Aerodynamics II

Part 2 – stability, turns, stalls, turning tendencies, load factor,etc.

Stability – Three Axes

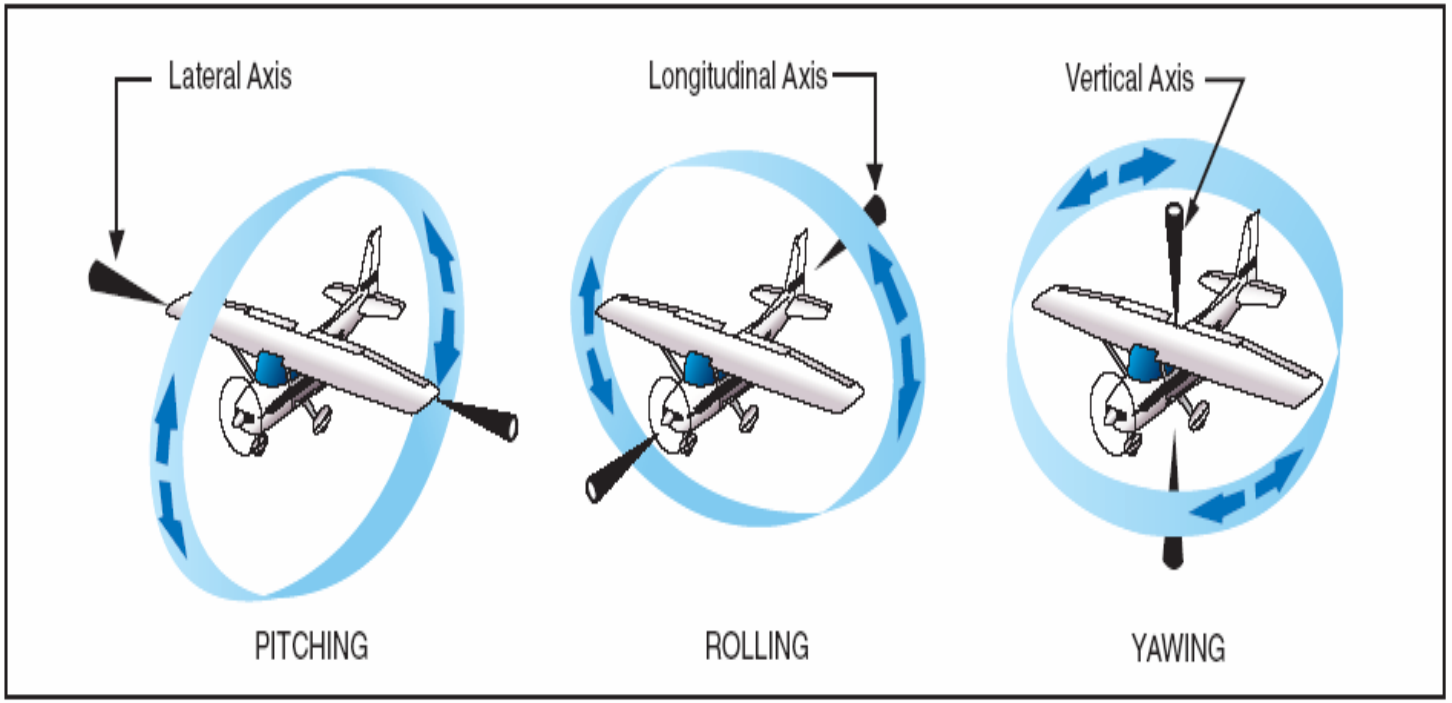


Figure 3-9. Axes of an airplane.

Stability

- Terminology:
  - Stability
  - Maneuverability
  - Controllability

Stability

- Static stability – initial tendency
  - Positive– initially returns to position before displacement
  - Neutral– tendency to remain in displaced position
  - Negative (*bad thing*) – tends to continue away from displaced position in same direction

