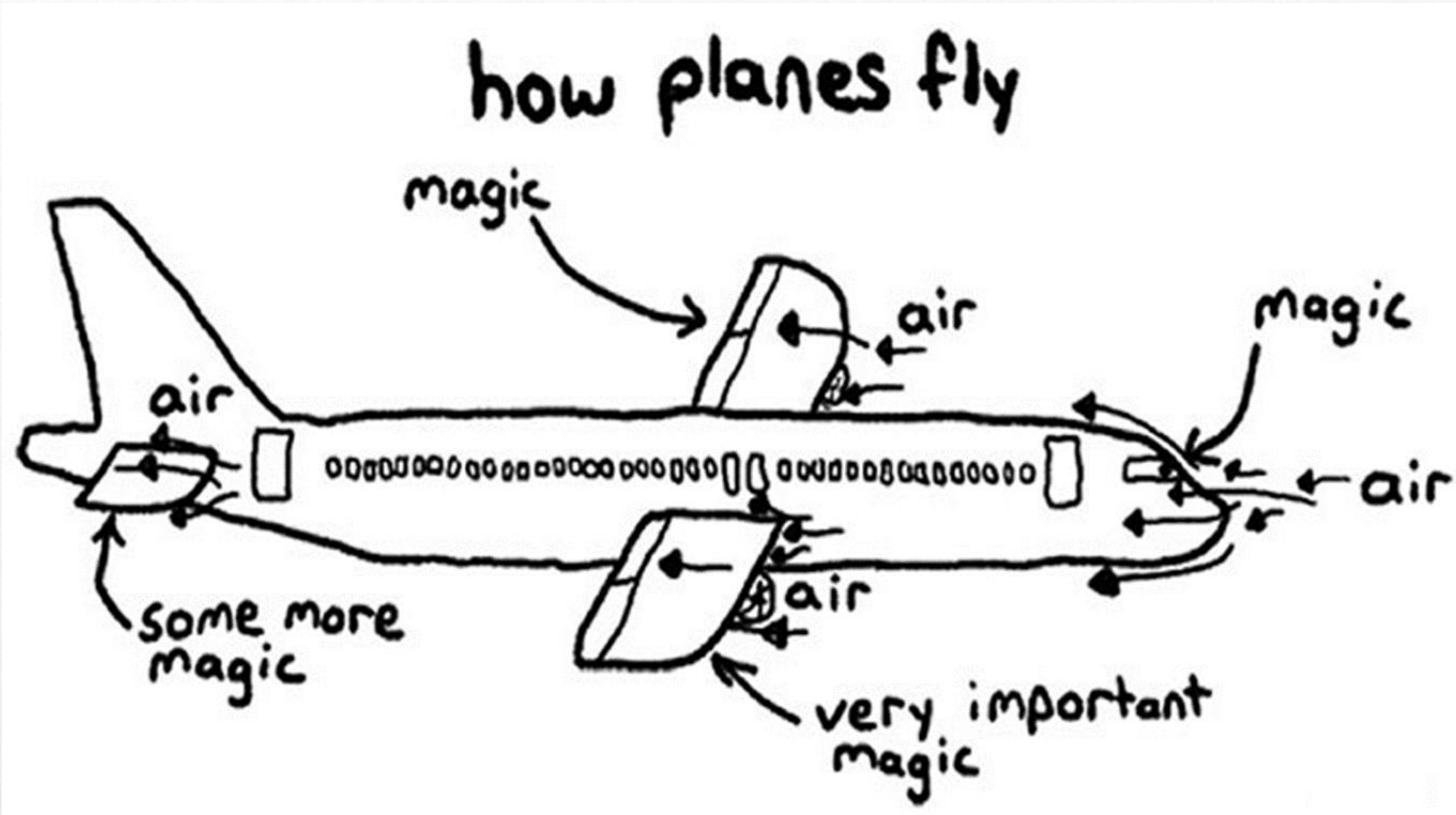
Introduction to Aerodynamics for Flight


how planes fly
magic
air
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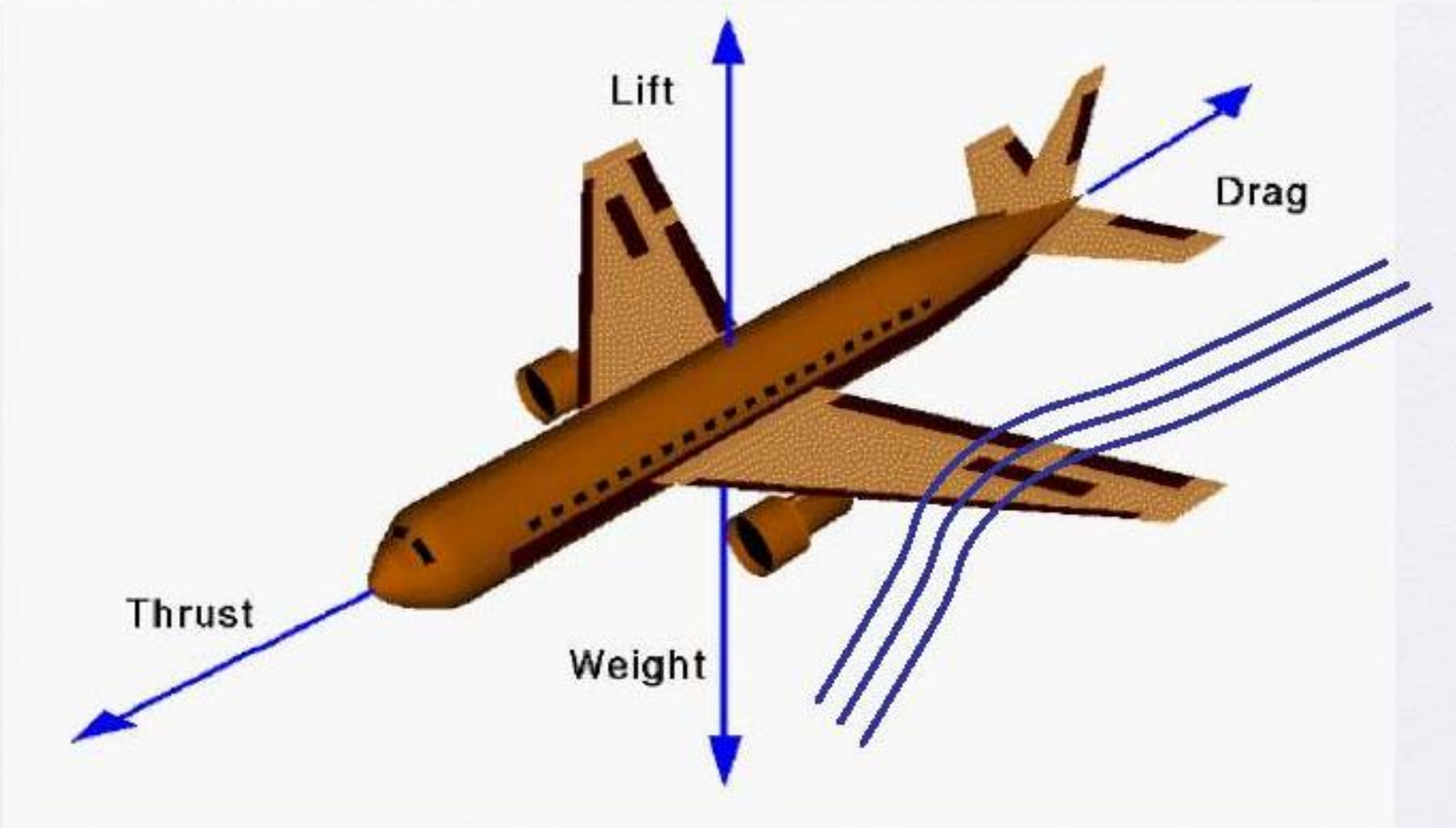
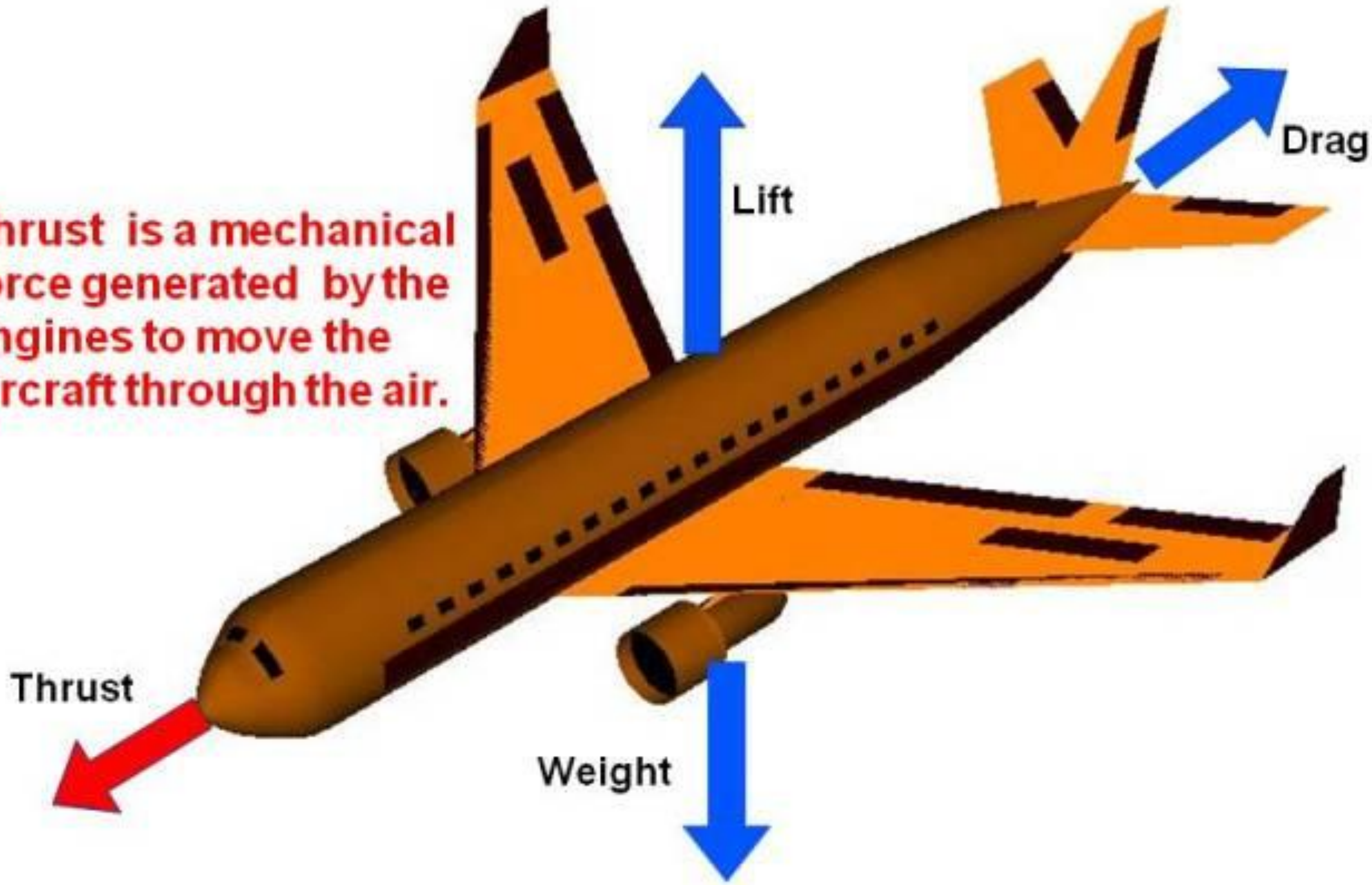
some more magic
very important magic

