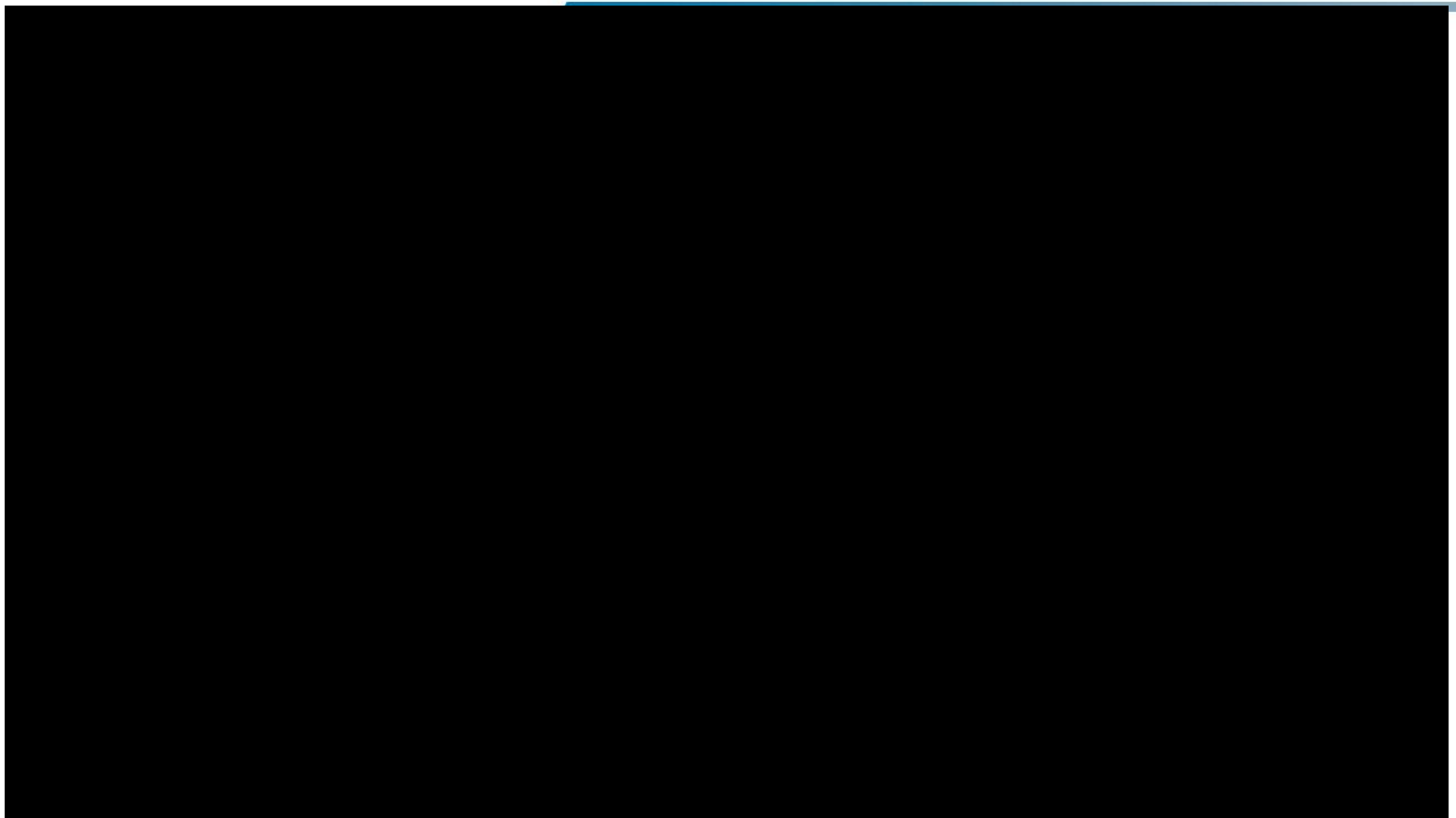
Lesson 1 – The Physics of Flight:

More than what you think (or are told)

His Aviatorness, Mr. Webber
DASOTA Flying Puffins Aviation and Aerospace Club

Cessna 172

Anatov-AN-225



Both of those aircraft – and indeed all heavier-than-air aircraft (from Kitty Hawk to the Super Hornet) – fly on the same principles.

What goes up…

How to Fly

- Like all systems in Classical Mechanics, motion will change (accelerate) when there are unbalanced forces.
- To get an airplane off the ground, lift must be greater than weight.
- For an airplane to fly straight-and-level, lift and weight must be in balance (net acceleration/force is 0).