Stability

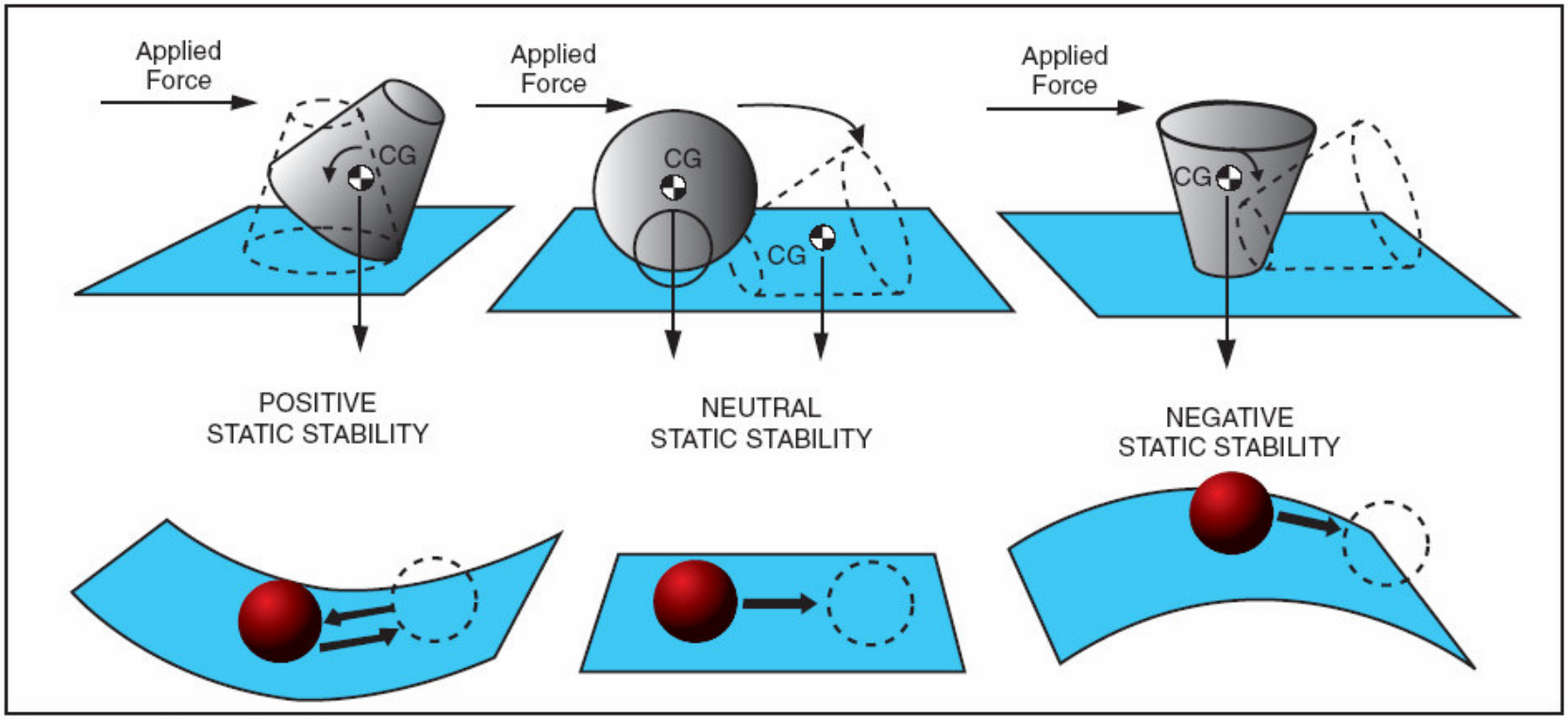
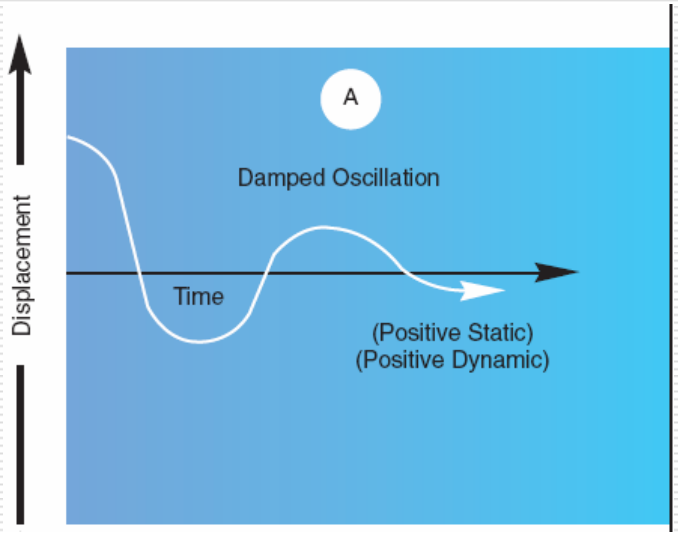


Figure 3-10. Types of stability.

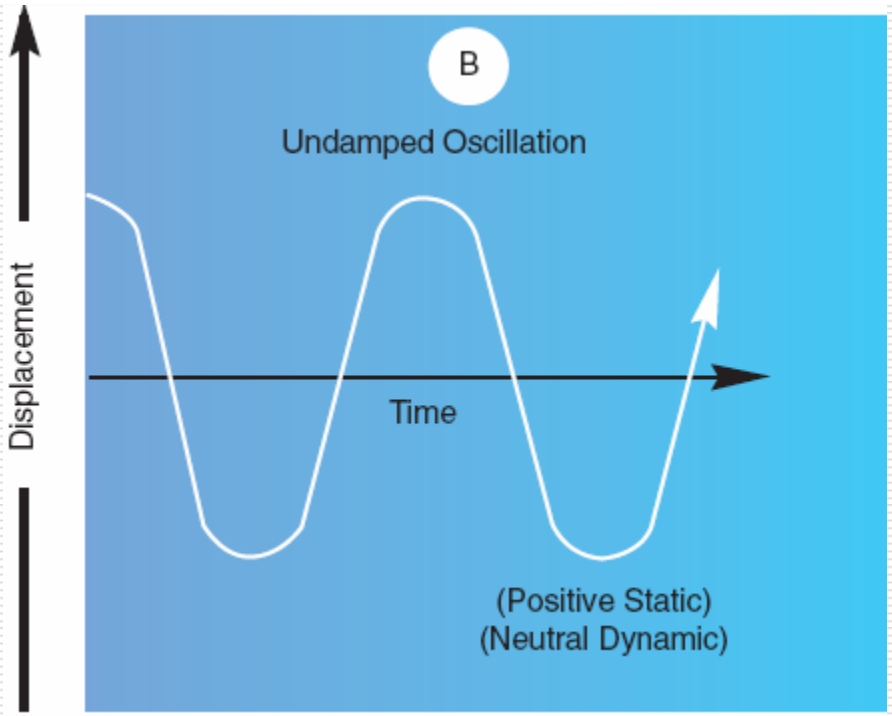
Stability

- Dynamic stability – long-term characteristics of the airplane
  - Positive dynamic stability:
  - Damped oscillations



