WING

EFFICIENT FROM STRUCTURAL, WEIGHT, AND DRAG STANDPOINTS;
STALL CHARACTERISTICS ARE NOT AS GOOD AS STRAIGHT WING;
COMPARABLE IN EFFICIENCY TO THE ELLIPTICAL WING;
CHEAPER THAN ELLIPTICAL WING.



THE EFFICIENCY OF THE WING IS OFTEN DESCRIBED BY THE TERM ASPECT RATIO. ASPECT RATIO IS THE RATIO OF WING SPAN TO WING CHORD. IN GENERAL, THE HIGHER THE ASPECT RATIO, THE MORE EFFICIENT THE WING.

ASPECT RATIO = WING SPAN ÷ AVERAGE CHORD

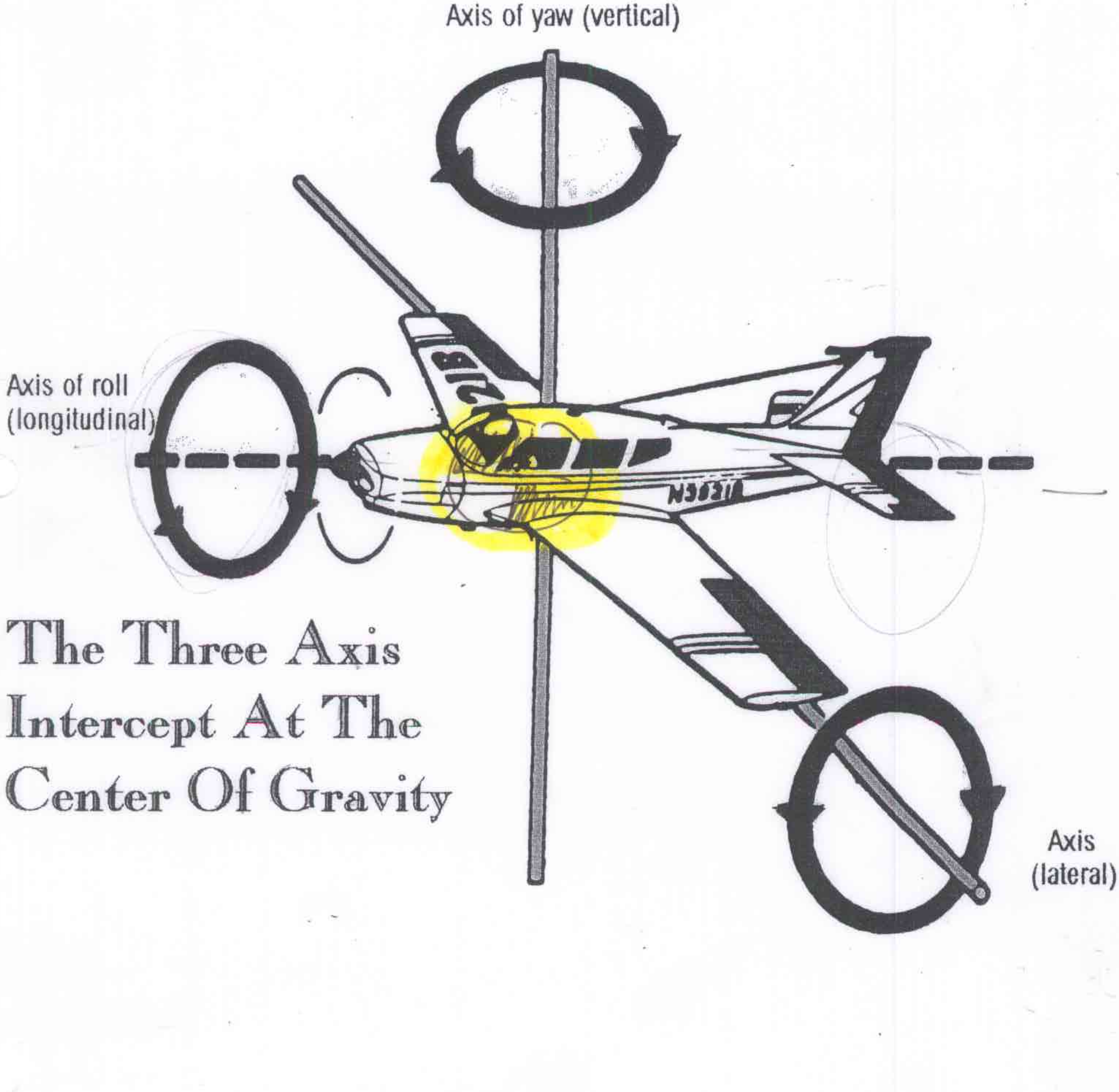


LOW ASPECT RATIO = HIGH WING LOADINGS AND HIGH STALL SPEEDS.

HIGH ASPECT RATIO = ARE USUALLY MORE FORGIVING OF IMPROPER PILOT TECHNIQUES.

MOST TRAINING AND GENERAL AVIATION AIRCRAFT ARE OPERATED AT HIGH-LIFT COEFFICIENTS AND THEREFORE HAVE COMPARATIVELY HIGH ASPECT RATIOS.

PART II



The Three Axis Intercept At The Center Of Gravity

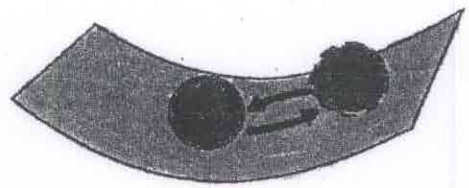
STABILITY IS THE AIRCRAFTS ABILITY TO RETURN TO NORMAL FLIGHT AFTER BEING DISTURBED. THE TWO TYPES OF STABILITY ARE STATIC AND DYNAMIC.

3 types of stability - Positive, neutral, negative.

(2) DYNAMIC STABILITY IS THE OVERALL TENDENCY THAT AN A/C DISPLAYS AFT ITS EQUILIBRIUM IS DISTURBED.

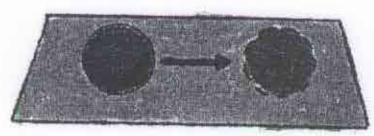
(1) STATIC STABILITY THE INITIAL TENDENCY THAT AN A/C DISPLAYS AFTER ITS EQUILIBRIUM IS DISTURBED.

POSITIVE STATIC STABILITY
THE INITIAL TENDENCY OF THE AIRPLANE TO RETURN TO THE ORIGINAL STATE AFTER BEING DISTURBED.



POSITIVE STATIC

NEUTRAL STATIC STABILITY
THE INITIAL TENDENCY OF THE AIRPLANE TO REMAIN IN A NEW CONDITION AFTER BEING DISTURBED.