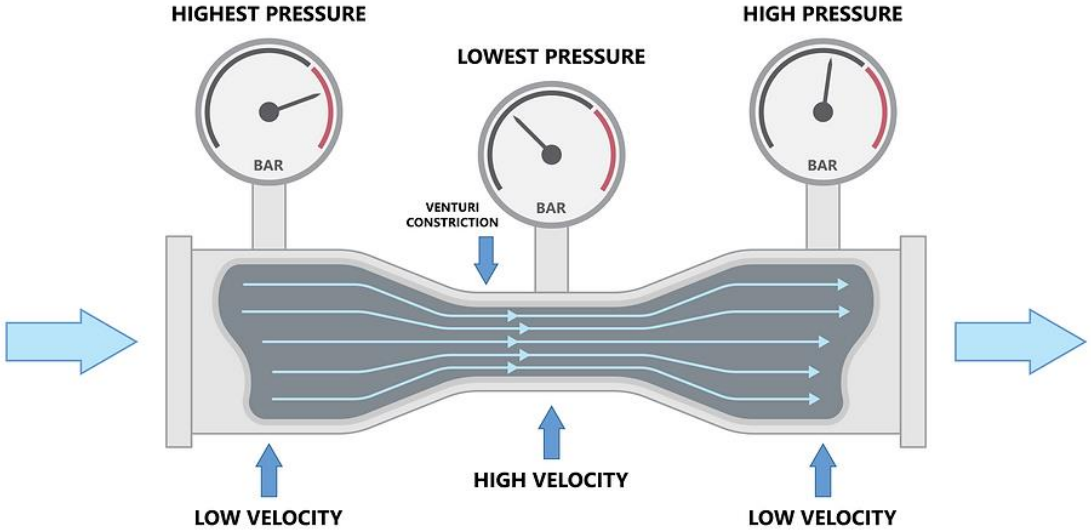
However, “lift” is a generic term that itself includes several components and considerations.

What does the FAA say?

- The FAA (Federal Aviation Administration) places a lot of emphasis on Bernoulli's Principle and Newton's Third Law only to account for the generation of lift.
- Bernoulli's Principle does work concert with Newton's Laws in explaining lift.
- However…
  - These are not the only, all-encompassing factors that generate lift.
  - But it is a good place for us to start!

Ia. The Venturi Effect (Bernoulli's Principle)

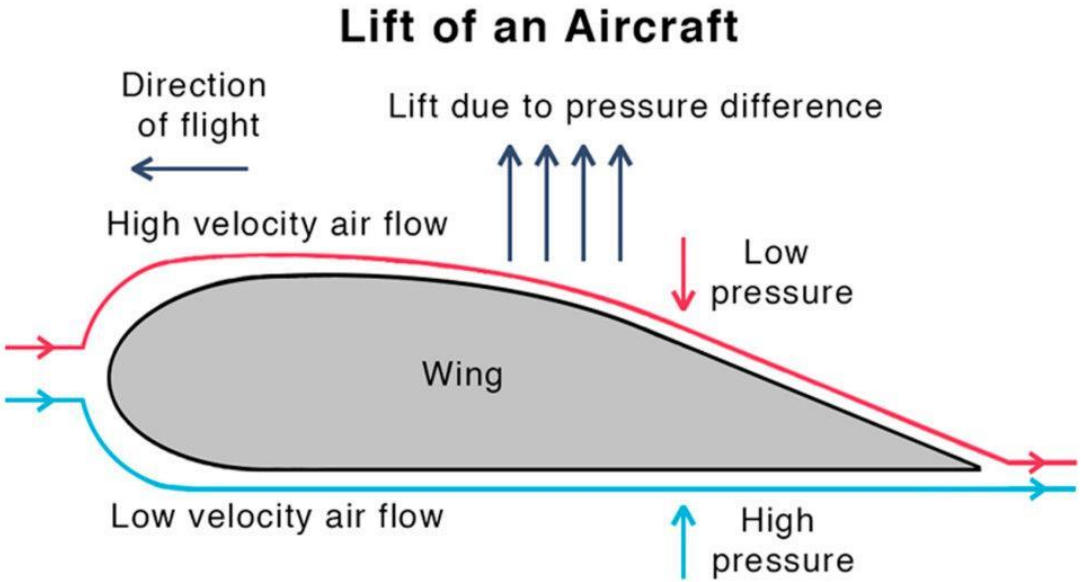
- The Venturi Effect is the reduction of pressure when the velocity of a fluid is increased.
- This effect can be measured in a Venturi Tube:



Ib. Bernoulli's Principle

- The "Equal Time Argument."
- In aviation, Bernoulli's Principle explains the lift on a wing by examining the shape of the airfoil and the Venturi Effect.