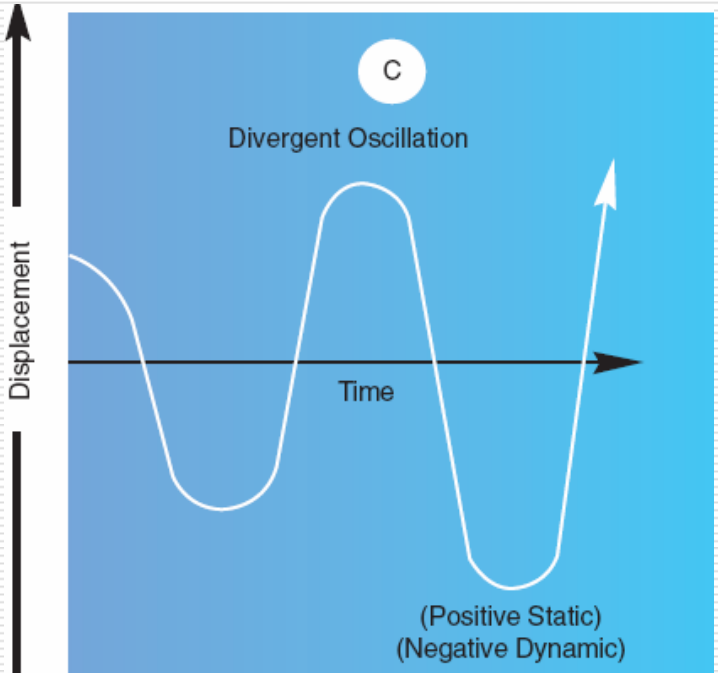
Stability

- Neutral dynamic stability
  - Persistent (phugoid) oscillations



Stability

- Negative dynamic stability
  - Increasing (divergent!) oscillations
  - Avoid at all costs!



Stability – how do we get it?

- Longitudinal (Pitch) Stability

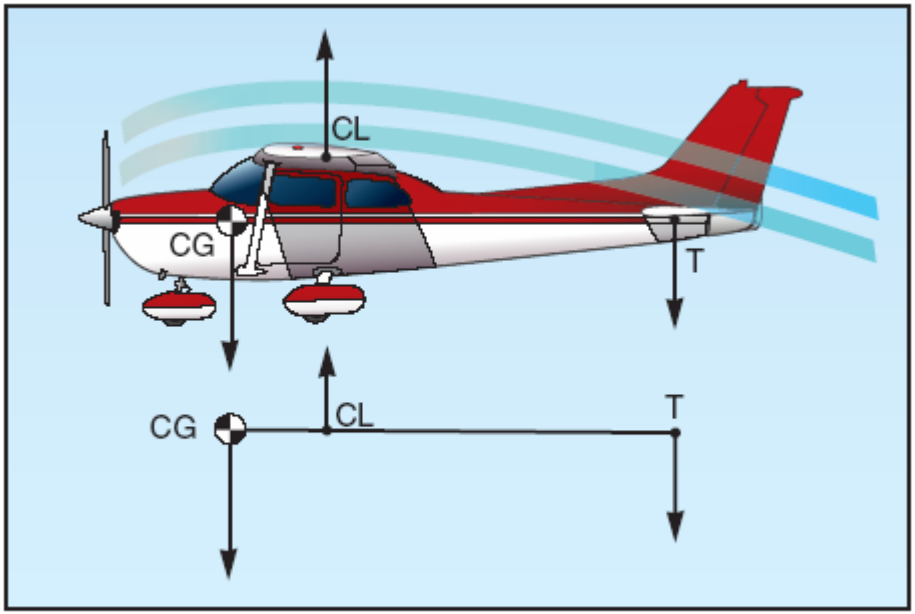


Figure 3-12. Longitudinal stability.

Stability – how do we get it?

- Lateral (roll) stability
  - Dihedral
  - "When the airplane is banked without turning, it tends to sideslip or slide downward toward the lowered wing. Since the wings have dihedral, the air strikes the low wing at much greater angle of attack than the high wing."

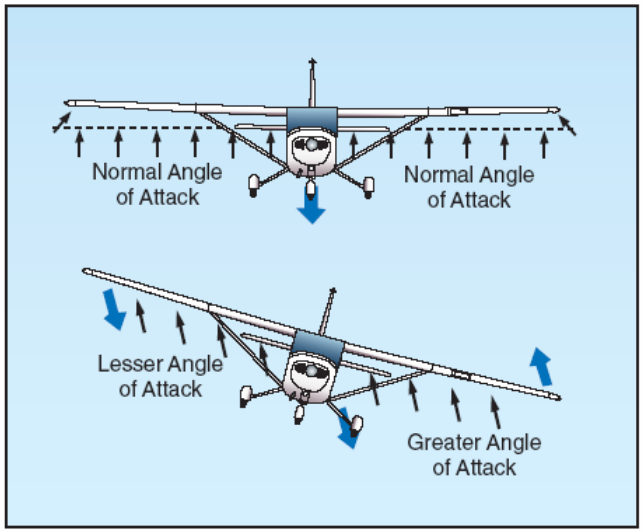
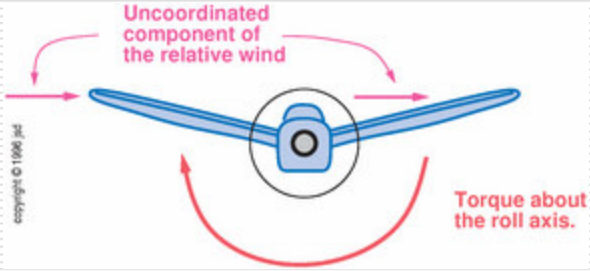


Figure 3-17. Dihedral for lateral stability.