NEUTRAL STATIC

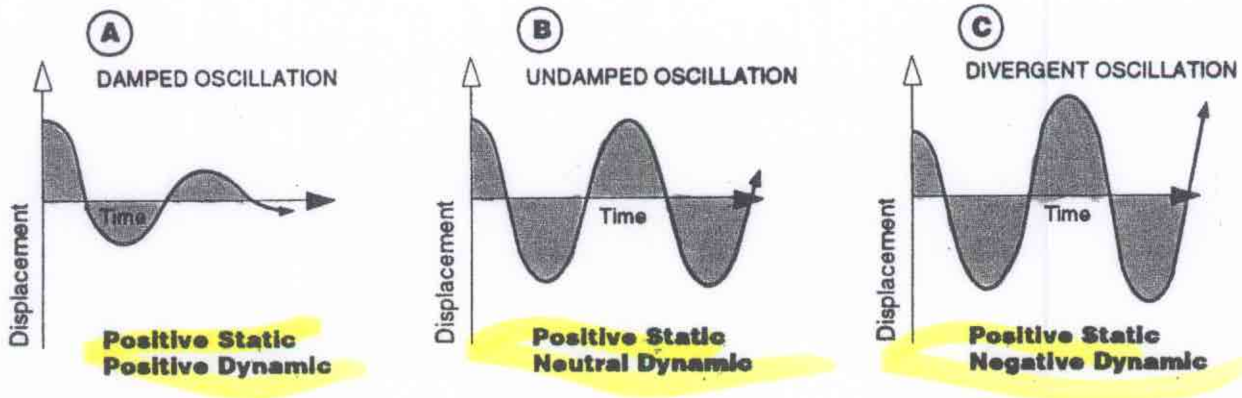
NEGATIVE STATIC STABILITY
THE INITIAL TENDENCY OF THE AIRPLANE TO CONTINUE AWAY FROM THE ORIGINAL STATE AFTER BEING DISTURBED.

NEGATIVE STATIC

MANEUVERABILITY IS THE QUALITY OF AN A/C THAT PERMITS IT TO BE MANEUVERED EASILY AND TO WITHSTAND THE STRESSES IMPOSED BY MANEUVERS.

ONTROLLABILITY IS THE CAPABILITY OF AN A/C TO RESPOND TO THE PILOT'S CONTROL, ESPECIALLY WITH REGARD TO FLIGHT PATH AND ATTITUDE. IT IS THE QUALITY OF THE AIRPLANE'S RESPONSE TO THE PILOT'S CONTROL APPLICATION WHEN MANEUVERING THE AIRPLANE, REGARDLESS OF ITS STABILITY CHARACTERISTICS.

Dynamic Stability



Dynamic stability come into play after the aircraft already has positive STATIC stability. Each of the examples above is statically stable, that is, when disturbed from the centerline, it tries to return to it. DYNAMIC STABILITY describes the behavior returning to the centerline. In each case, the centerline is overshot and positive stability again returns the aircraft to center (i.e. Level flight). Oscillations result, which die out if the aircraft is dynamically stable and worsen if the aircraft is dynamically unstable.

LATERAL STABILITY OR ROLL STABILITY IS OBTAINED THROUGH THE USE OF AILERONS. LATERAL STABILITY REFERS TO AN AIRPLANE'S TENDENCY TO RETURN TO WINGS-LEVEL FLIGHT FOLLOWING A DISPLACEMENT.

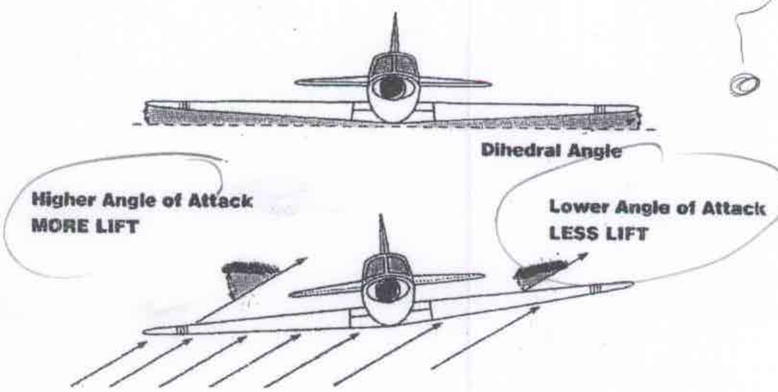
AIRPLANES ARE DESIGNED TO HAVE STATIC STABILITY ABOUT THE LONGITUDINAL AXIS. ONE WAY THIS IS ACCOMPLISHED IS WITH DIHEDRAL, OR A SLIGHT UPWARD ANGLING OF THE WINGS.

DIHEDRAL

IS A DESIGN FEATURE IN WHICH EACH WING IS INCLINED UPWARD ≈ 1-3° FROM THE WING ROOT TO THE WINGTIP.

Like a side slip

WHEN THE AIRPLANE IS BANKED, THE WING ON THE LOW SIDE OF THE BANK PRODUCES MORE LIFT, ENCOURAGING THE AIRPLANE TO RETURN TO LEVEL FLIGHT.



Slip

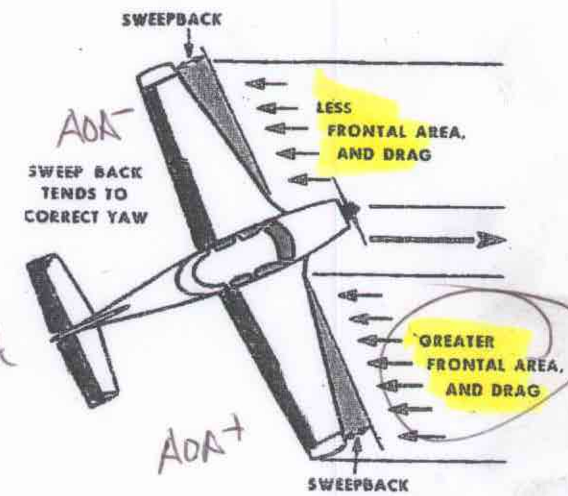
SWEEPBACK

IS THE ANGLE AT WHICH THE WINGS ARE SLANTED REARWARD FROM THE ROOT TO THE TIP.
THE EFFECT OF SWEEPBACK IN PRODUCING LATERAL STABILITY IS SIMILAR TO THAT OF DIHEDRAL.

IF ONE WING LOWERS IN A SLIP, THE AOA ON THE LOW WING INCREASES, PRODUCING GREATER LIFT. THIS RESULTS IN A TENDENCY FOR THE LOWER WING TO RISE, AND RETURN THE AIRPLANE TO LEVEL FLIGHT.

Bring up
Bring back

up + Back



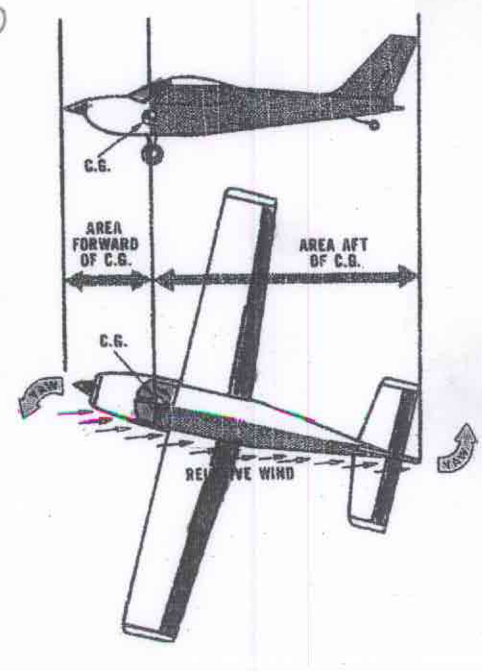
Lift up + Bring Back =. to rel. the wind

KEEL EFFECT

DEPENDS UPON THE ACTION OF THE RELATIVE WIND ON THE SIDE AREA OF THE AIRPLANE FUSELAGE.