- Pressure seeks equilibrium, so the high pressure "pushes" up on the wing toward the low pressure.
- By Newton's Second Law, which relates net forces to acceleration ($\boldsymbol{F} = m\boldsymbol{a}$), this creates an unbalanced force, causing lift.



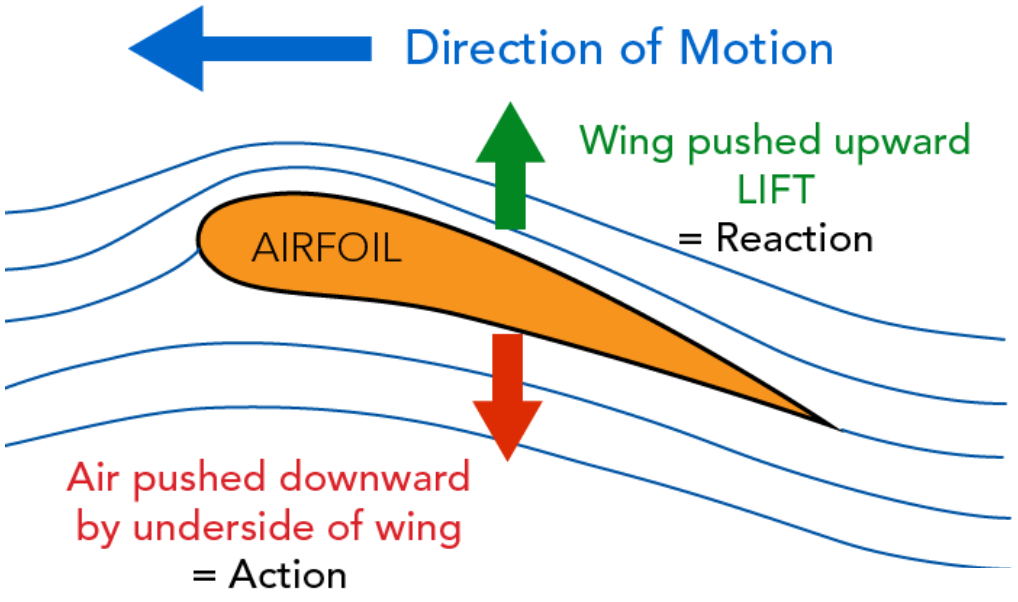
Speaking of Newton

Newton's Three Laws of Motion:

1. Law of Inertia: *An object in motion will tend to stay in motion and object at rest will tend to stay at rest unless acted upon by a net external force.*
2. Law of Acceleration: $\boldsymbol{F} = m\boldsymbol{a}$.
3. Law of Action and Reaction: *Forces come in pairs; for every action there is an equal and opposite reaction.*

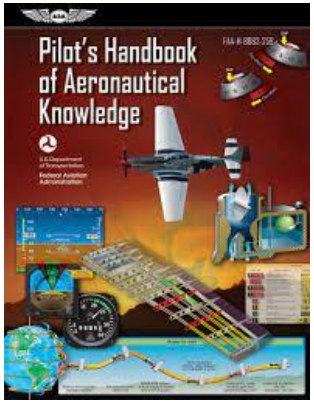
II. Newton's Third Law

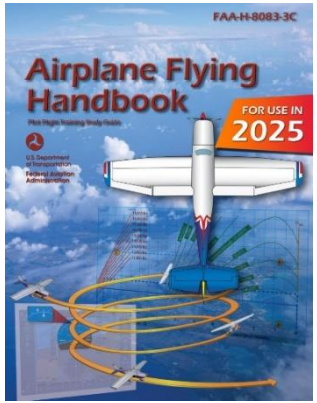
- As the Angle of Attack (AOA) of the wing changes, air is directed downward.
- By Newton's Third Law, the force of the air molecules deflected downward is counteracted by an equal force upward, as shown…



The “Unmentioned” Forces

- There are two additional principles in physics that account for an airplane being able to fly.
- The two main texts in General Aviation, the *Pilot’s Handbook of Aeronautical Knowledge (PHAK)* and the *Airplane Flying Handbook*, do not really focus on them.
- However, we are better than that!