Four Forces Acting on an Airplane

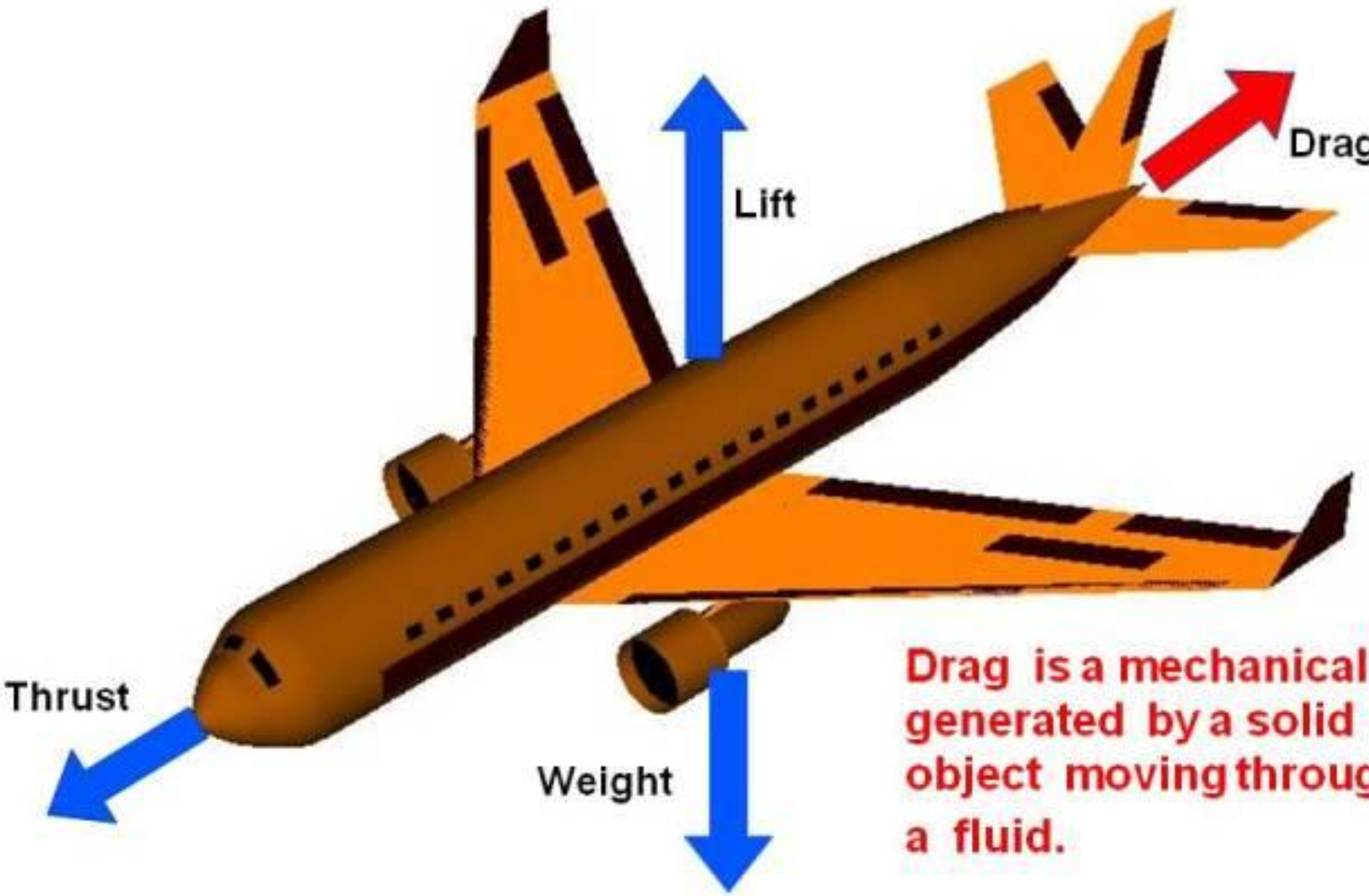


What is Thrust ?

Thrust is a mechanical force generated by the engines to move the aircraft through the air.

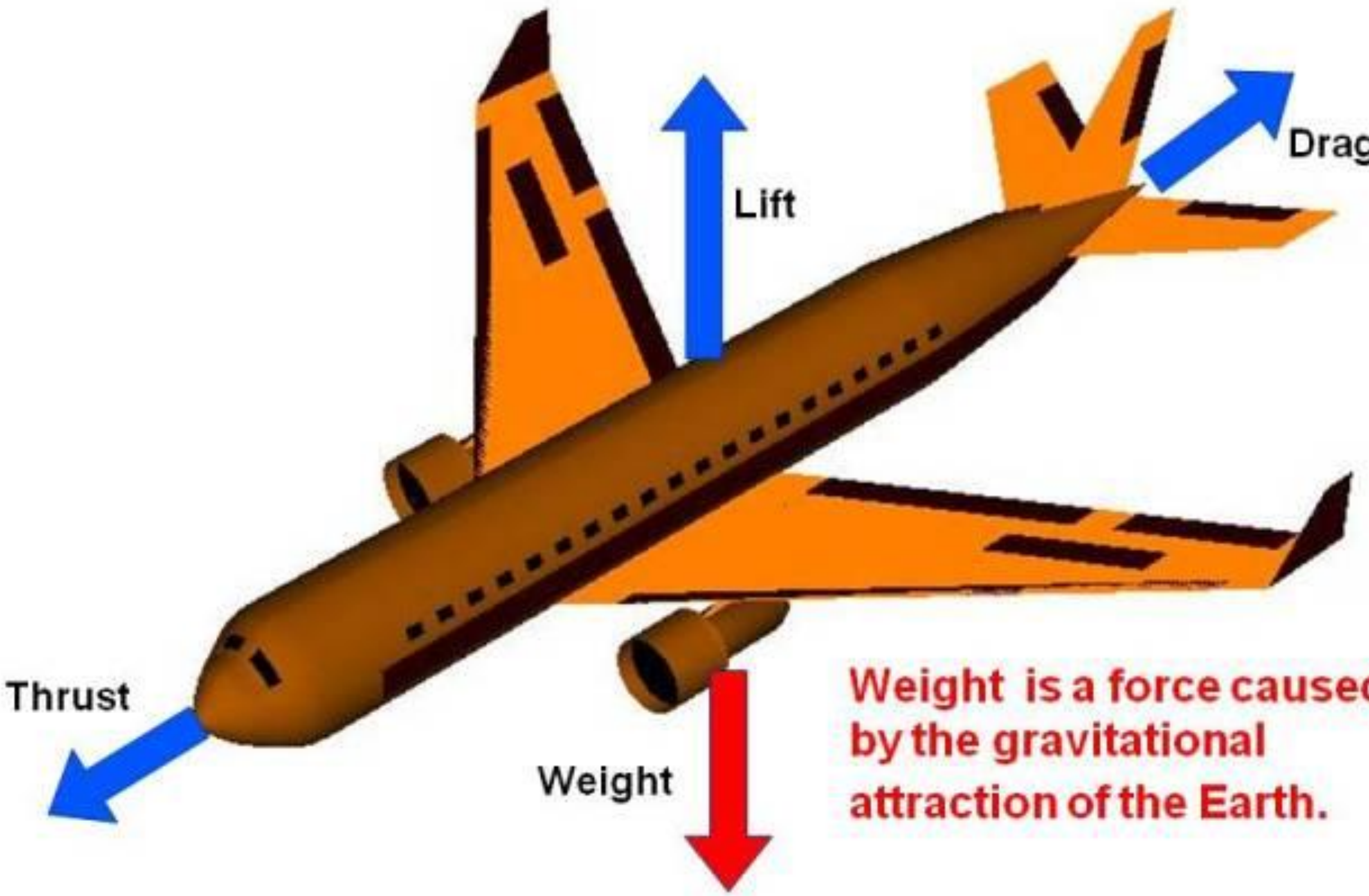


What is Drag ?



Drag is a mechanical force generated by a solid object moving through a fluid.

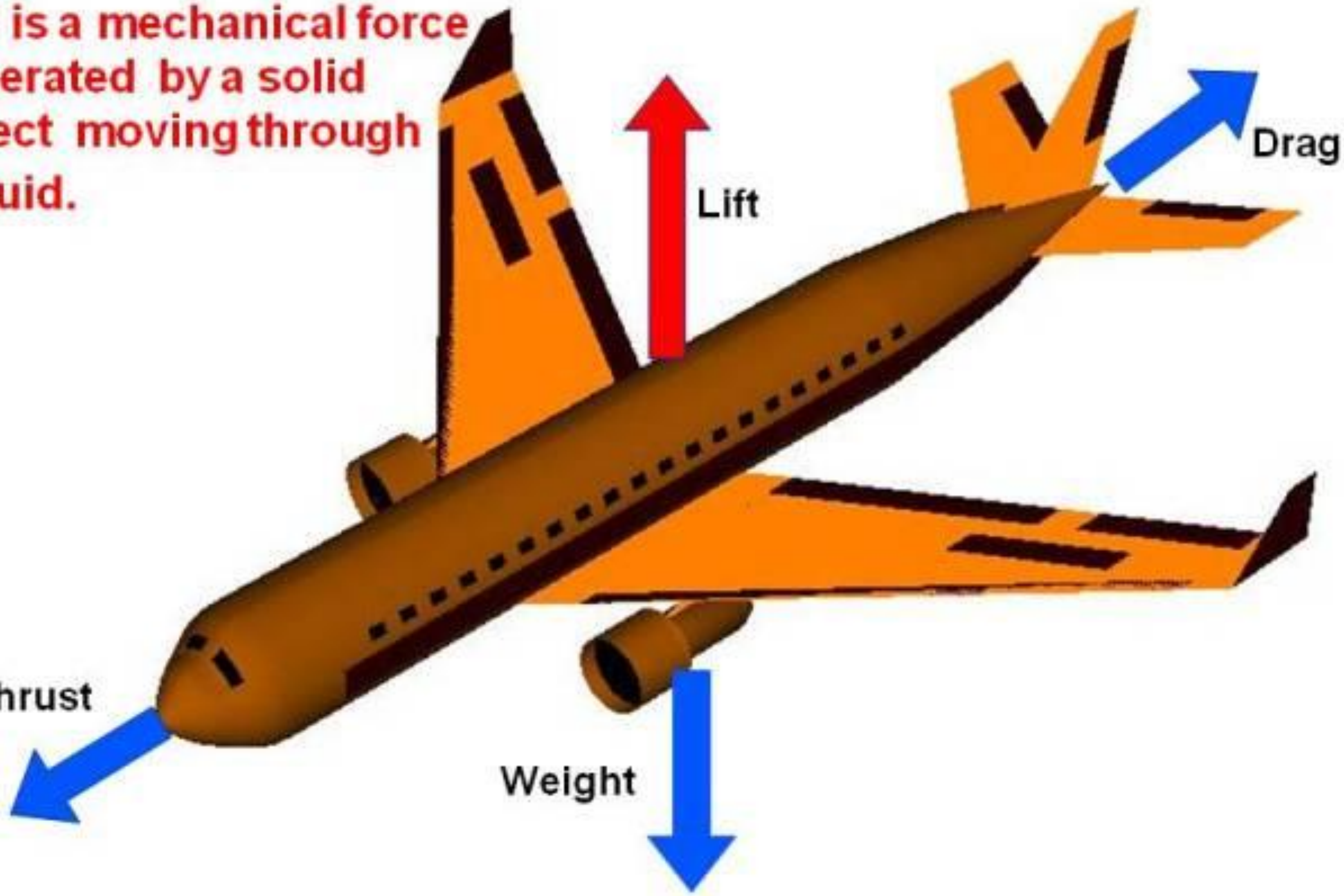
What is Weight ?