IN A SLIGHT SLIP THE FUSELAGE PROVIDES A BROAD AREA UPON WHICH THE RELATIVE WIND WILL STRIKE, FORCING THE FUSELAGE TO PARALLEL THE RELATIVE WIND. THIS AIDS IN PRODUCING LATERAL STABILITY.

Back up
Ad
relative
wind.



In side slip - lowered wing
- getting more relative wing.
- raised wing less ∠ of attack

LONGITUDINAL STABILITY ABOUT THE LATERAL AXIS

∠ of attack
– tail force
What do you have to do w/ A/C Fwd + Aft to fly str. and level.

THE TENDENCY OF AN AIRPLANE TO REMAIN LEVEL ABOUT ITS LATERAL AXIS.

LONGITUDINAL STABILITY, ALSO CALLED PITCH STABILITY, IS PROVIDED BY THE HORIZONTAL TAIL LOAD OF THE AIRPLANE.

NEUTRAL

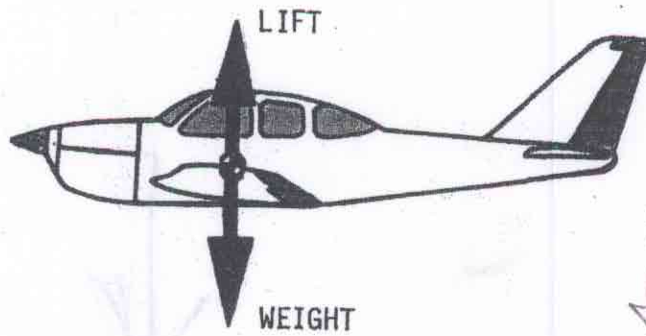


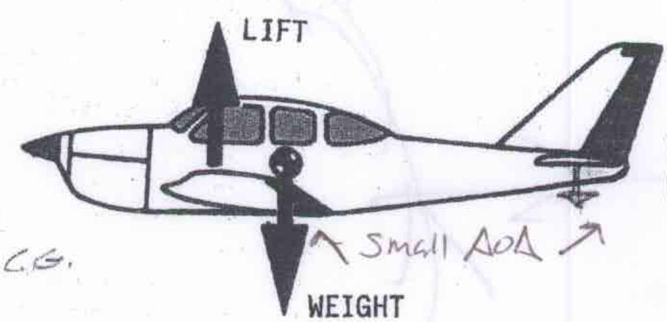
Figure 1-27. *Neutral stability.*

THE C.G., WHICH DOES NOT CHG W/ A/S, IS LOCATED SO THAT IT CAUSES THE AIRPLANE TO ROTATE NOSE-DOWN ABT ITS LAT. AXIS.

THE TAIL LOAD, WHICH DOES CHANGE WITH A/S, IS LOCATED BEHIND THE C.G., AND IT CAUSES THE AIRPLANE TO ROTATE NOSE-UP ABOUT ITS LATERAL AXIS.

more efficient (Economy) & controlability but less stable w/ aft C.G.

NEGATIVE



Small AOA

Less down Load !! Less Drag

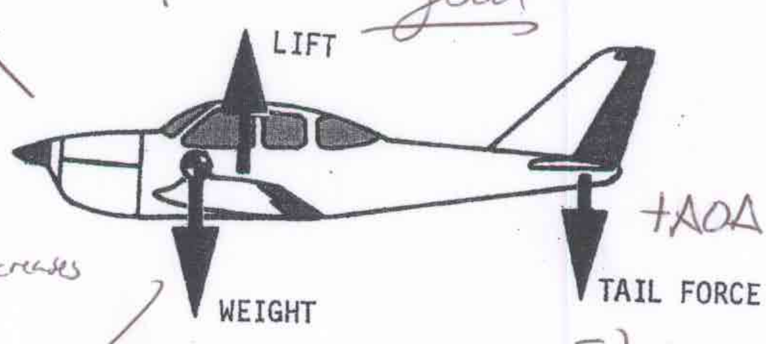
Figure 1-28. *Negative stability.*

(1) IF THE NOSE PITCHES DOWN,
(2) THE A/S BUILDS UP, ∠ of attack decreases AND THE DOWNWARD TAIL LOAD INCREASES.

THIS BRINGS THE NOSE BACK TO A LEVEL FLIGHT ATTITUDE.

good

POSITIVE



+AOA

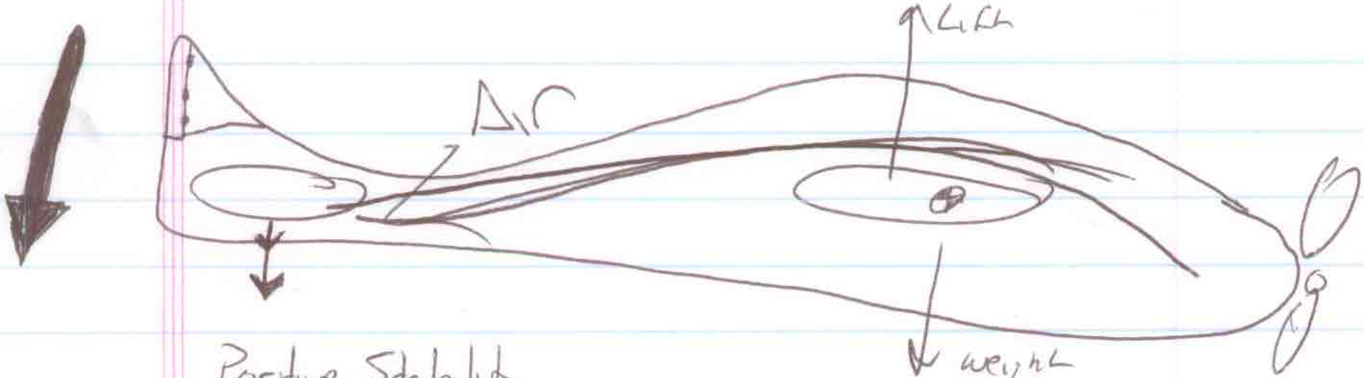
(1) IF THE NOSE PITCHES UP,
(2) THE A/S SLOWS DOWN, ∠ of attack increases AND THE TAIL LOAD DECREASES

THE C.G. CAUSES THE NOSE TO RETURN TO A LEVEL FLIGHT ATTITUDE.