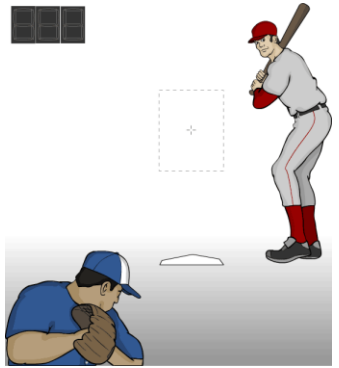




- These two addition principles are:
  1. Magnus Effect
  2. Coanda Force

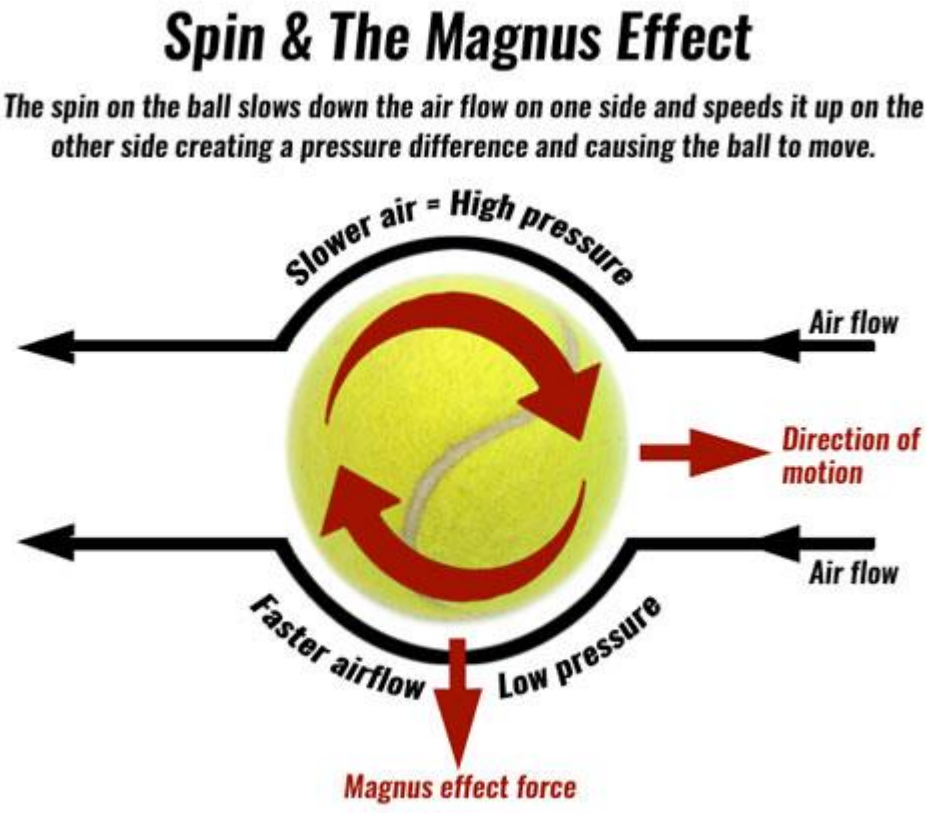
III. Magnus Effect

- I hate to throw a “curveball” at you (har!).