Weight is a force caused by the gravitational attraction of the Earth.

What is Lift ?

Lift is a mechanical force generated by a solid object moving through a fluid.



Aerodynamics-Basics

These fundamental basics first must be acknowledged:

- Air is a fluid. It can be compressed and expanded.
- Like liquids (hydrodynamics), air (aerodynamics) is affected by the Coanda Effect ,Venturi/Bernoulli's Principle, and Newton's Laws of Motion (mainly the 3rd law).

Coanda Effect

Because air is a fluid, it utilizes the properties of the Coanda Effect: The tendency for a fluid to follow the object along its flow path.

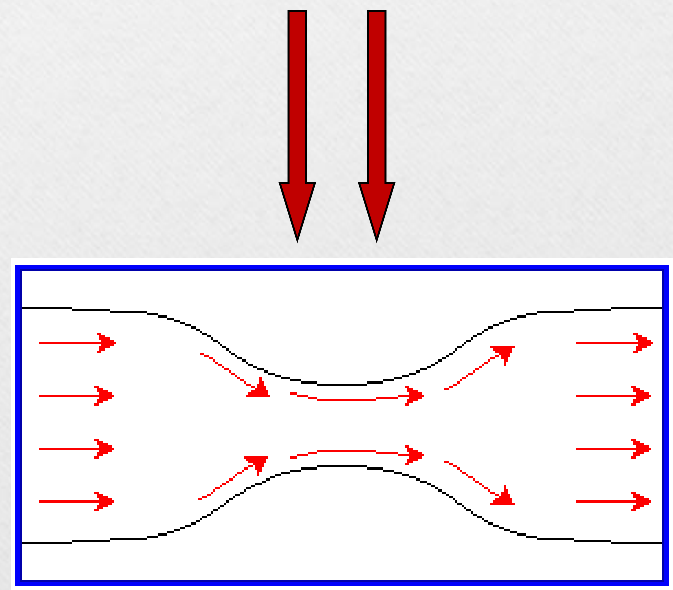
http://www.youtube.com/watch?v=AvLwqRCbGKY

Bernoulli’s Principle

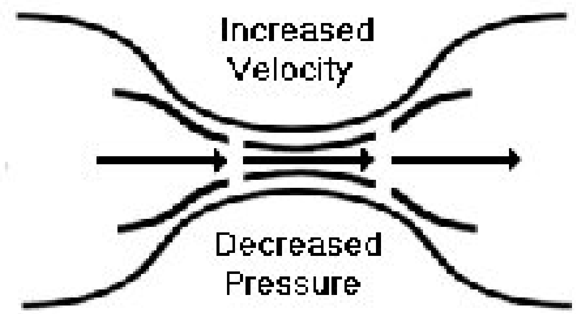
Bernoulli’s Principle of Pressure:

An increase in the speed of movement or flow will cause a decrease in the fluid’s pressure. - Example: the Venturi tube

High Velocity =
Low Static Pressure

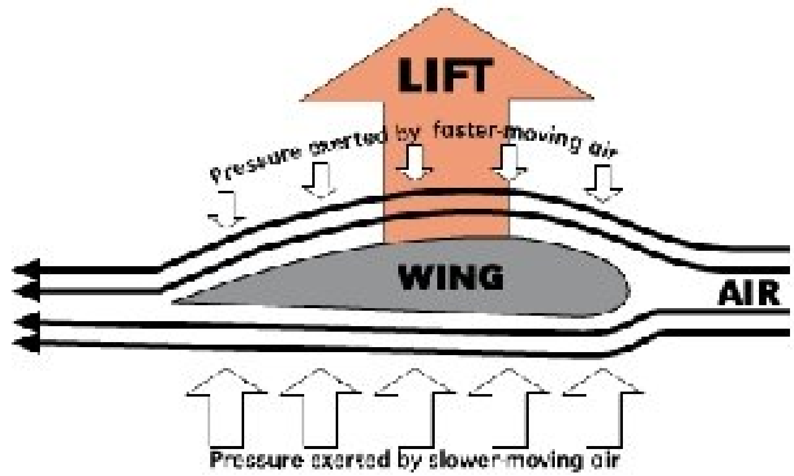


Bernoulli's Principle



The velocity can be increased by pushing the air over or through a CONSTRICTION

A change in pressure results in a NET FORCE towards the low pressure region.



Newton's Laws of Motion

https://www1.grc.nasa.gov/beginners-guide-to-aeronautics/newtons-laws-of-motion/#what-are-newtons-laws-of-motion

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Law 1 – A body at rest will remain at rest. A body in motion will remain in motion.

- The motion of an airplane when a pilot changes the throttle setting of an engine.

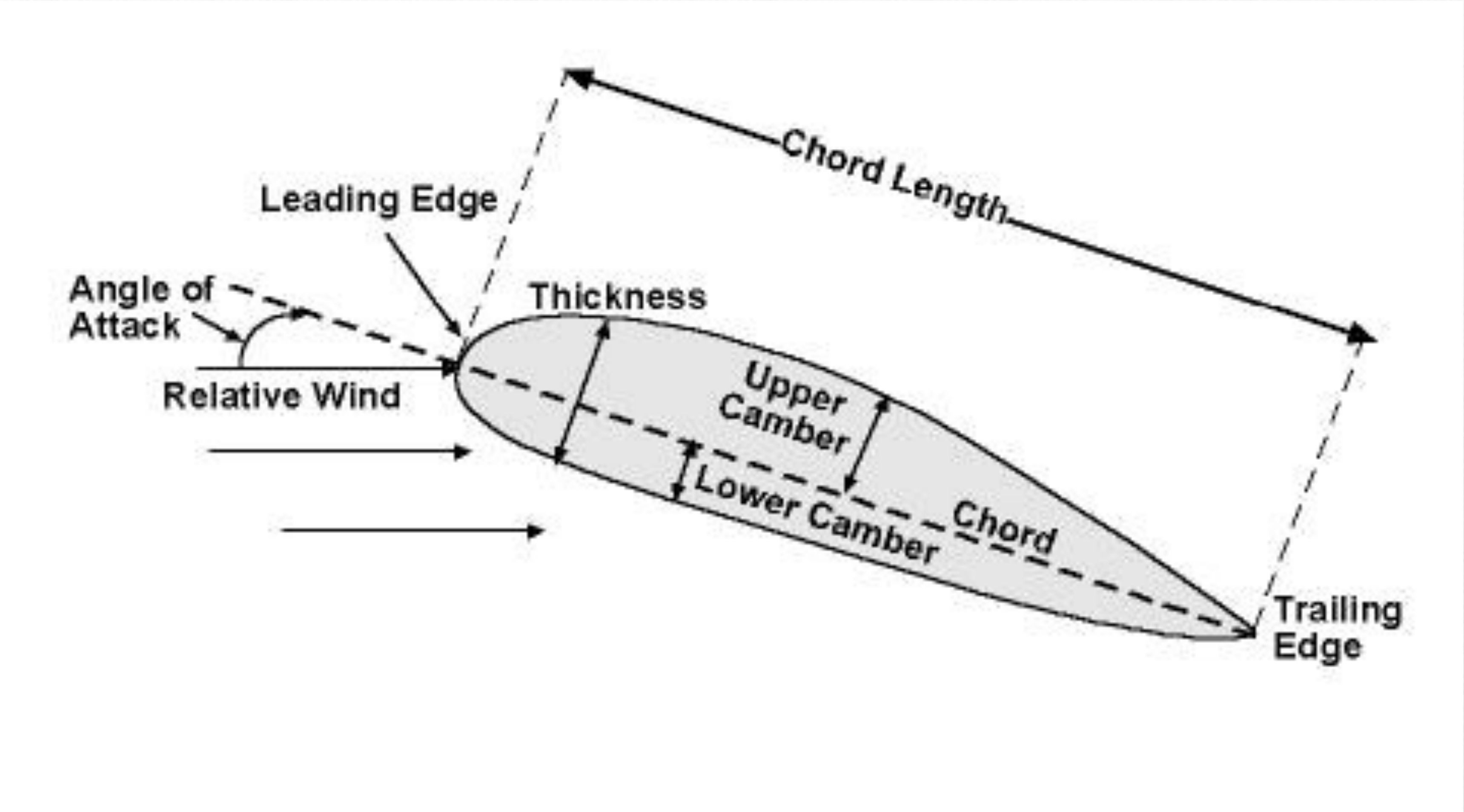
Law 2 – F=MA Force is equal to mass times acceleration.

- An aircraft's motion resulting from aerodynamic forces, aircraft weight, and thrust.

Law 3 – For every action there is an equal and opposite reaction.

- The motion of lift from an airfoil, the air is deflected downward by the airfoil's action and, in reaction, the wing is pushed upward.
- The motion of a jet engine produces thrust and hot exhaust gases flow out the back of the engine, and a thrusting force is produced in the opposite direction.

Airfoil Terminology



- Chord line=the line from the leading edge of the wing to the trailing edge.
- Relative wind=perpendicular to lift, relative to the airfoil.

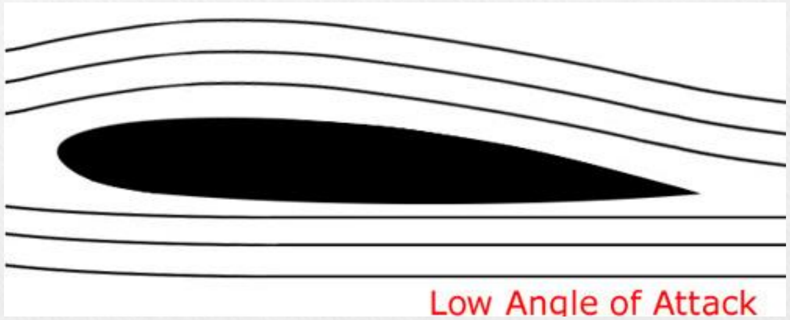
Stalls

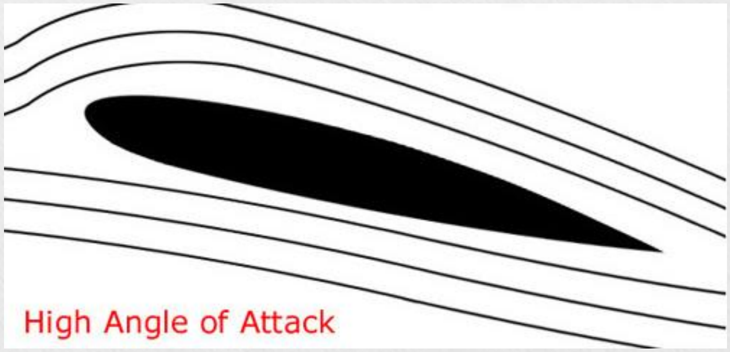
What is angle of attack?