Stronger tail force

Figure 1-29. *Positive stability.*

+AOA



Positive Stability

St + level – Back elevator pressure to hold – Nose up
∠ of attack increases > Tail load increases
A/S decreases
Back to st/level

Indirectly

Climb – Back nose up
• ∠ attack ~~increases~~ increase > ~~Tail load increases~~
• A/S decrease — Less downwash pushes tail ~~down~~ up.
• Back to st/level.

Decent. – Push nose down
• ∠ of attack decreases > ~~less tail load~~
• A/S increases – more downwash forces tail ~~up~~ down
• Back to st. and lev

Air Strikes upper surface of stabilator + creates downward tail force. to counteract.

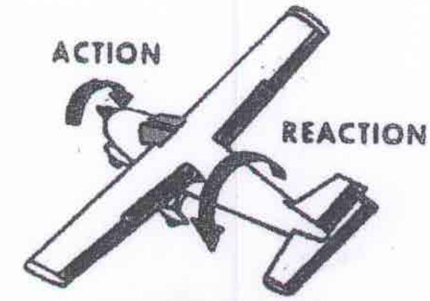
LEFT TURNING TENDENCIES (TORQUE EFFECT)

TORQUE EFFECT IS THE FORCE WHICH CAUSES THE AIRPLANE TO HAVE A TENDENCY TO SWERVE (YAW) TO THE LEFT, AND IS CREATED BY THE ENGINE AND PROPELLER. IT IS GREATEST WHEN AT LOW AIRSPEEDS WITH HIGH POWER SETTING AND A HIGH ANGLE OF ATTACK. Eng is off centered to the Right

TORQUE REACTION

FOR EVERY ACTION THERE IS AN EQUAL AND OPPOSITE REACTION. THE ROTATION OF THE PROPELLER (FROM THE COCKPIT) TO THE RIGHT, TENDS TO ROLL OR BANK THE AIRPLANE TO THE LEFT.

T-O Roll puts more pressure on LT Tire Acting like A Breake pulling the RT wing towards the LT.

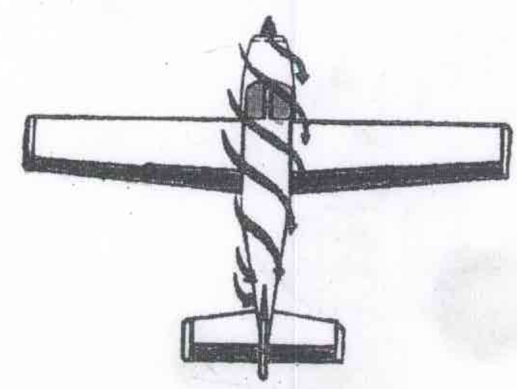


TORQUE REACTION

CORKSCREWING SLIPSTREAM

THE SPIRALING SLIP-STREAM HITS THE LEFT SIDE OF THE TAIL, WHICH MAKES THE AIRPLANE WANT TO YAW TO THE LEFT AND ROLL TO THE RIGHT.

MOST AIRPLANES HAVE THE TAIL OFFSET SLIGHTLY FROM CENTER TO RESIST THIS TENDENCY.

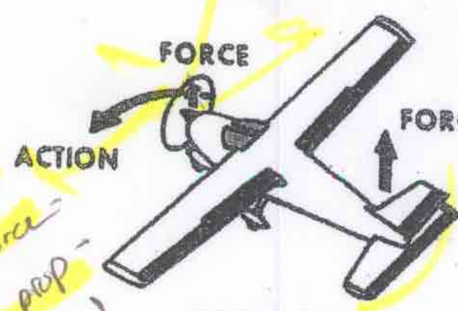


SLIPSTREAM

GYROSCOPIC PRECESSION - Tail dragger tail Lifts

IS THE RESULTANT REACTION OF ~~AN OBJECT OF~~ WHEN FORCE IS APPLIED. THE REACTION TO A FORCE APPLIED TO A GYRO ACTS IN THE DIRECTION OF ROTATION AND APPROXIMATELY 90° AHEAD OF THE POINT WHERE FORCE IS APPLIED.

Tail dragger lifts tail - applys force - acts on spinning prop - 90° ahead of rotation + right

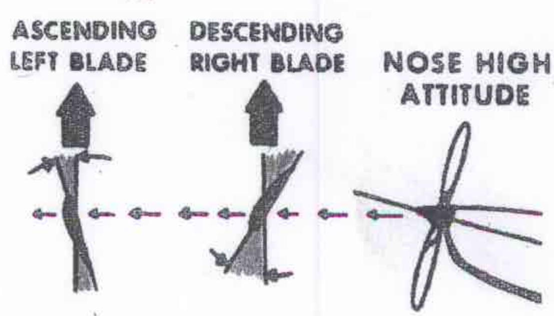


PRECESSION

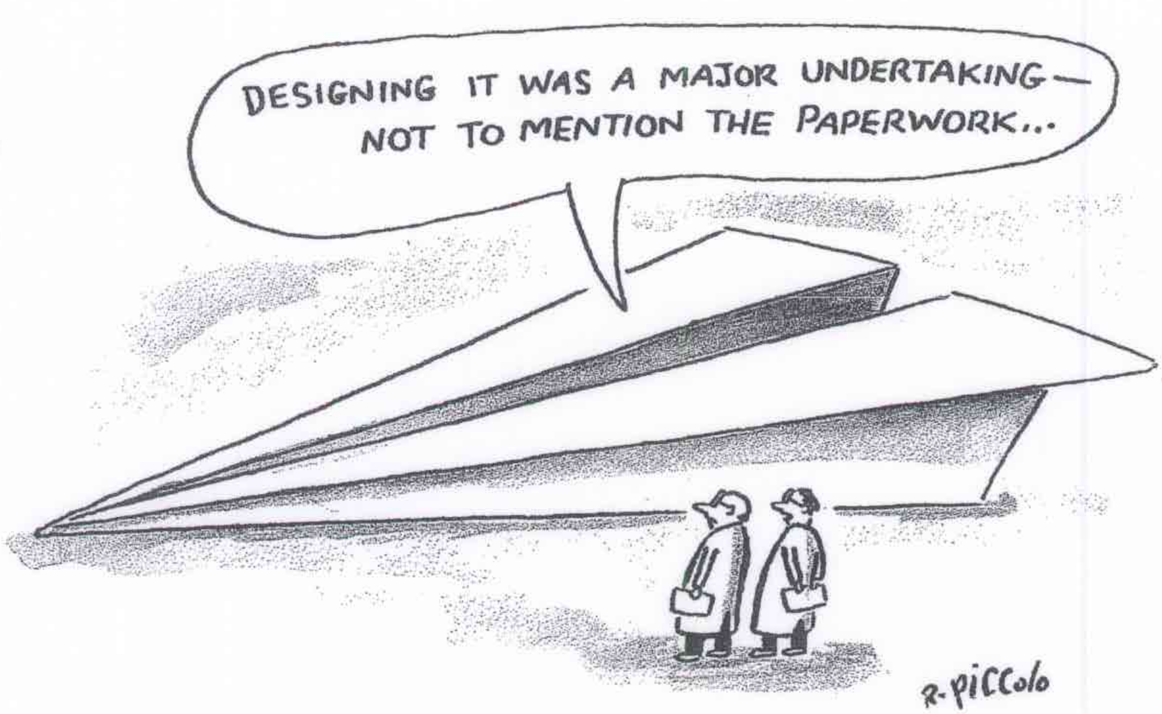
P-FACTOR Slow Flight! w/ handy

IN NOSE HIGH ATTITUDES THE RIGHT PROPELLER BLADE HAS MORE THRUST THAN THE LEFT.