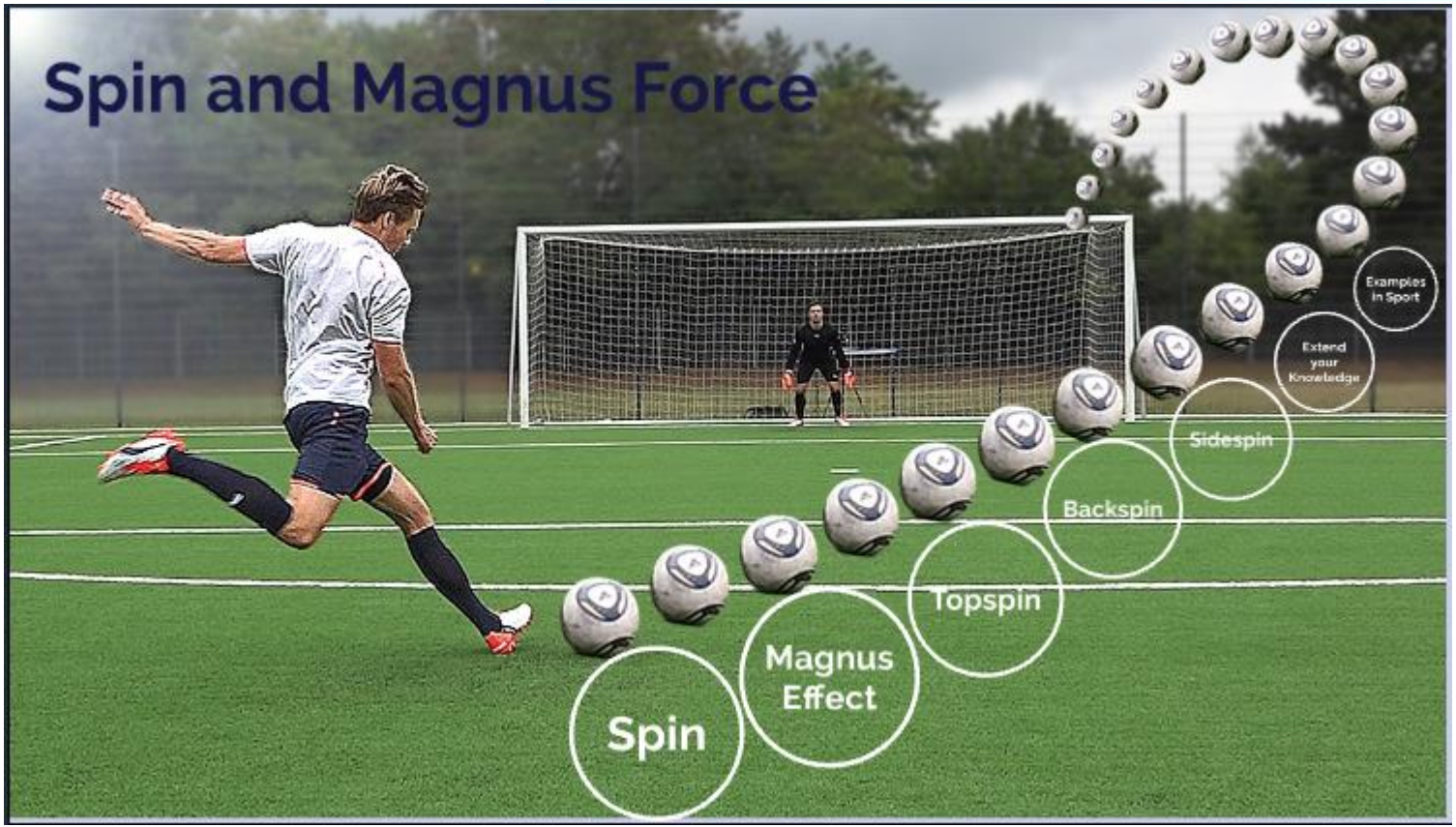
- The Magnus Effect is the phenomenon where a spinning object moving through a fluid (like air) experiences an uneven force due to pressure differences created by the object's rotation, causing its path to deviate.

III. Magnus Effect



- The side of the cylinder or sphere turning into the air slows the airflow, creating high pressure.
- The side of the cylinder or sphere turning away from the air increases the airflow, creating low pressure.
- By Newton's Second Law and Bernoulli's Principle, this pitches the cylinder or sphere toward the low-pressure side.