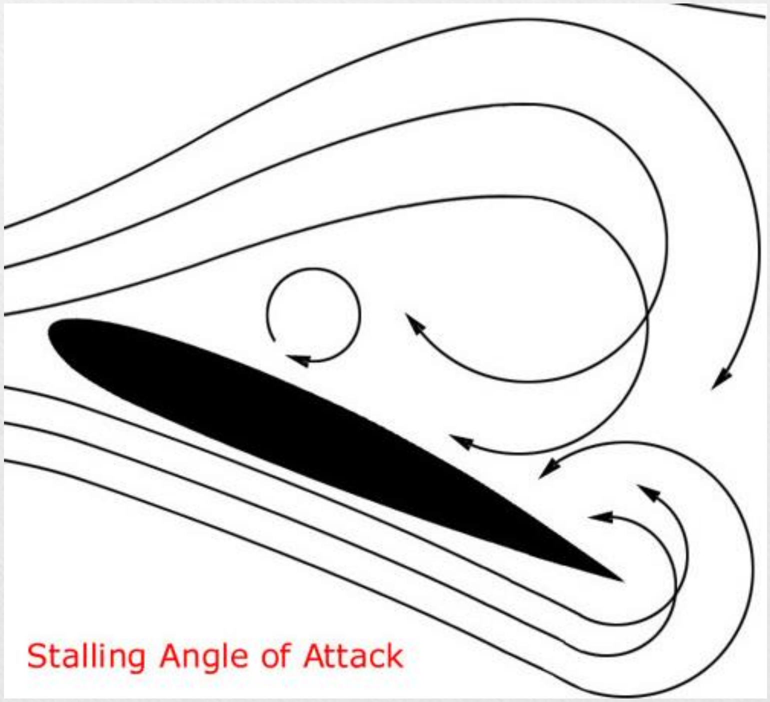
Angle of attack is the angle between the chord line and the relative wind.

When does an airplane stall?

When it exceeds the critical angle of attack.







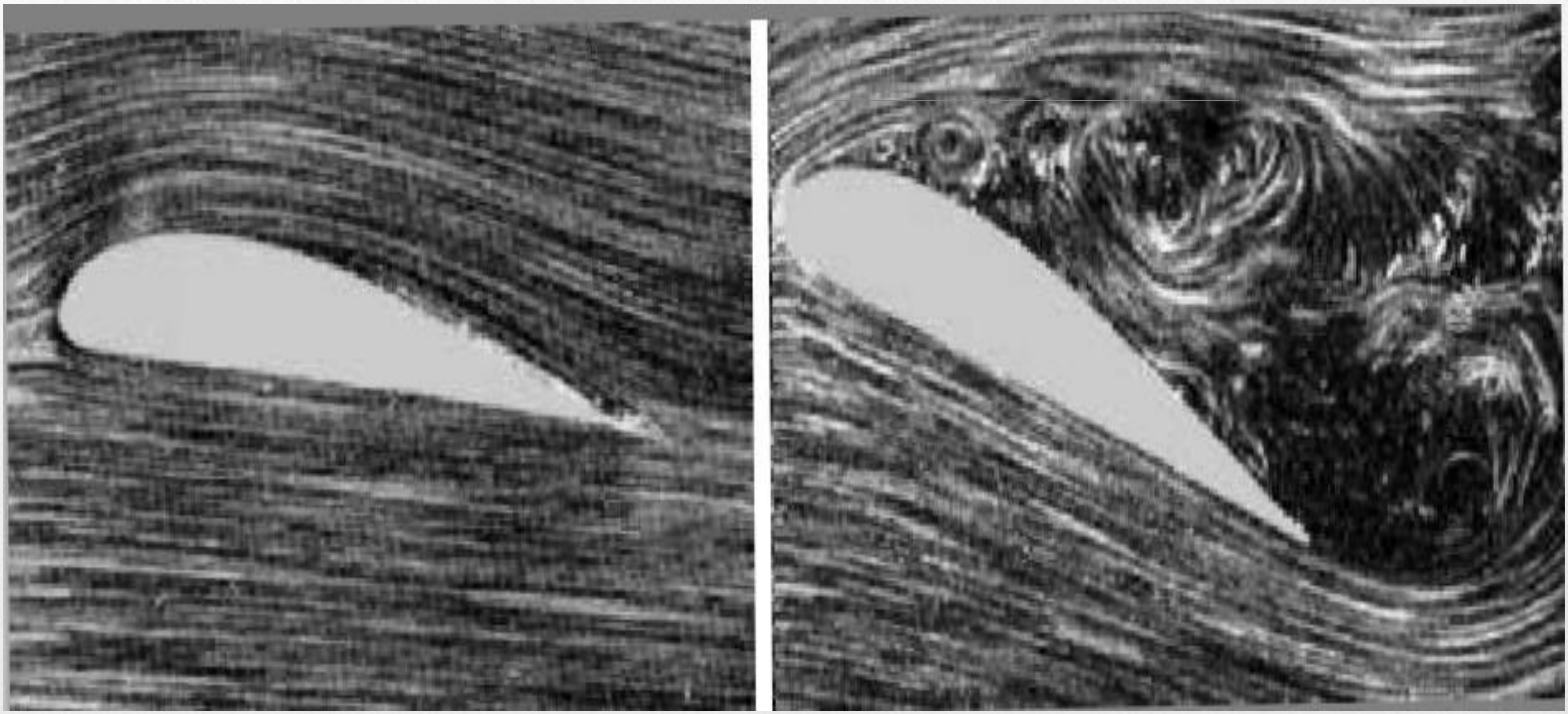
Stalls

A stall occurs first at the wing root, then works out toward the tip. This design characteristic is so that you still maintain aileron control as long as possible.

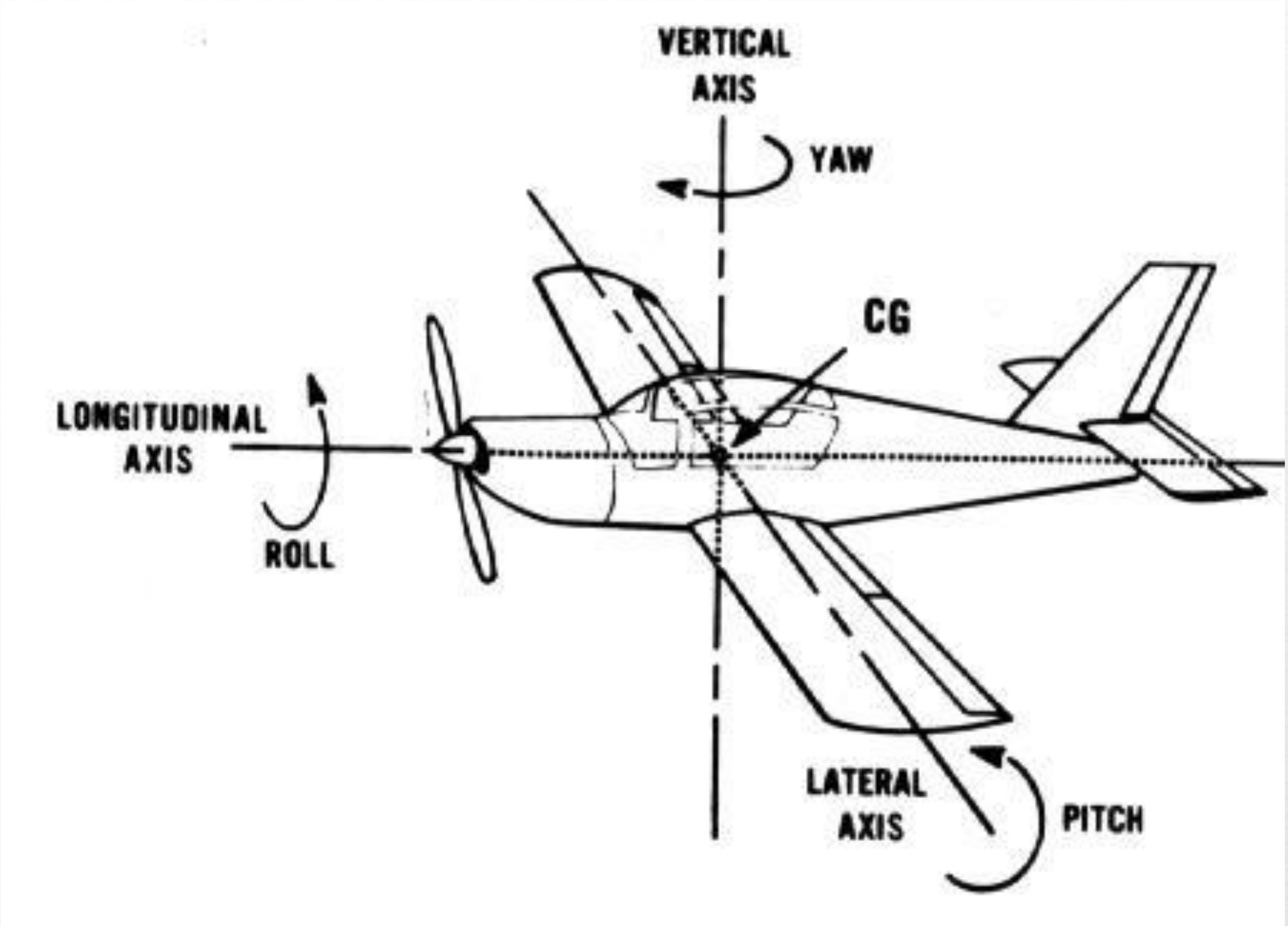
Regardless of airspeed, the plane will ALWAYS stall when the critical angle of attack is exceeded.