Stability - how do we get it?

- Lateral (roll stability)
  - Keel effect

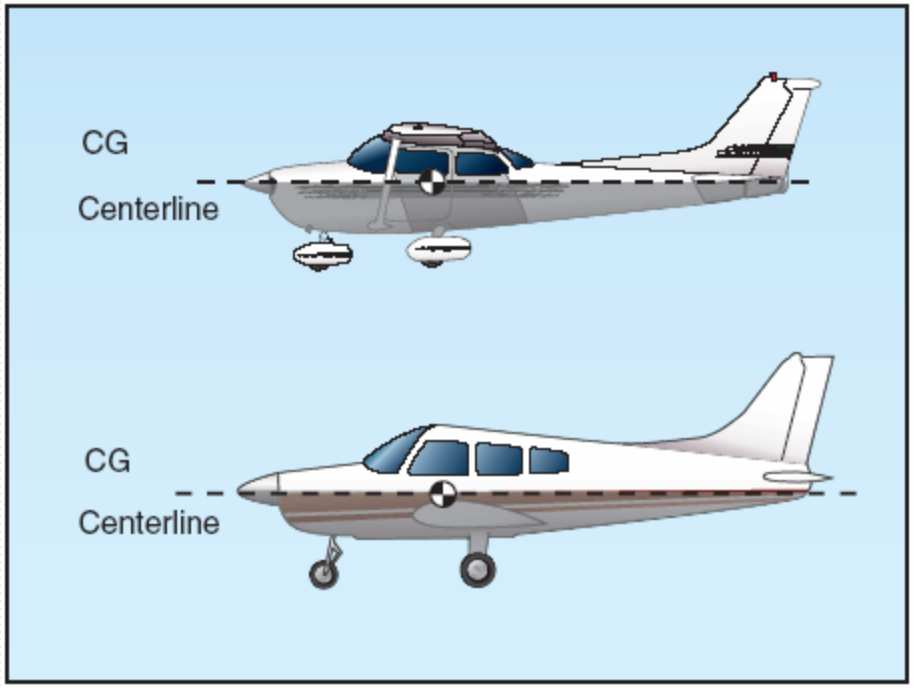


Figure 3-18. Keel area for lateral stability.

Stability - how do we get it?

- Yaw stability
  - Vertical *stabilizer*!

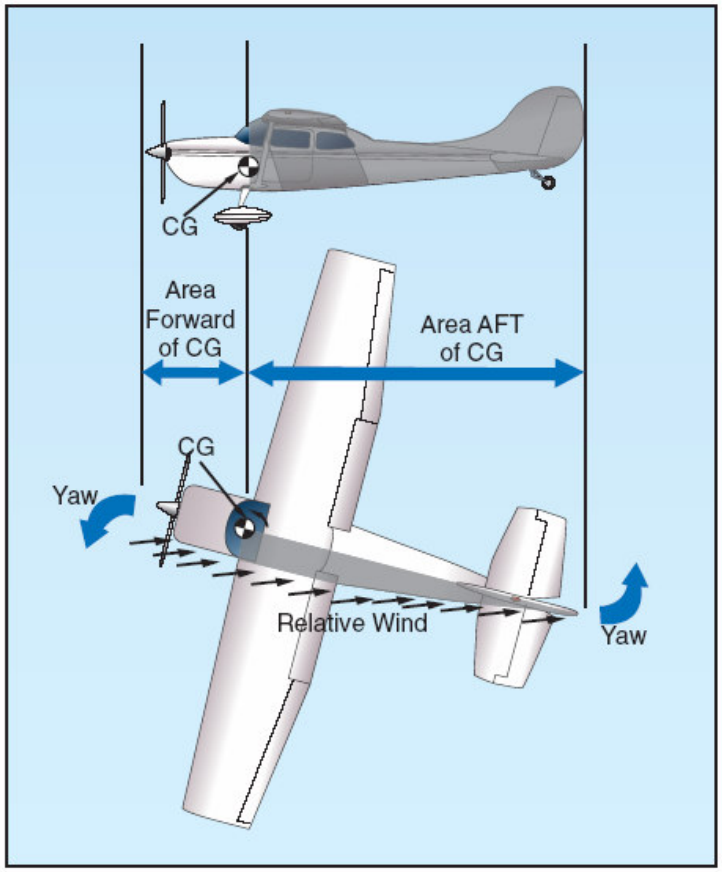


Figure 3-19. Fuselage and fin for vertical stability.

The Turn

- Airplanes turn by creating a horizontal component of lift.
- Airplanes must be banked to turn.