III. Magnus Effect



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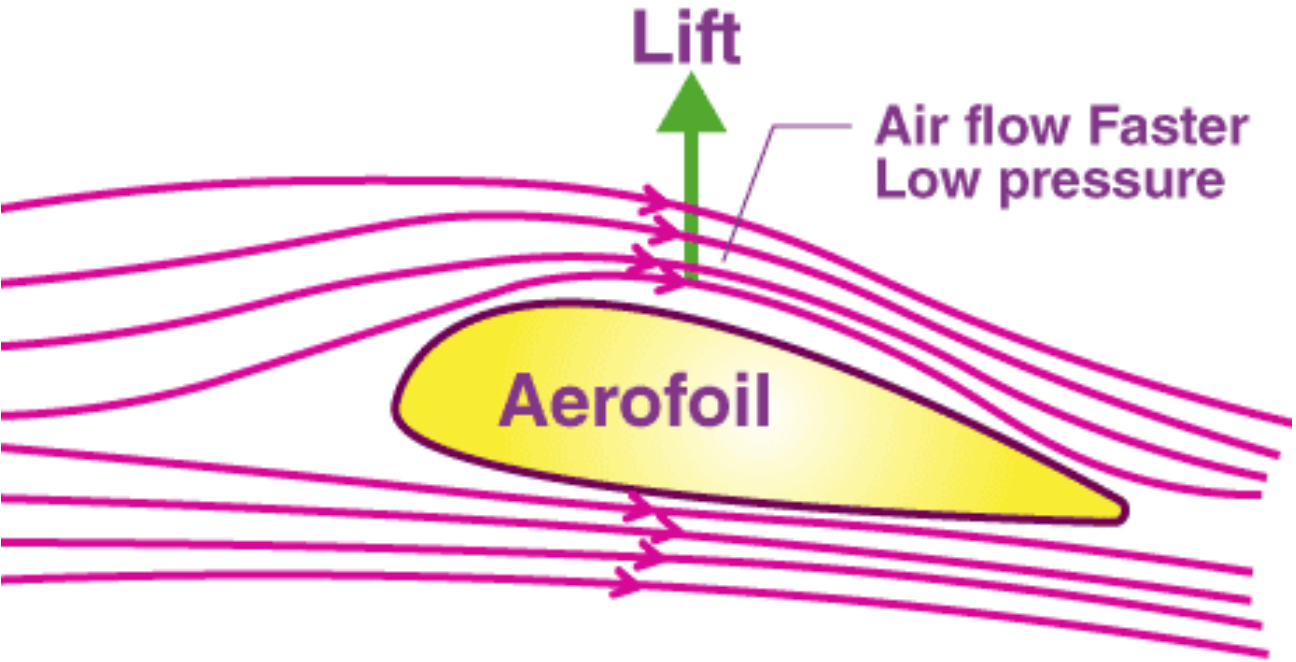
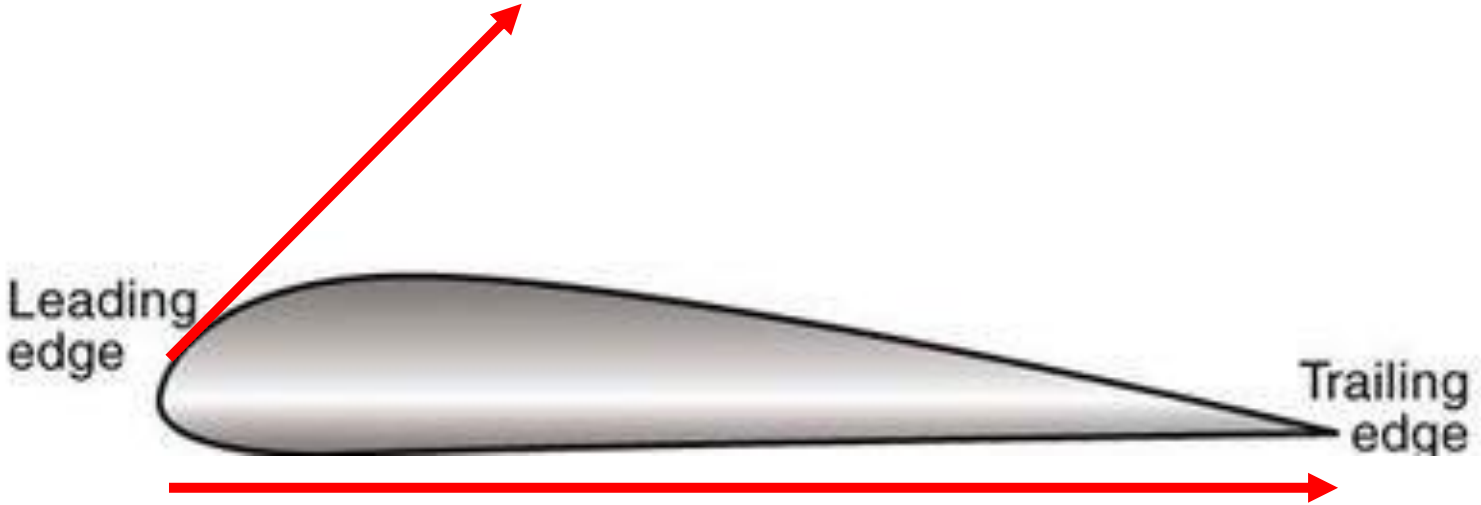


The asymmetric shape of an airplane's wing also generates the Magnus Effect, which can create lift.