https://www.youtube.com/watch?v=AzSZIVEQAnQ

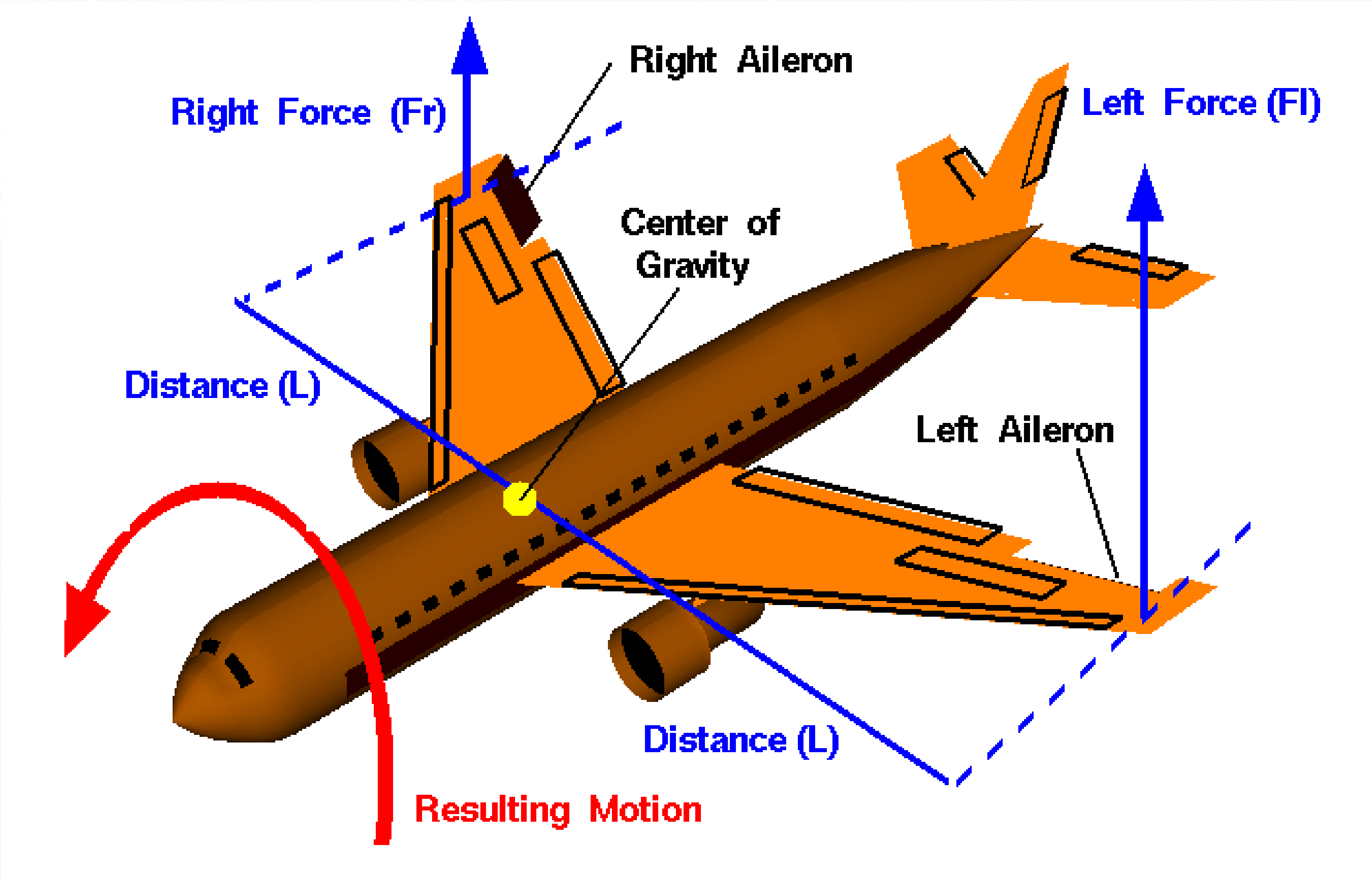
Stall & Separation



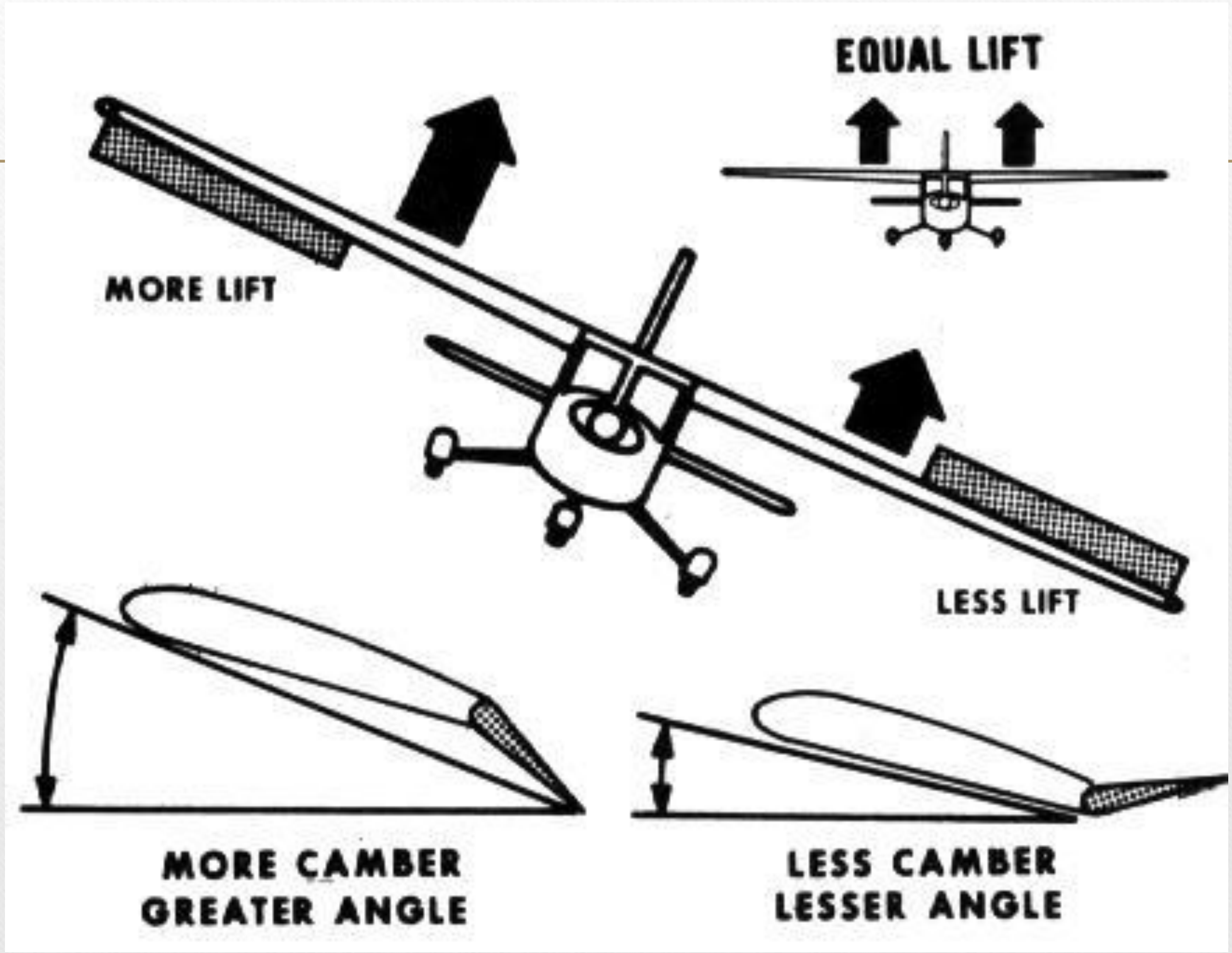
Aircraft Axes



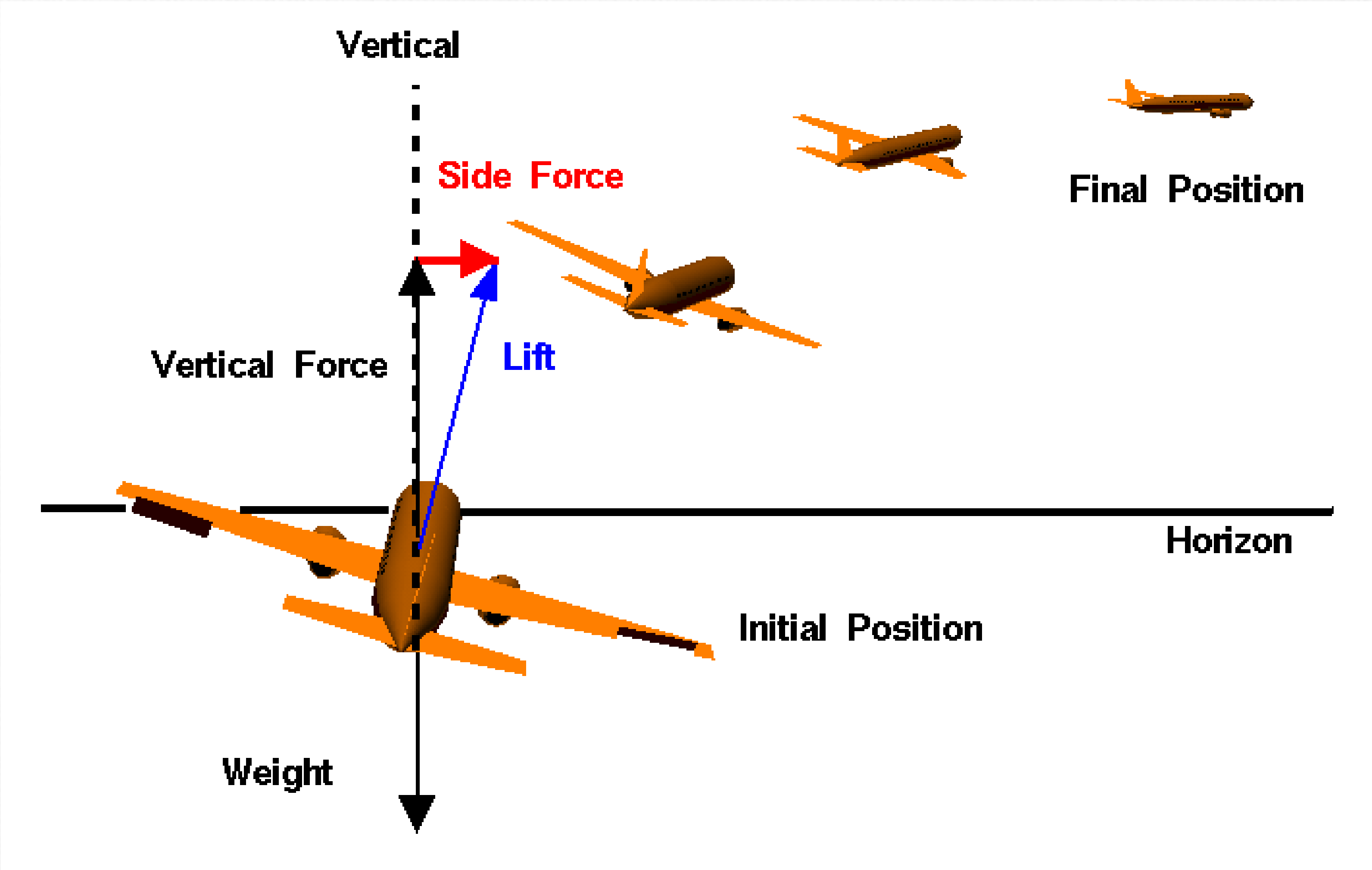
Banking Turns-Ailerons



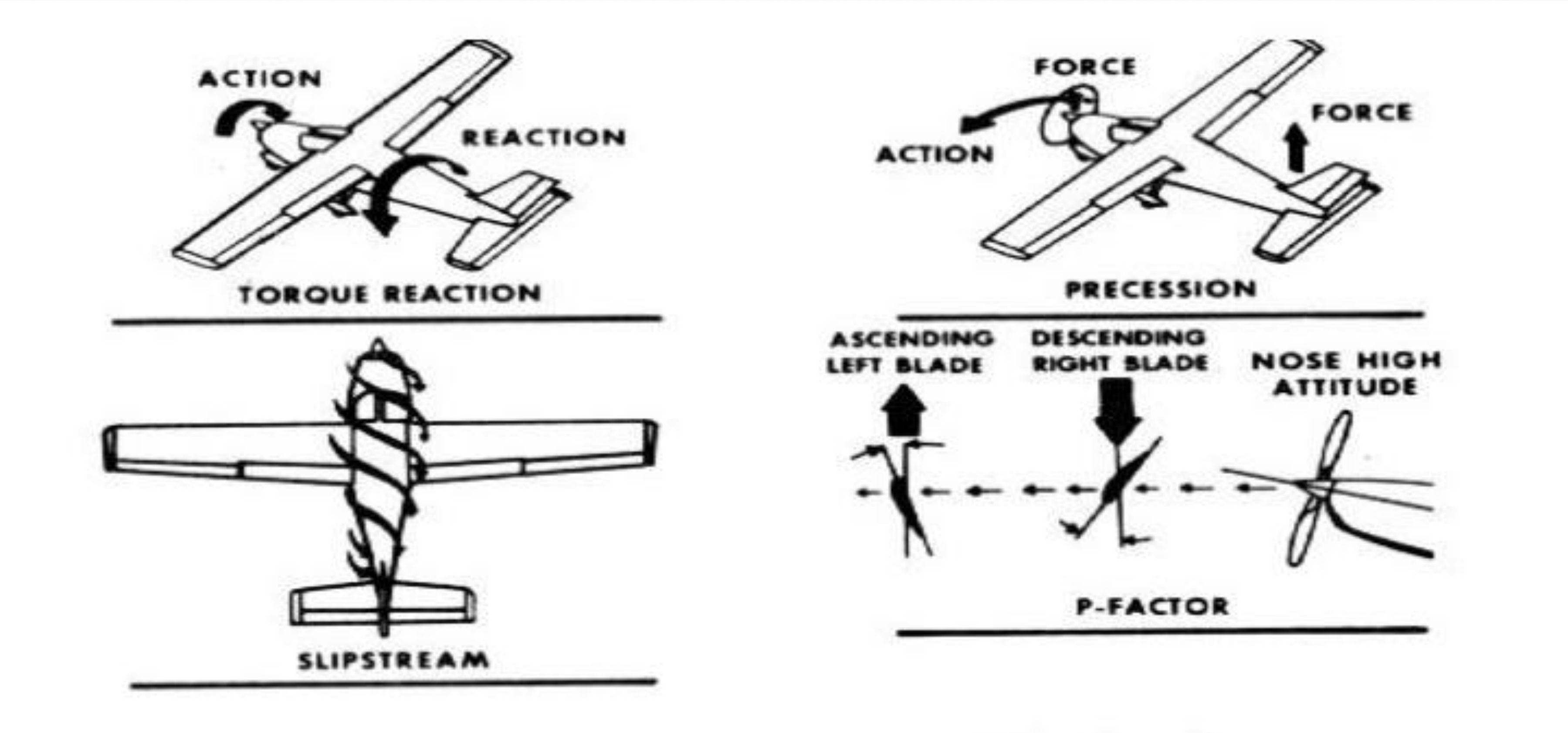
Banking Turns-Ailerons



Banking Turns-Ailerons
Vertical Component of Lift ➡ Horizontal Elevator Usage

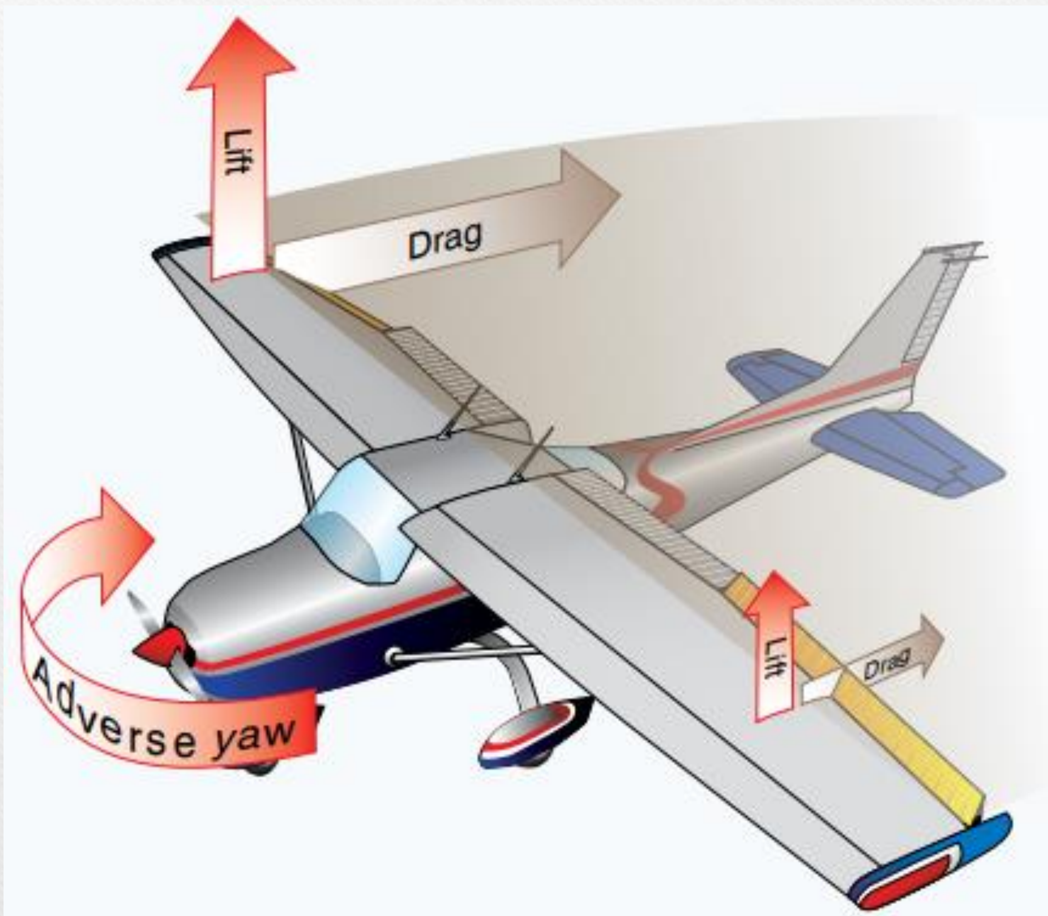


Coordinating Turns-Rudder
Left Turning Tendencies



Coordinating Turns-Rudder Adverse Yaw

Adverse yaw is caused by higher drag on the outside wing that is producing more lift.



Ailerons & Rudder

Turns-Review & Links

- A fundamental aircraft motion is a **banking turn**. This maneuver is used to change the aircraft heading. The turn is initiated by using the ailerons to roll, or bank, the aircraft to one side. On the figure, the airliner is banked to the right by lowering the left aileron and raising the right aileron. The lift of the wings of the aircraft is a vector quantity which is always directed perpendicular to the flight path and perpendicular to the wings generating the lift. As the aircraft is rolled, the lift vector is tilted in the direction of the roll. We can break the lift vector into two components. One component is vertical