in a decent the Left BLAde TAker A Biger Bite



P-FACTOR

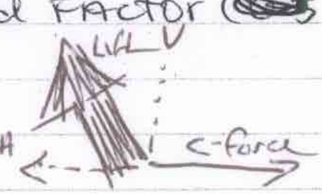

DESIGNING IT WAS A MAJOR UNDERTAKING— NOT TO MENTION THE PAPERWORK...
R. PICCOLO

PART III

"G" refers to the Pull of GRAVITY

OAD FACTOR — IS The Ratio of The TOTAL Load supported by The A/C's Wings TO The Gross Weight of The Airplane

esulTANT Load = Load FACTOR ( )



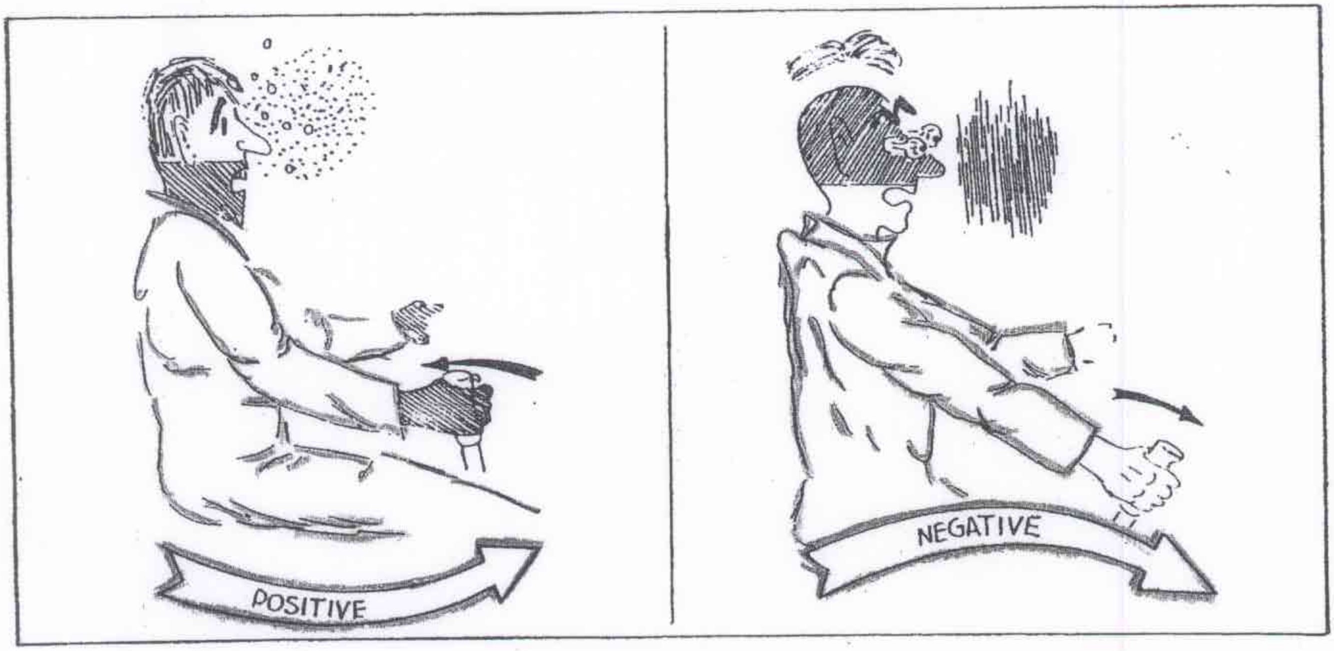
entrifugal Force = ·14 IS The Reaction of the Airplane TO ~~The~~ A Change in direction of Flight And Acts opposite to the horizontal Component of Lift

naneuvering Speed

IS the MAXIMUM speed @ Which Abrupt or excessive Control movement can be Applied W/OUT exceeding Design Load FACTOR Limits

POSITIVE AND NEGATIVE "G" EFFECTS ON THE PILOT

"G" REFERS TO THE PULL OF GRAVITY



ALL AIRPLANES ARE DESIGNED TO MEET CERTAIN STRENGTH REQUIREMENTS DEPENDING ON THE INTENDED USES OF THE AIRPLANE. CLASSIFICATION OF AIRPLANES AS TO STRENGTH AND OPERATIONAL USE IS KNOWN AS THE CATEGORY SYSTEM.

← Arrow II   Arrow II - 3.8 -0   no inv. manv

NORMAL CATEGORY: LIMIT LOAD FACTOR 3.8 TO -1.52 GS.
STALLS, LAZY EIGHTS, CHANDELLES, AND STEEP TURNS IN WHICH THE BANK ANGLE DOES NOT EXCEED 60°.
Look in POH - Before Spinning

UTILITY CATEGORY: LIMIT LOAD FACTOR 4.4 TO -1.76 GS.
ALL NORMAL CATEGORY OPERATIONS PLUS, SPINS (IF APPROVED FOR THAT AIRPLANE) LAZY EIGHTS, CHANDELLES, AND STEEP TURNS IN WHICH THE BANK ANGLE IS MORE THAN 60°.

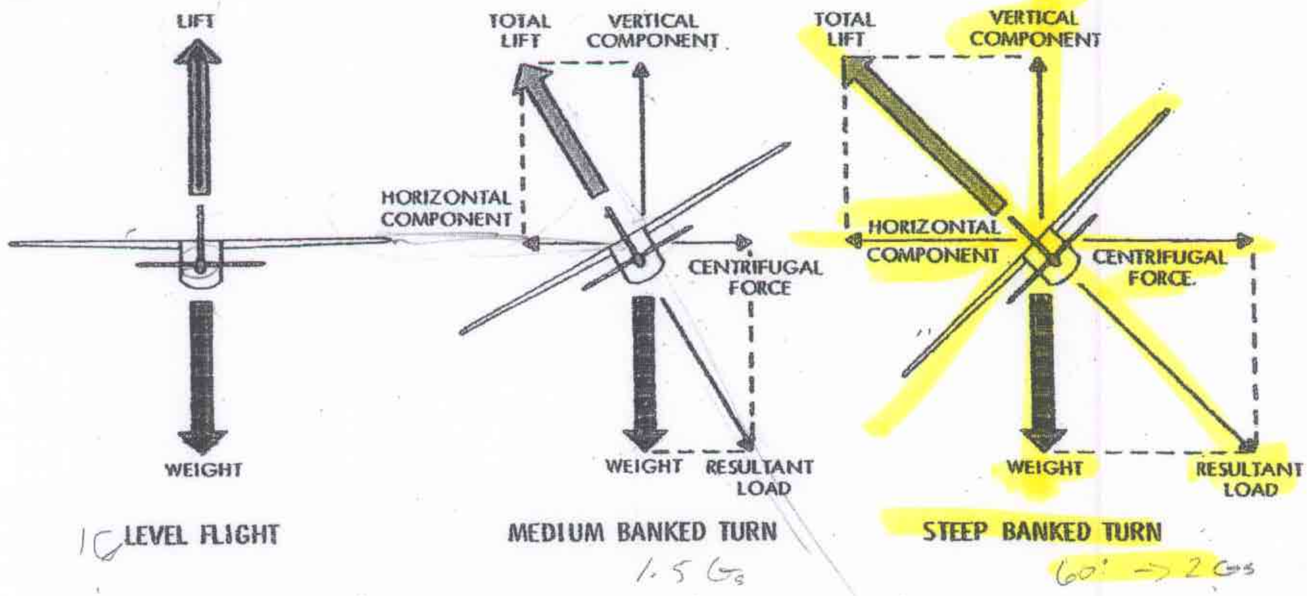
ACROBATIC: LIMIT LOAD FACTOR 6.0 TO -3.0 GS.
NO RESTRICTIONS EXCEPT THOSE SHOWN TO BE NECESSARY AS A RESULT OF REQUIRED FLIGHT TESTS.