Newton vs. Bernoulli

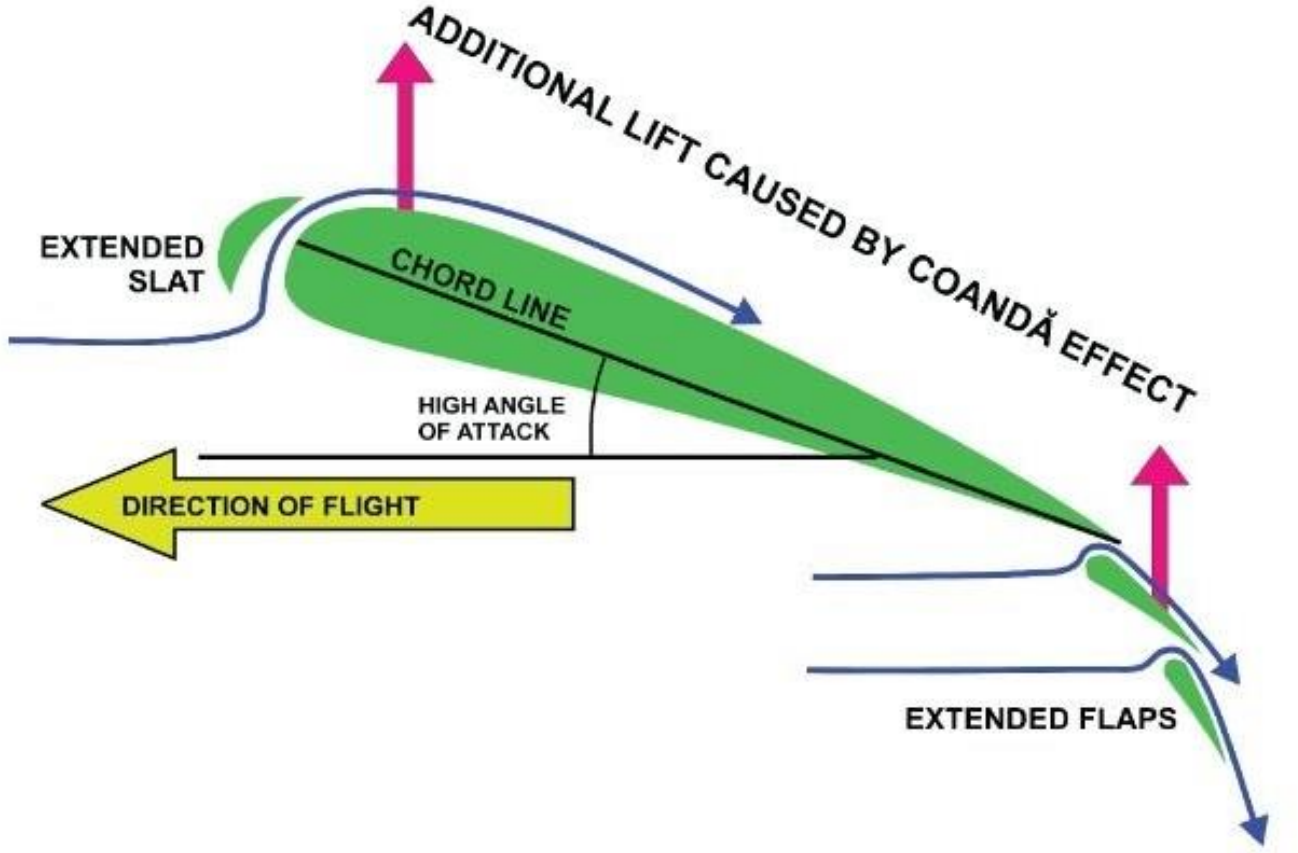
Newton's First Law would seem to contradict Bernoulli's Principle:



IV. Coanda Force

- The Coanda Force was the last effect to be understood when it comes to the principles of flight (1910 by Henri Coanda).
- It states that a fluid moving over a surface tends to stick to the surface even when the surface bends.
- So, you think I am “all wet” telling you this…!

IV. Coanda Force



Summary

- So what makes an airplane fly?

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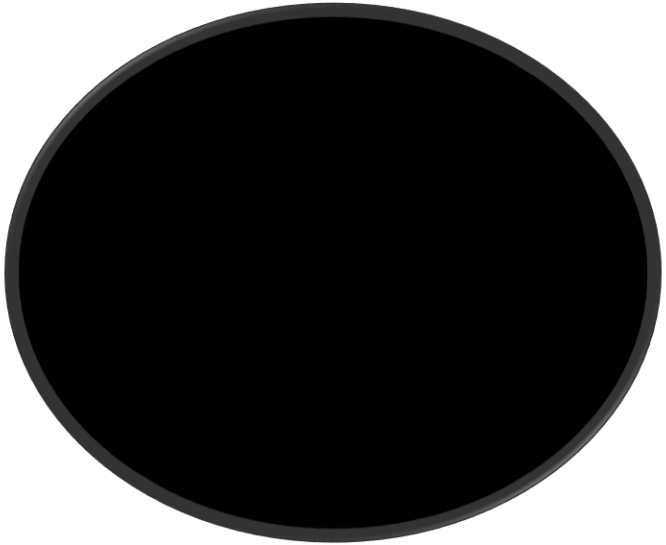