and opposed to the weight which is always directed towards the center of the earth. The other component is an unopposed side force which is in the direction of the roll, and perpendicular to the flight path.
- As long as the aircraft is banked, the side force is a constant, unopposed force on the aircraft. The resulting motion of the center of gravity of the aircraft is a circular arc. When the wings are brought level by an opposing motion of the ailerons, the side force is eliminated and the aircraft continues to fly in a straight line along a new heading. Notice that the rudder is not used to turn the aircraft. The aircraft is turned through the action of the side component of the lift force. The rudder is used during the turn to **coordinate** the turn, i.e. to keep the nose of the aircraft pointed along the flight path. If the rudder is not used, one can encounter an **adverse yaw** in which the drag on the outer wing pulls the aircraft nose away from the flight path.

Maneuverability, Controllability, & Stability

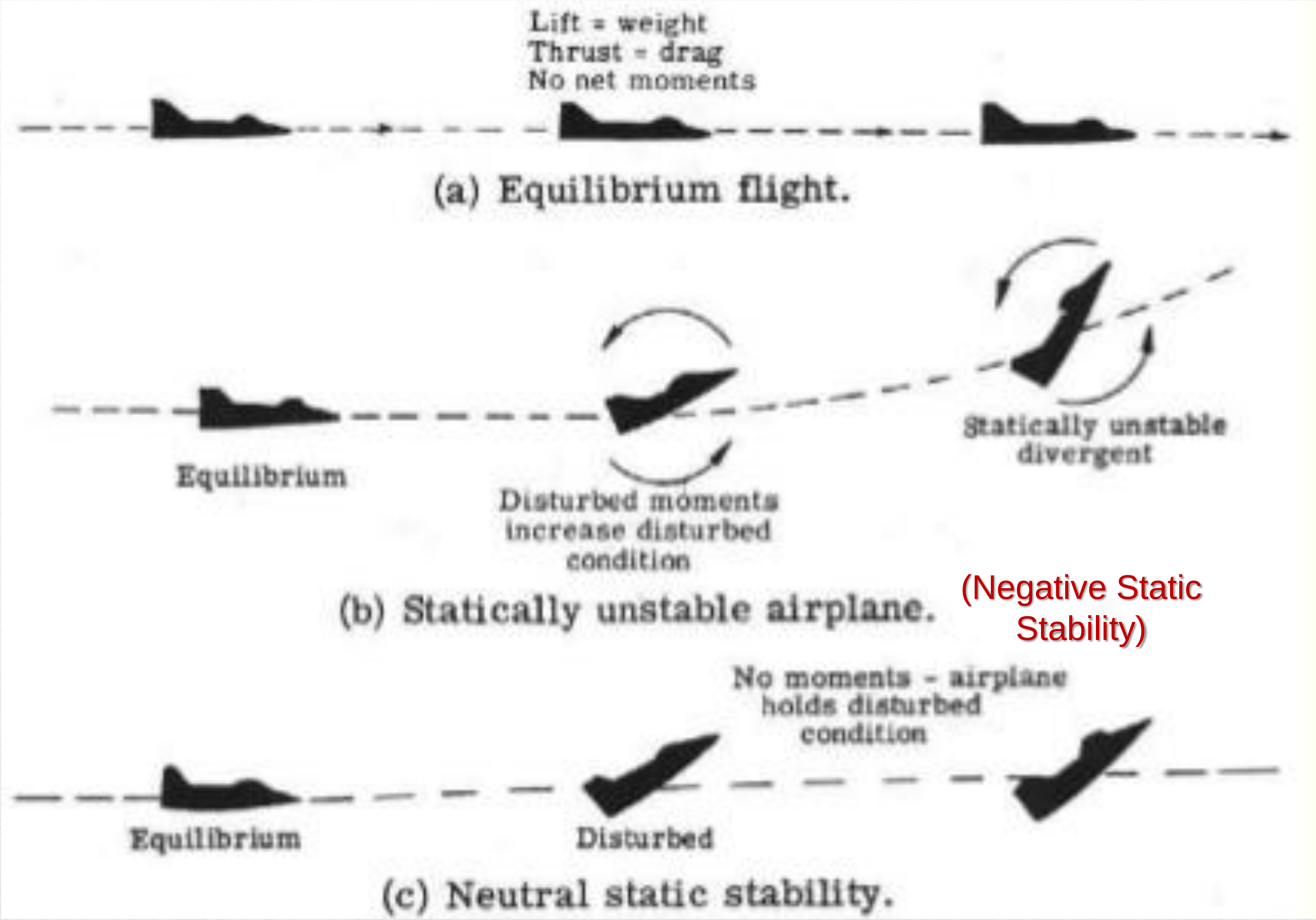
- **Maneuverability**=the ability to change attitude and withstand stresses.
- **Controllability**=the aircraft's response to pilot inputs
- **Stability**=the tendency to correct back to the original state.