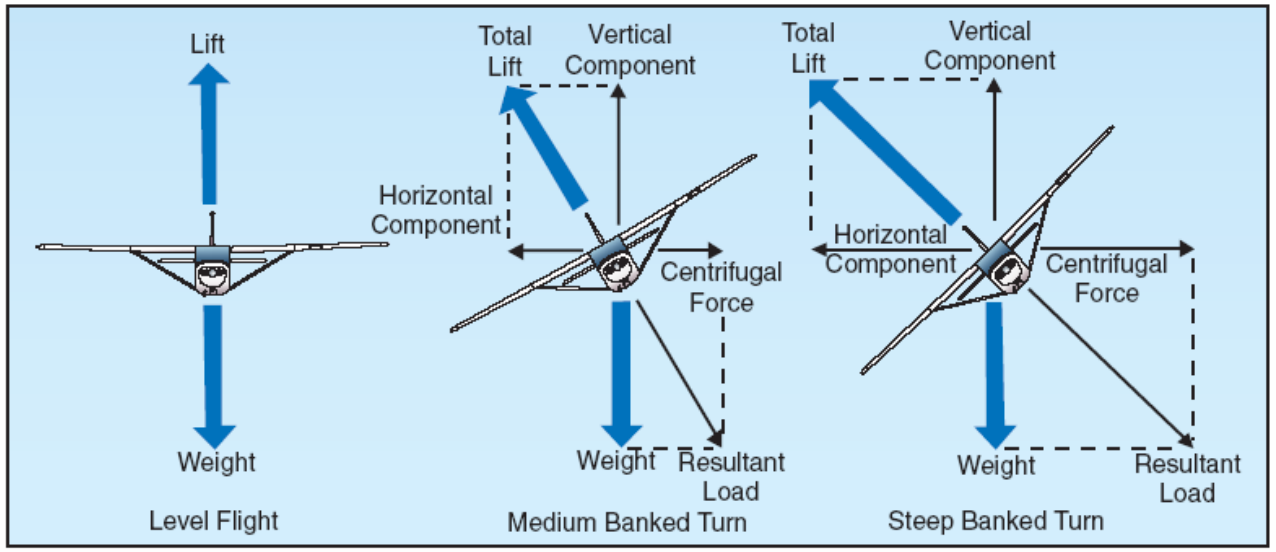


Figure 3-20. Forces during normal coordinated turn.

The Turn

- Total lift must be increased!
  - Increase back pressure during a turn
  - More bank = more back pressure req'd

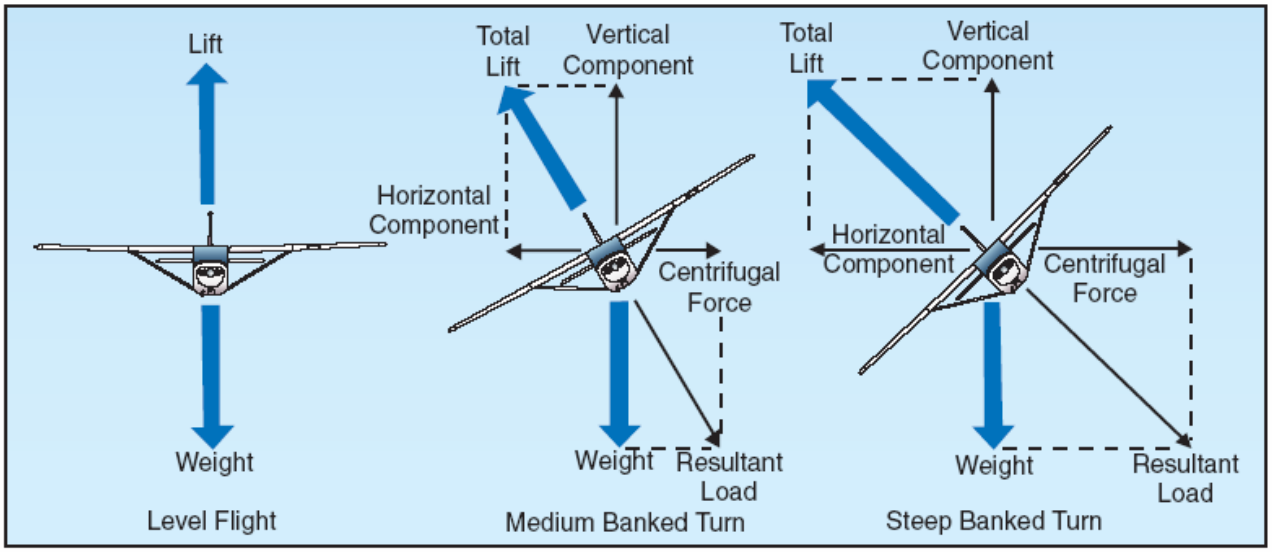
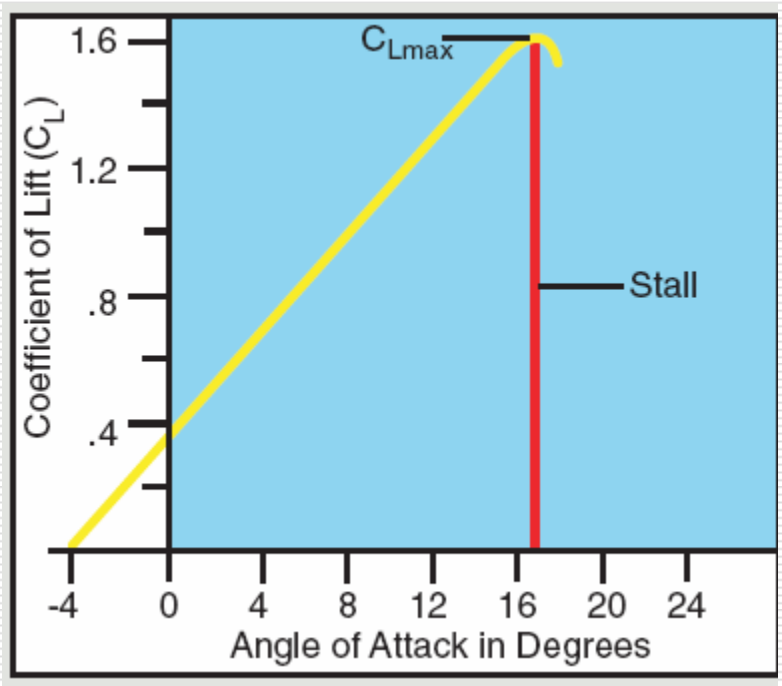


Figure 3-20. Forces during normal coordinated turn.