Normal - (arrow II) 3.8 -0
Utility - 4.4 - -1.76 g (all normal + spins) turns +60°
Acrobatic - 6.0 - -3.0 g (no restrictions) except those in flt tests

LOAD FACTORS

THE RATIO OF THE TOTAL LOAD SUPPORTED BY THE AIRPLANE'S WING TO THE GROSS WEIGHT OF THE AIRPLANE.

What ↗



REMEMBER:

LOAD FACTOR = $\frac{\text{ACTUAL WING LOAD}}{\text{TOTAL WEIGHT OF THE AIRPLANE}}$

NORMAL CAT......... 3.8 Gs / -1.52 Gs
UTILITY CAT.......... 4.4 Gs / -1.76 Gs
ACROBATIC CAT..... 6.0 Gs / -3.00 Gs

ONE G IS ONE TIMES THE FORCE OF GRAVITY.

DID YOU KNOW THAT ANY LEVEL TURN WILL INCREASE THE LOAD FACTOR. DURING STRAIGHT-AND-LEVEL FLIGHT, THE WINGS SUPPORT THE GROSS WEIGHT OF THE AIRPLANE. AS LONG AS YOUR FLYING IN A STRAIGHT LINE, AT A CONSTANT SPEED, THE LOAD WILL REMAIN CONSTANT, BUT TOSS IN A 60° STEEP BANK AND THE WINGS WILL HAVE TO SUPPORT TWICE THE GROSS WEIGHT OF THE AIRPLANE. (60° = 2G)

EXAMPLE: WHEN A LOAD FACTOR OF 2.0 IS IMPOSED ON AN AIRPLANE WEIGHING 3,250 POUNDS, AS IT WOULD BE IN A LEVEL 60° BANKED TURN, THE WING WOULD CARRY A LOAD OF 3,250 X 2.0 = 6,500 POUNDS. 3250 lb x 2.0g = 6500 lbs (60° turn)

AN AIRPLANE CAN BE FORCED INTO AN ACCELERATED STALL IN A STEEP TURN. THE STALL SPEED INCREASES WITH THE SQUARE ROOT OF THE LOAD FACTOR. AN AIRPLANE WHICH IS FORCED INTO AN ACCELERATED STALL AT TWICE ITS NORMAL STALL SPEED WILL HAVE A LOAD FACTOR OF 4 GS. THIS EXCEEDS THE DESIGN LIMITS OF MANY GENERAL AVIATION AIRCRAFT. EXAMPLES SHOWN ON THE LOAD FACTOR / STALL SPEED CHART.

LOAD FACTOR IS IMPORTANT TO PILOTS BECAUSE OF THE OBVIOUSLY DANGEROUS OVERLOAD THAT IT IS POSSIBLE FOR A PILOT TO IMPOSE ON THE AIRCRAFT STRUCTURE; AND BECAUSE AN INCREASED LOAD FACTOR INCREASES THE STALLING SPEED AND MAKES STALLS POSSIBLE AT SEEMINGLY SAFE FLIGHT SPEEDS.