Types of Stability: Static & Dynamic

- Static- the aircraft’s initial response.
- Dynamic-the response over a period of time.

- **Static Stability (initial tendency)**
  - Positive Static=immediately return to the original state.
  - Negative Static=continue away from the original state.
  - Neutral Static=remain in the new position.
- **Dynamic Stability (over time)**
  - Positive Dynamic=returns to original state.
  - Negative Dynamic=continues going away, becomes more divergent if displaced.
  - Neutral Dynamic-Once displaced, the plane neither increases or decreases in amplitude, stays the same.

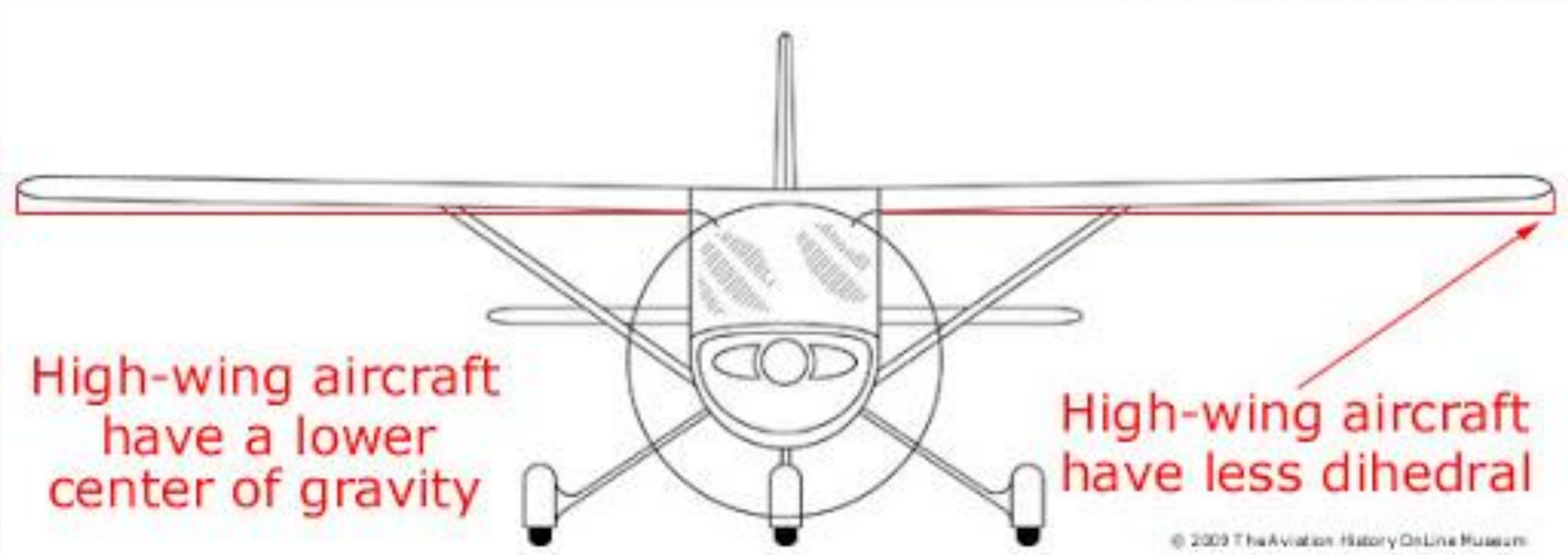
Aircraft Stability



(Negative Static Stability)

Wing Dihedral & Stability

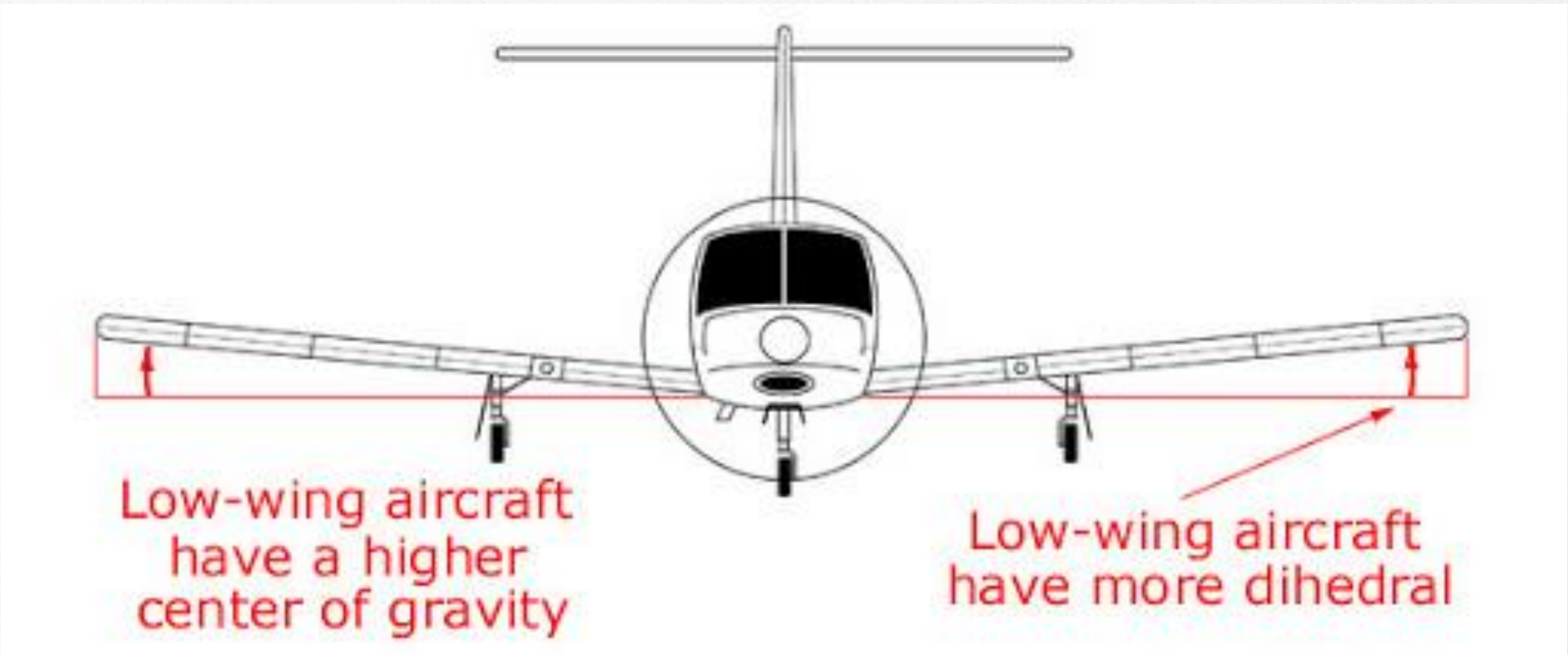
High wing aircraft have less dihedral, making them less stable than low wing aircraft.



https://www.youtube.com/watch?v=I8iLR2xRNKY

Wing Dihedral & Stability

Low wing aircraft have more dihedral, making them more stable than high wing aircraft.



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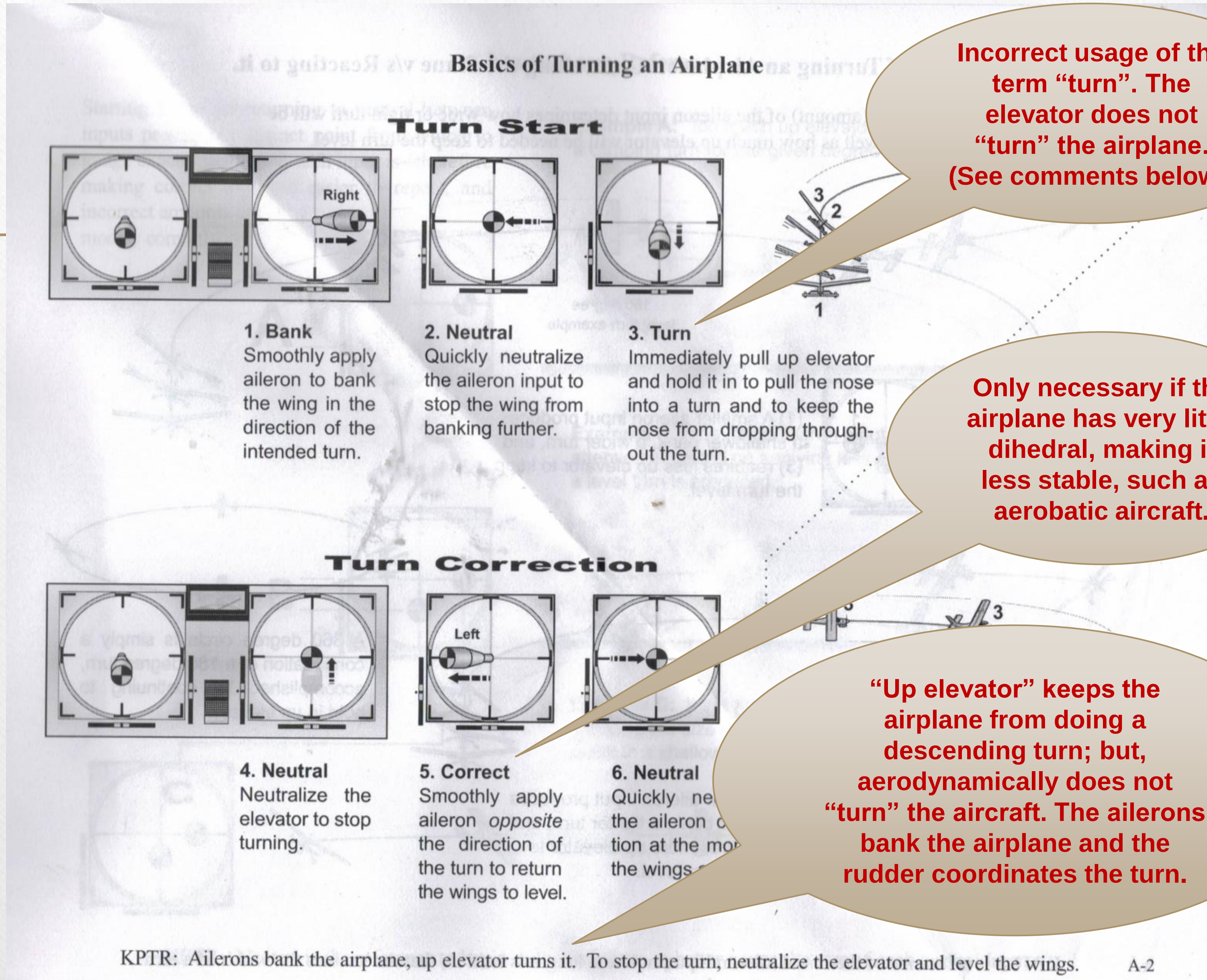
RC Airplane Verbiage


Basics of Turning an Airplane

Turn Start

1. Bank
Smoothly apply aileron to bank the wing in the direction of the intended turn.

2. Neutral
Quickly neutralize the aileron input to stop the wing from banking further.

3. Turn
Immediately pull up elevator and hold it in to pull the nose into a turn and to keep the nose from dropping throughout the turn.