The stall

- Coefficient of lift
  - An arbitrary airfoil:

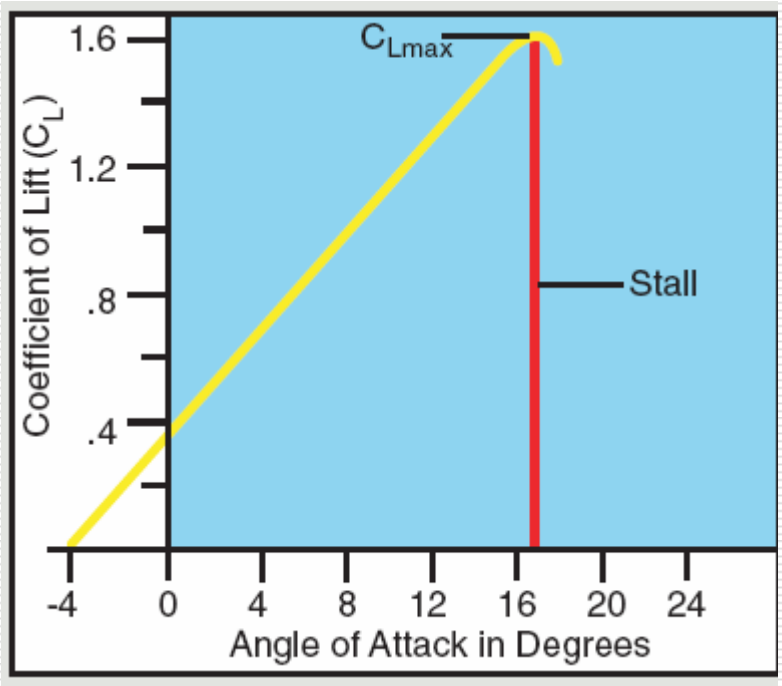


The stall

- Stalls occur by exceeding the critical angle of attack
- ***Stalls can occur at any attitude and any airspeed***
  - "Stall speed" of an aircraft refers to straight-and-level, unaccelerated flight

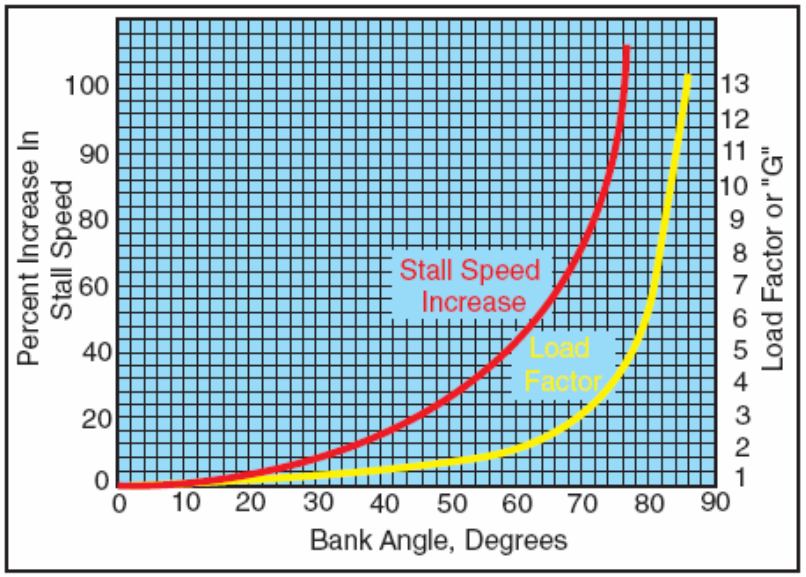
The spin

- The spin is the result of stalling in “uncoordinated” flight. (more later)
- Both wings are stalled…one wing is “more stalled” than the other:



Load Factor

- Ratio of "weight" of the airplane (e.g., on the ground) to lift
- Load factor is 1 in S&L
- Any acceleration affects load factor



Maneuvering Speed (V_A)

- Fastest speed an aircraft can travel when a full deflection of the controls is possible.
- Increases with increased weight (why?)

Turning tendencies

- Torque reaction
- Corkscrewing effect of slipstream
- P-factor (asymmetric disc loading)
- Gyroscopic action of propeller

“Torque Reaction”

- Newton! – Airplane turns propeller, propeller turns airplane
- A left-banking tendency

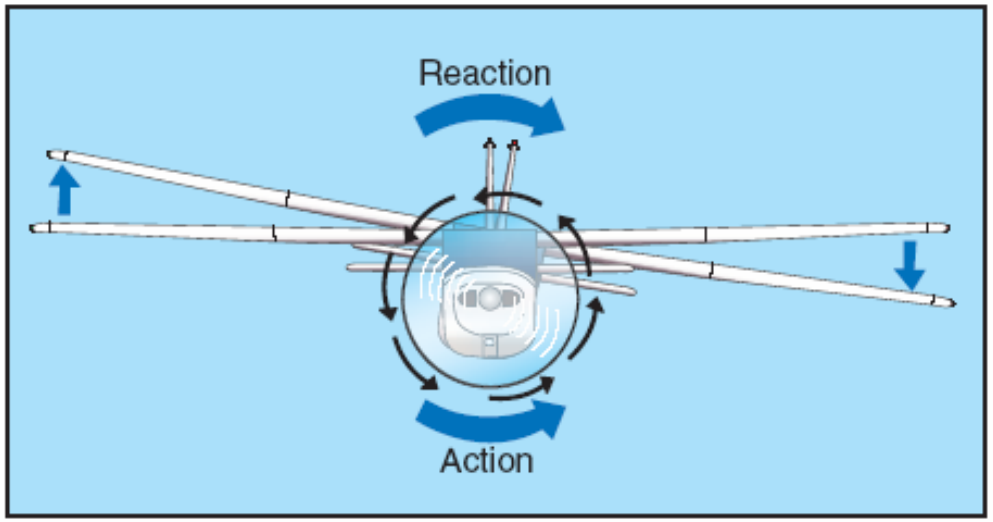


Figure 3-30. Torque reaction.