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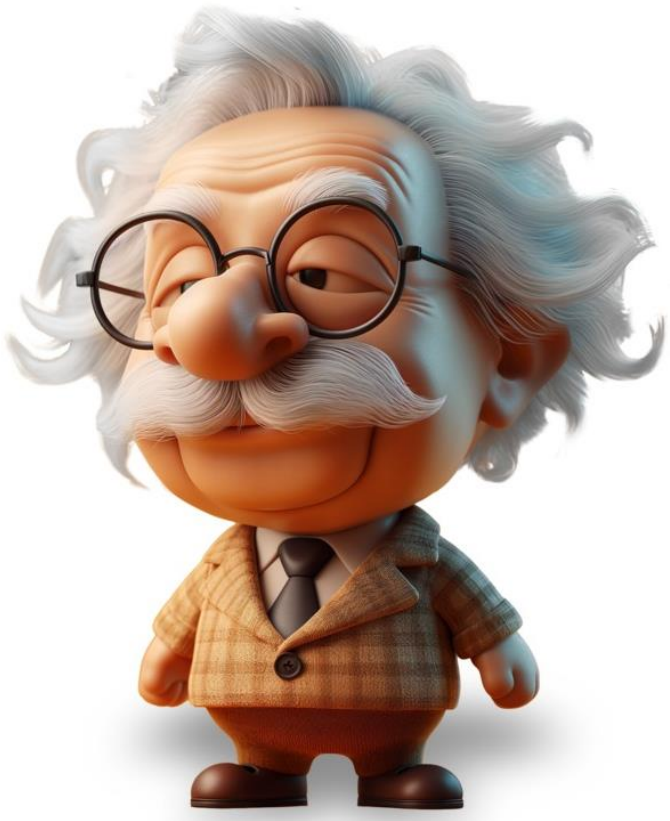
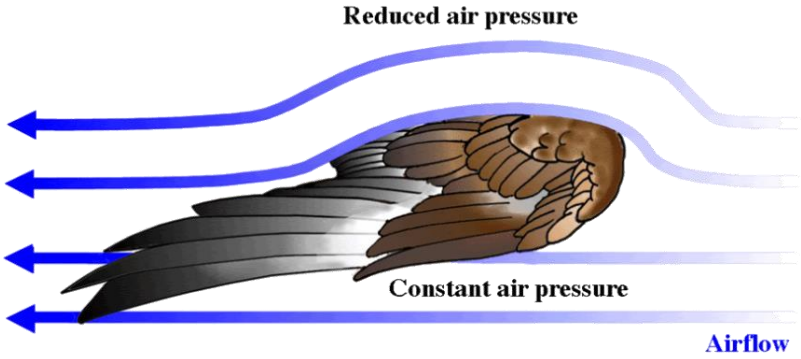
Summary

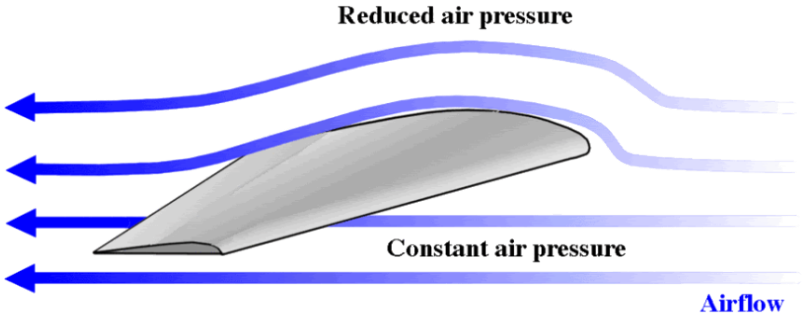
- So what makes an airplane fly?
  - $$$ Money $$$?
  - Magic?
- Physics!
  1. Bernoulli's Principle
  2. Newton's Laws of Motion
  3. Magnus Effect
  4. Coanda Force



Summary

- Mother Nature knew this long before we did…





Questions?