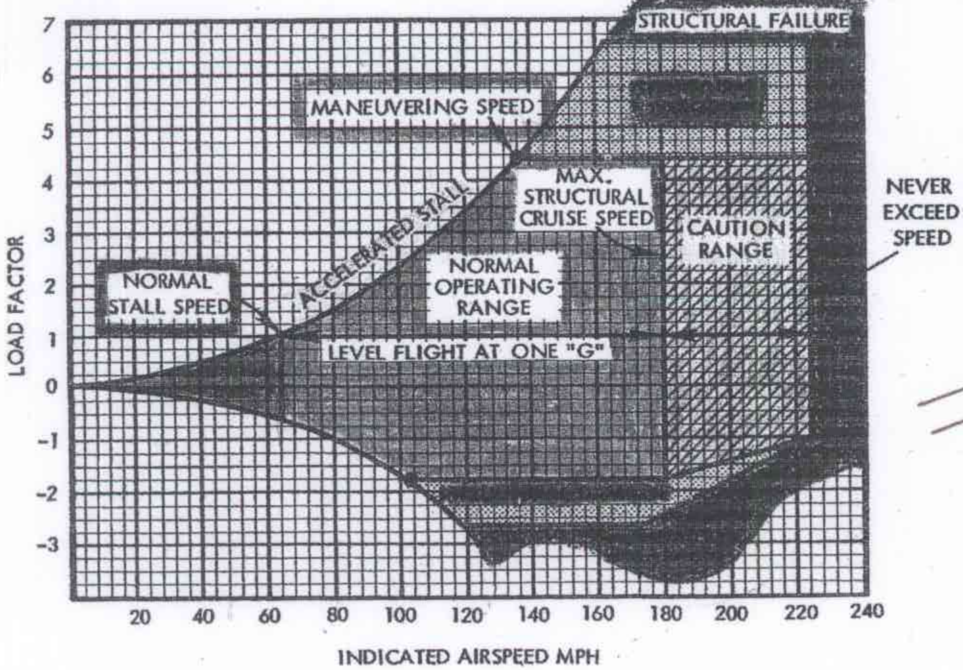
Why ↗

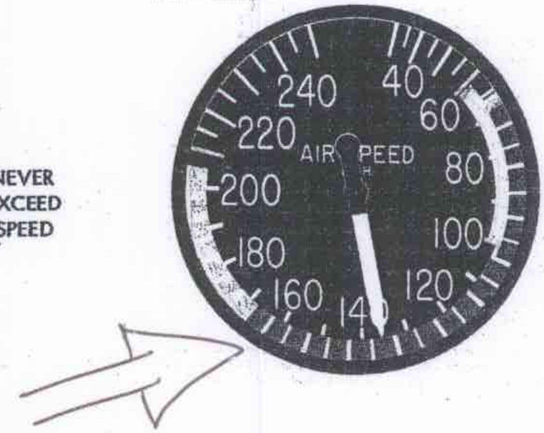
STRUCTURAL LOAD LIMITS

← Show these During Presentation

Use sheet, not board

TYPICAL VG DIAGRAM



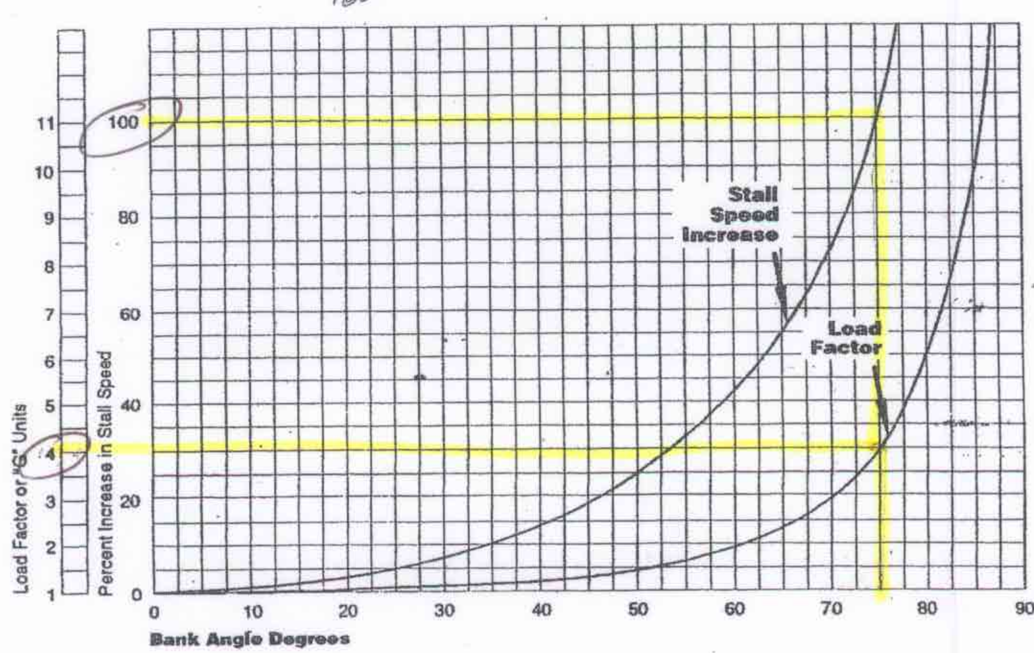


THE VG DIAGRAM DEPICTS VELOCITY VERSUS "G" LOADS OR LOAD FACTOR. THE DIAGRAM INDICATES THE BASIC FLIGHT OPERATING STRENGTH OF AN AIRPLANE BY DESCRIBING THE ALLOWABLE COMBINATIONS OF AIRSPEEDS AND LOAD FACTORS FOR SAFE OPERATIONS. EACH AIRPLANE HAS ITS OWN VG DIAGRAM WHICH IS VALID AT A CERTAIN WEIGHT AND ALTITUDE.

LOAD FACTOR / STALL SPEED CHART

RULE: FOR DETERMINING THE SPEED AT WHICH A WING WILL STALL IS THAT THE STALLING SPEED INCREASES IN PROPORTION TO THE SQUARE ROOT OF THE LOAD FACTOR.

EXAMPLE: THE LOAD FACTOR IN A 75° BANK IS 4.
NOW VERIFY THIS BY LOOKING AT THE CHART. THE STALL SPEED INCREASES WITH THE SQUARE ROOT OF THE LOAD FACTOR. THE SQUARE ROOT OF 4 IS 2, AND SURE ENOUGH, THE CHART SHOWS THE STALL SPEED INCREASE OF 100% IN A 75° TURN.



75° Bank = 4G's load factor

100% increase in stall speed

70mph + (100% × 70mph) = 140mph

ADVERSE YAW

what?

.S A CONDITION OF FLIGHT IN WHICH THE NOSE OF AN AIRPLANE STARTS TO MOVE IN THE DIRECTION OPPOSITE THE DIRECTION THE TURN IS TO BE MAKE.

Why?

ADVERSE YAW IS CAUSED BY THE DECREASED DRAG ON THE LOWERED WING AND THE INCREASED DRAG ON THE RAISED WING. THE INCREASED DRAG ON THE RAISED WING CAUSES THE NOSE OF THE A/C TO MOMENTARILY YAW IN THE OPPOSITE DIRECTION OF THE TURN.

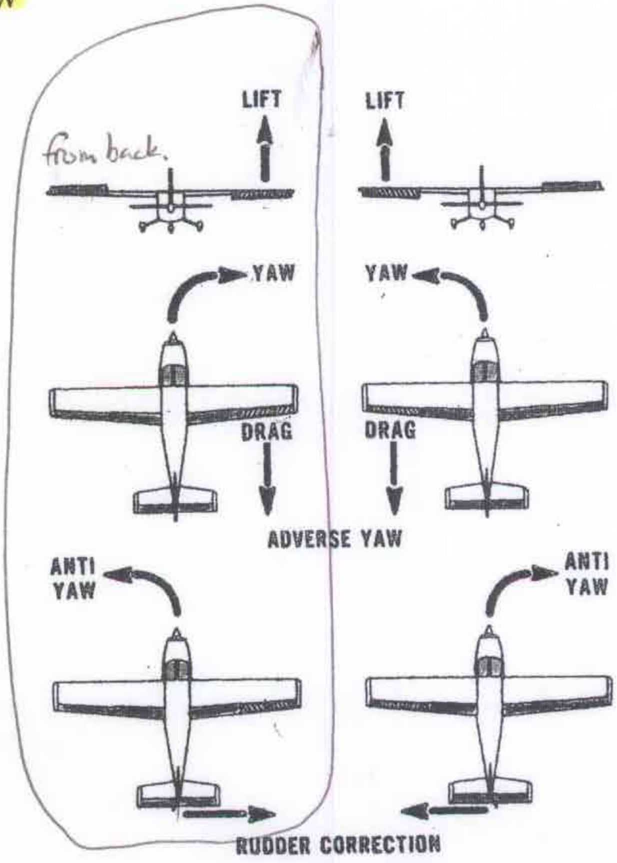


Figure 4-4 Cause and Effect of Adverse Yaw

A TURN TO THE LEFT, FOR EXAMPLE, THE RIGHT AILERON IS DEFLECTED DOWNWARD PRODUCING MORE LIFT AND DRAG, THAN THE LEFT AILERON. THIS ADDED DRAG ATTEMPTS TO PULL THE AIRPLANE'S NOSE IN THE DIRECTION OF THE RAISED WING (RIGHT); THAT IS, IT TRIES TO TURN THE AIRPLANE IN THE DIRECTION OPPOSITE TO THAT DESIRED. THIS UNDESIRED VEERING IS REFERRED TO AS ADVERSE YAW.