Corkscrew effect (spiraling slipstream)

- Propwash tends to spiral around fuselage
- Vertical stabilizer is on the top of the airplane, not the bottom
- A left-yawing tendency

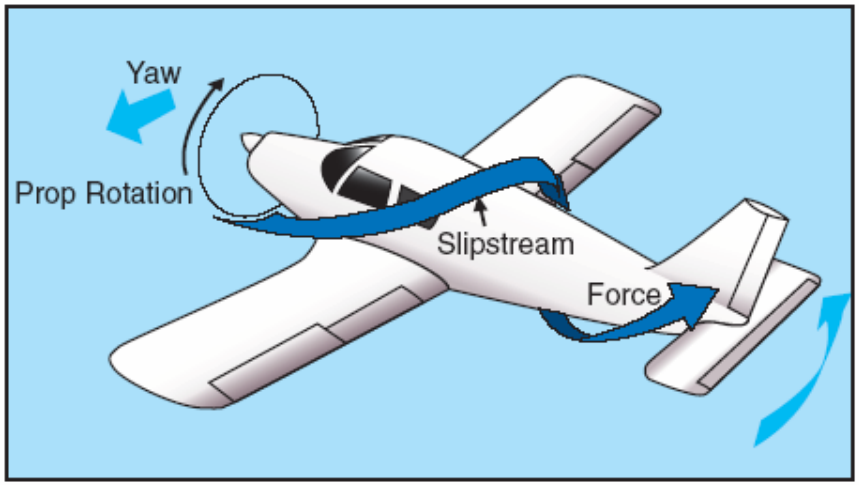
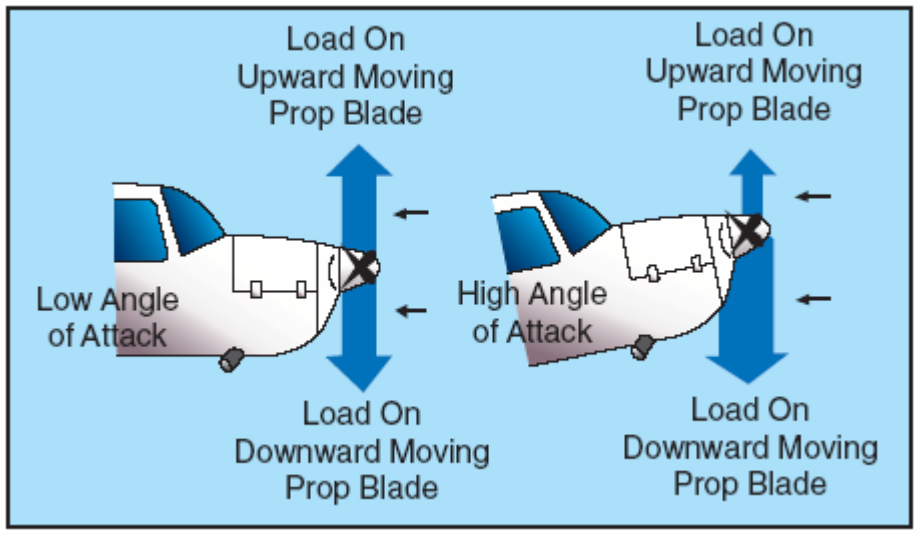


Figure 3-31. Corkscrewing slipstream.

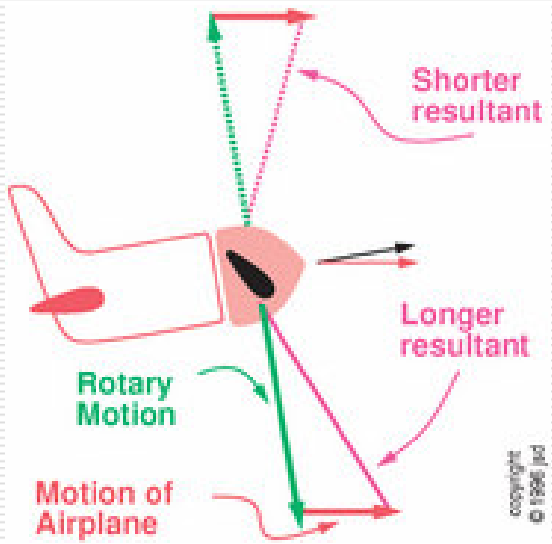
“P-factor”

- Downward moving blade takes a bigger “bite” of air than upward moving blade



P-Factor

- A left-yawing tendency at high angles of attack



Gyroscopic precession

- "90 degrees ahead in the direction of rotation"
- Occurs during *pitching* (e.g. rotation about the lateral axis)
- Right-yaw tendency when the nose is rising
- Left-yaw tendency when the nose is falling