Turn Correction

4. Neutral
Neutralize the elevator to stop turning.

5. Correct
Smoothly apply aileron *opposite* the direction of the turn to return the wings to level.

6. Neutral
Quickly ne… the aileron … tion at the mo… the wings …

KPTR: Ailerons bank the airplane, up elevator turns it. To stop the turn, neutralize the elevator and level the wings.

A-2

Incorrect usage of the term "turn". The elevator does not "turn" the airplane. (See comments below.)

Only necessary if the airplane has very little dihedral, making it less stable, such as aerobatic aircraft.

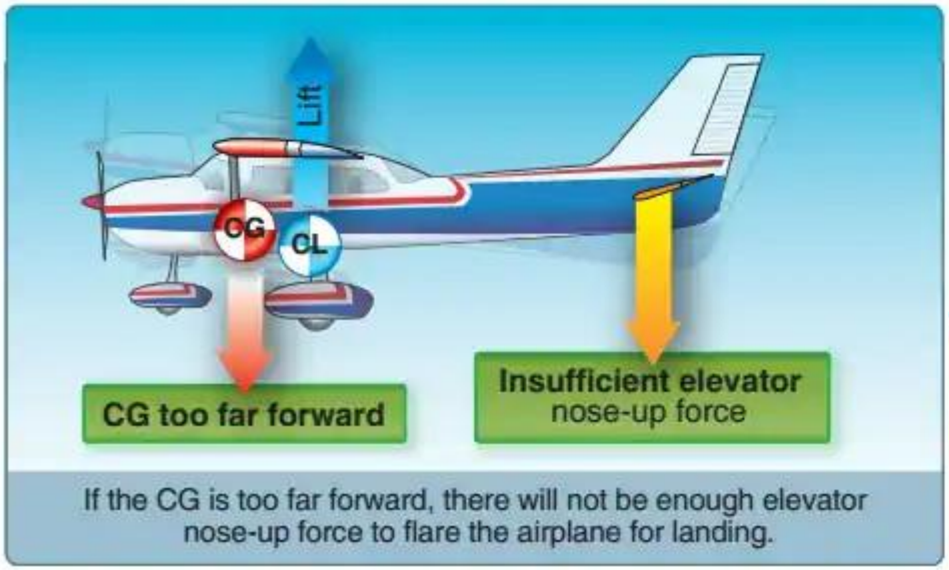
"Up elevator" keeps the airplane from doing a descending turn; but, aerodynamically does not "turn" the aircraft. The ailerons bank the airplane and the rudder coordinates the turn.

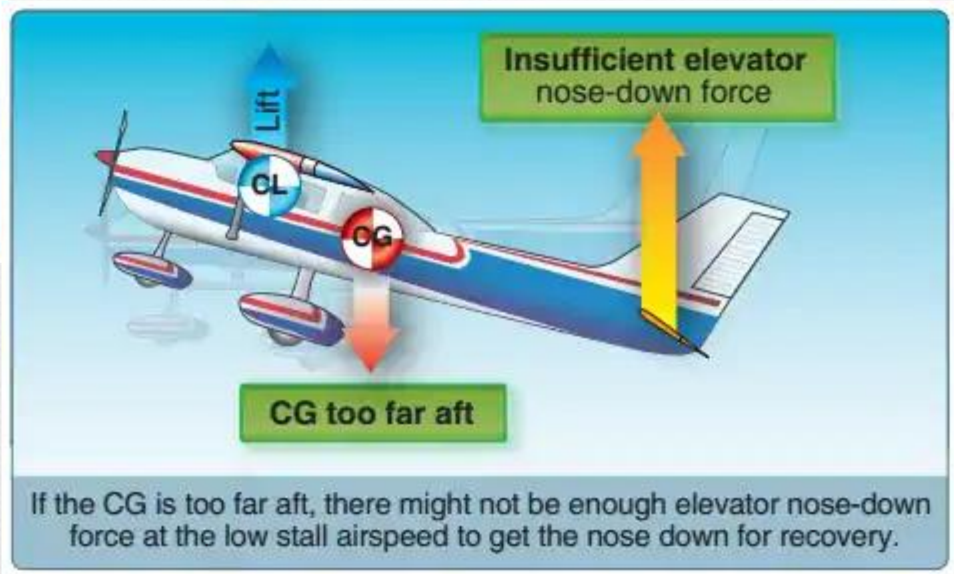
Center of Gravity

An airplane in flight can be maneuvered by the pilot using the aerodynamic control surfaces; the elevator, rudder, or ailerons. As the control surfaces change the amount of force that each surface generates, the aircraft rotates about a point called the center of gravity. The center of gravity is the average location of the weight of the aircraft. The weight is actually distributed throughout the airplane, and for some problems it is important to know the distribution. But for total aircraft maneuvering, we need to be concerned with only the total weight and the location of the center of gravity.

Battery placement in an RC airplane is important as it affects the CG, which, in turn, affects takeoffs, landings, and stall recoveries.

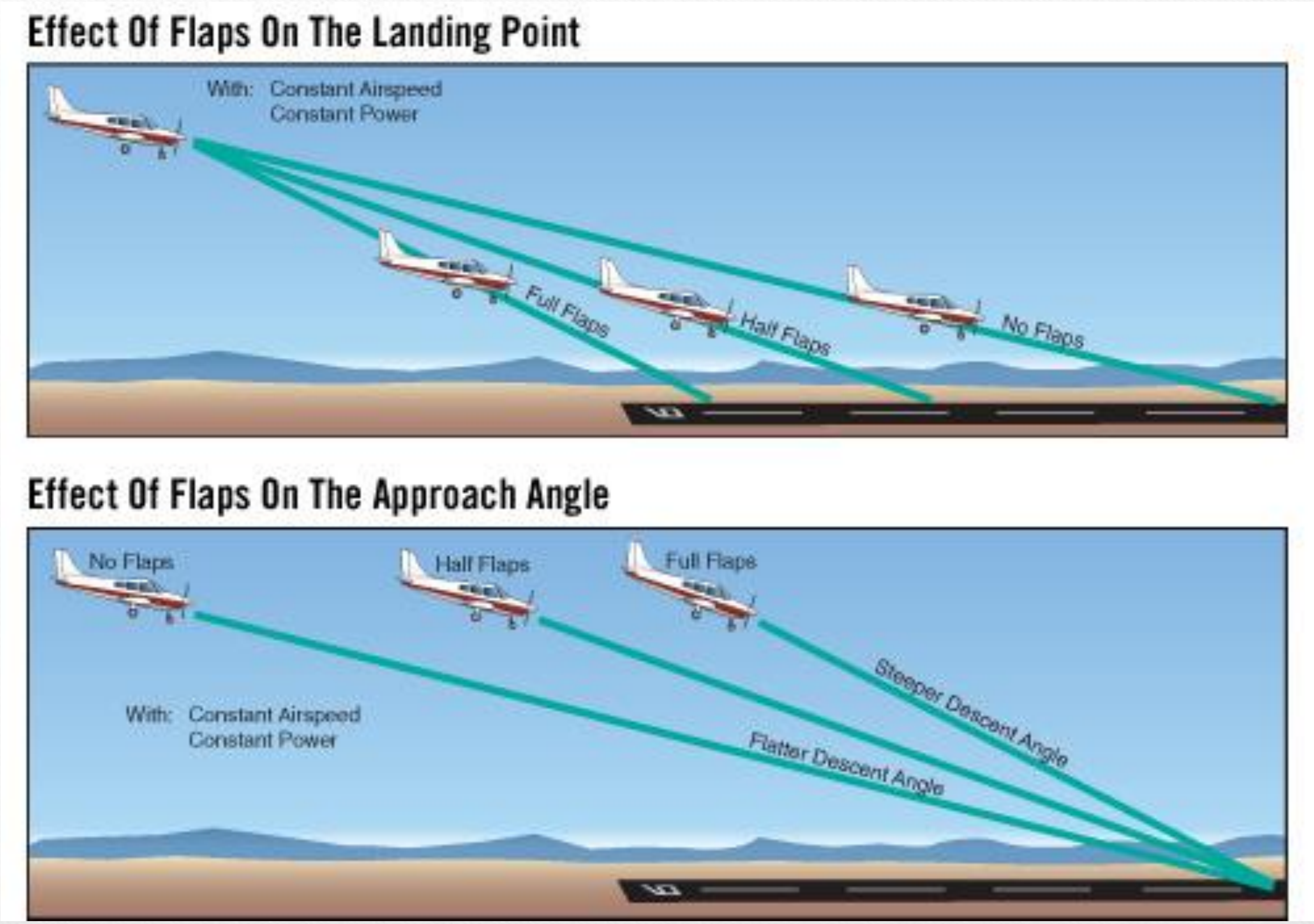
Center of Gravity





Flaps

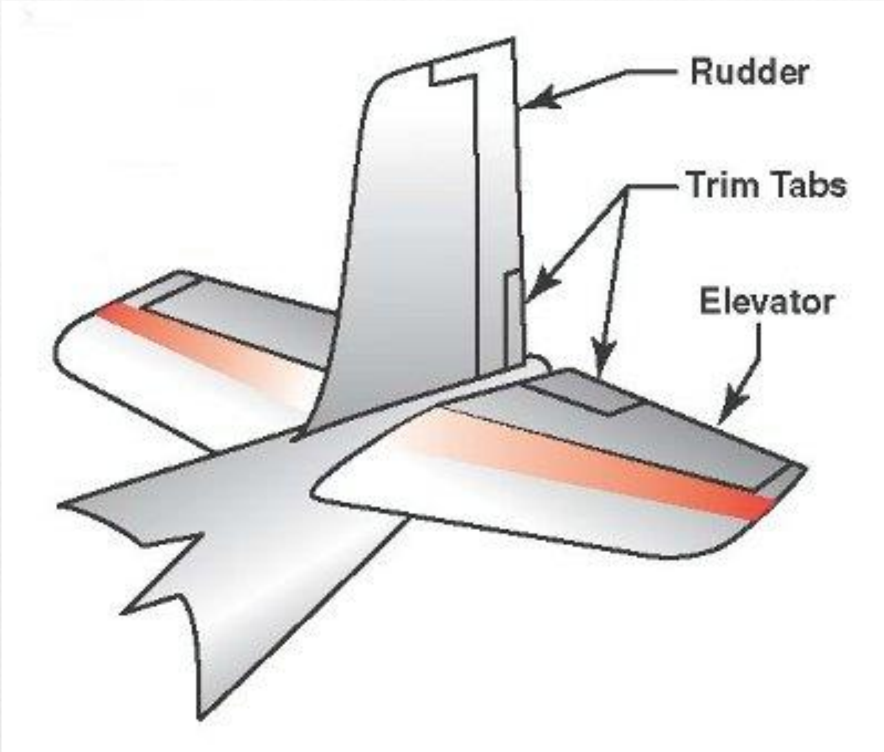
https://www.youtube.com/watch?v=MWWEjwideag



Trim

Trim Tabs:

Once the airplane is stable, whether in climb, descent, level flight, or a banking turn, the pilot “trims” the aircraft by moving a smaller control surface on the elevator’s, aileron’s, and/or rudder’s trailing edge — the trim tab. This replaces the pressure the pilot must physically exert on the stick to keep the airplane’s attitude stable.



Aerodynamics Review

https://www.youtube.com/watch?v=E3i_XHlVCeU&t=741s