HOW IS ADVERSE YAW CONTROLLED IN A/C DESIGN? AN AILERON MAY BE DESIGNED TO HAVE MORE UPWARD MOVEMENT THAN DOWNWARD MOVEMENT. THIS WILL RESULT IN LESS DRAG ON THE DOWN AILERON AND NO INCREASE IN DRAG ON THE UP AILERON.

Demo Dutch Roll w/out Rudder

WHEN ROLLING OUT OF A STEEP-BANKED TURN, THE YAW EFFECT WILL OFTEN BE MORE APPARENT THAN WHEN ROLLING INTO THE TURN. THIS IS CAUSED BY THE HIGHER AOA, THE HIGHER WING LOADING AND THE SLOWER A/S WHICH EXISTS WHEN THE ROLL-OUT IS STARTED.

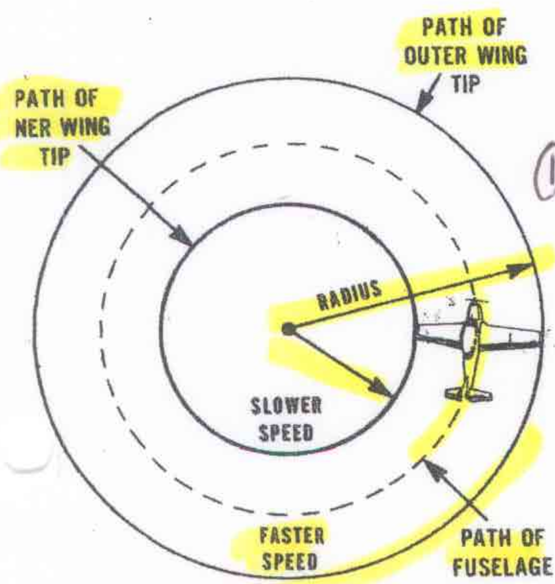


Figure 6-7 Cause of Overbanking Tendency

Overbanking Tendency

(1) what [AS THE RADIUS OF THE TURN BECOMES SMALLER, A SIGNIFICANT DIFFERENCE DEVELOPS BETWEEN THE SPEED OF THE INSIDE WING AND THE SPEED OF THE OUTSIDE WING. (2) why [THE WING ON THE OUTSIDE OF THE TURN TRAVELS A LONGER CIRCUIT THAN THE INSIDE WING, YET BOTH COMPLETE THEIR RESPECTIVE CIRCUITS IN THE SAME LENGTH OF TIME.] THEREFORE, THE OUTSIDE WING MUST TRAVEL FASTER THAN THE INSIDE WING AND AS A RESULT IT DEVELOPS MORE LIFT. THIS CREATES A SLIGHT DIFFERENTIAL BETWEEN THE LIFT OF THE INSIDE AND OUTSIDE WINGS AND TENDS TO FURTHER INCREASE THE BANK.

Draw ~~Dog Dount~~ Dounut

outside wing travels faster – thus more lift.

FORCES IN A TURN

Ask - What makes an aircraft turn?

SO WHAT'S NECESSARY TO MAKE AN A/C TURN? THE ANSWER IS A CHANGE IN THE DIRECTION OF LIFT.

WHEN AN AIRPLANE IS ROLLED INTO A BANK, THE LIFT IS SPLIT INTO TWO VECTORS; THE VERTICAL COMPONENT OF LIFT AND THE HORIZONTAL COMPONENT OF LIFT. THE VCL OPPOSES GRAVITY, AND IT IS THE HCL THAT ACTUALLY CAUSES THE AIRPLANE TO TURN. WHEN THE TURN IS COORDINATED THE HCL EQUALS AND OPPOSES CENTRIFUGAL FORCE.

TURNING

WHEN AN AIRPLANE IS BANKED INTO A TURN, PART OF THE LIFT FROM THE WINGS IS DIVERTED AWAY FROM HOLDING THE AIRPLANE UP AND IS USED TO OVERCOME CENTRIFUGAL FORCE AND TURN THE AIRCRAFT.

HOWEVER, TO MAINTAIN LEVEL FLIGHT, THE VCL MUST STILL EQUAL THE AIRPLANE'S WEIGHT.
THUS, MORE TOTAL (RESULTANT) LIFT FROM THE WINGS IS NEEDED.

THAT IS WHY YOU HAVE TO PULL BACK ON THE CONTROL WHEEL TO MAINTAIN ALTITUDE IN A TURN AND WHY STALL SPEED IS HIGHER.

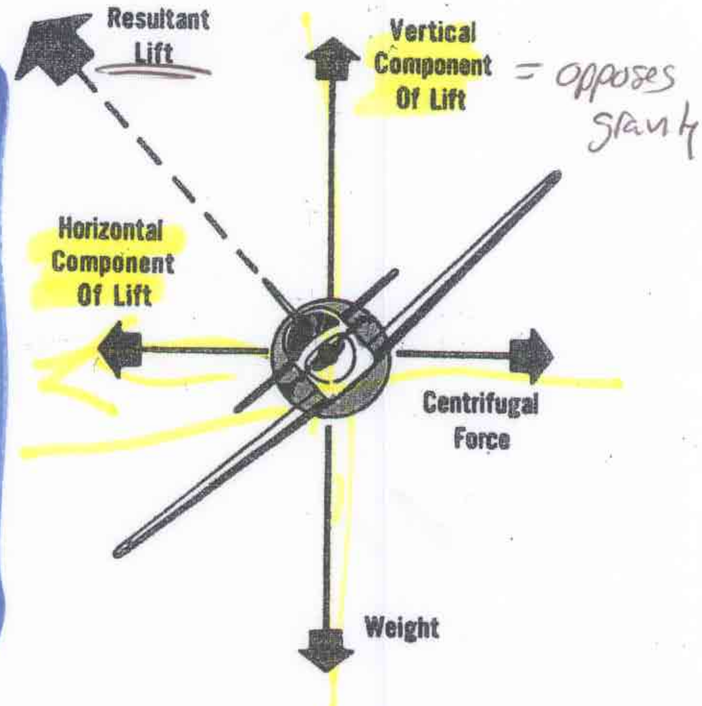


Figure 1-45. *Forces acting on an airplane in a turn.*

Why pull back in turn? Vertical Component must = wt.

IF YOU INCREASE THE B/A, THE VCL DECREASES AND THE SINK RATE INCREASES. IF YOU DON'T PULL BACK ON THE CONTROL YOKE, AND MAYBE ADD POWER, YOU'LL LOOSE ALTITUDE. RIGHT??

NOW THE RATE OF TURN IS HOW MANY DEGREES YOU TURN IN A GIVEN TIME PERIOD. AND THE RADIUS OF TURN HOW LARGE A CIRCLE YOU MAKE IN THE AIR WHILE TURNING.

WHAT IF YOU WANT TO INCREASE THE RATE AND DECREASE THE RADIUS OF TURN? THE ANSWER IS STEEPEN THE BANK, DECREASE THE AIRSPEED, OR BOTH.

Rate - Degrees / Time

Radius - How large a circle

Draw

Increase rate
Decrease radius
(1) Steepen bank
(2) Decrease A/S