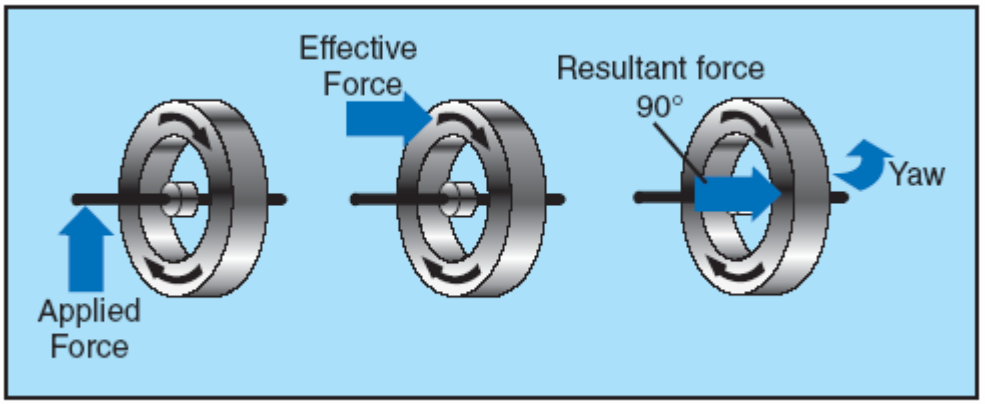


Figure 3-32. Gyroscopic precession.

Gyroscopic precession

- A left-turning tendency during takeoff in taildragger aircraft only.

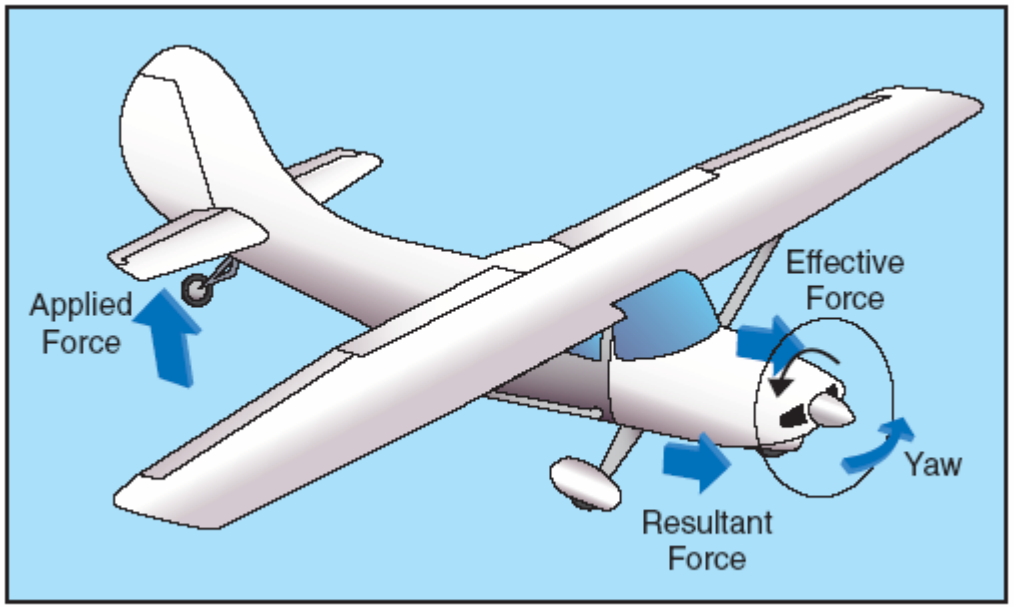


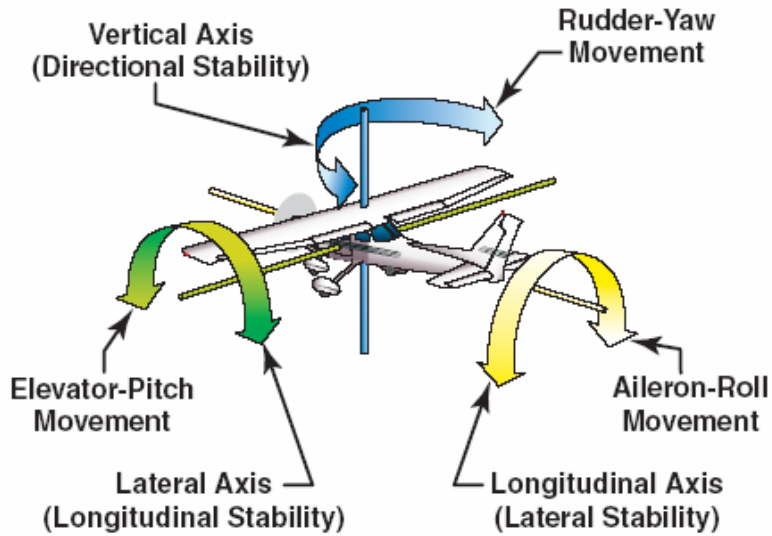
Figure 3-33. Raising tail produces gyroscopic precession.

Weight & Balance

- FAA W&B Handbook:
- http://av-info.faa.gov/data/traininghandbook/faa-s-8083-1.pdf
- Also covered later in *PHAK* and in this course.

Primary Flight Controls

- Aileron
- Elevator
- Rudder



PRIMARY CONTROL SURFACE	AIRPLANE MOVEMENT	AXES OF ROTATION	TYPE OF STABILITY
Aileron	Roll	Longitudinal	Lateral
Elevator/ Stabilator	Pitch	Lateral	Longitudinal
Rudder	Yaw	Vertical	Directional

Adverse Yaw

- What happens when an airplane banks?
- Left-bank: left aileron up, left wing down. Right wing has more lift → more drag!
- Airplane tends to yaw in opposite direction of desired turn.
- Primary function of the rudder is to control yaw.
- Use rudder in the direction of the deflection of the ailerons.

Aerodynamics Questions

3210. An airplane said to be inherently stable will

a) be difficult to stall.

b) require less effort to control.

c) not spin.