# Aerodynamics: Lift and Drag

## Objective

To understand basic aerodynamic concepts like lift, drag, and the nomenclature we use to describe it.

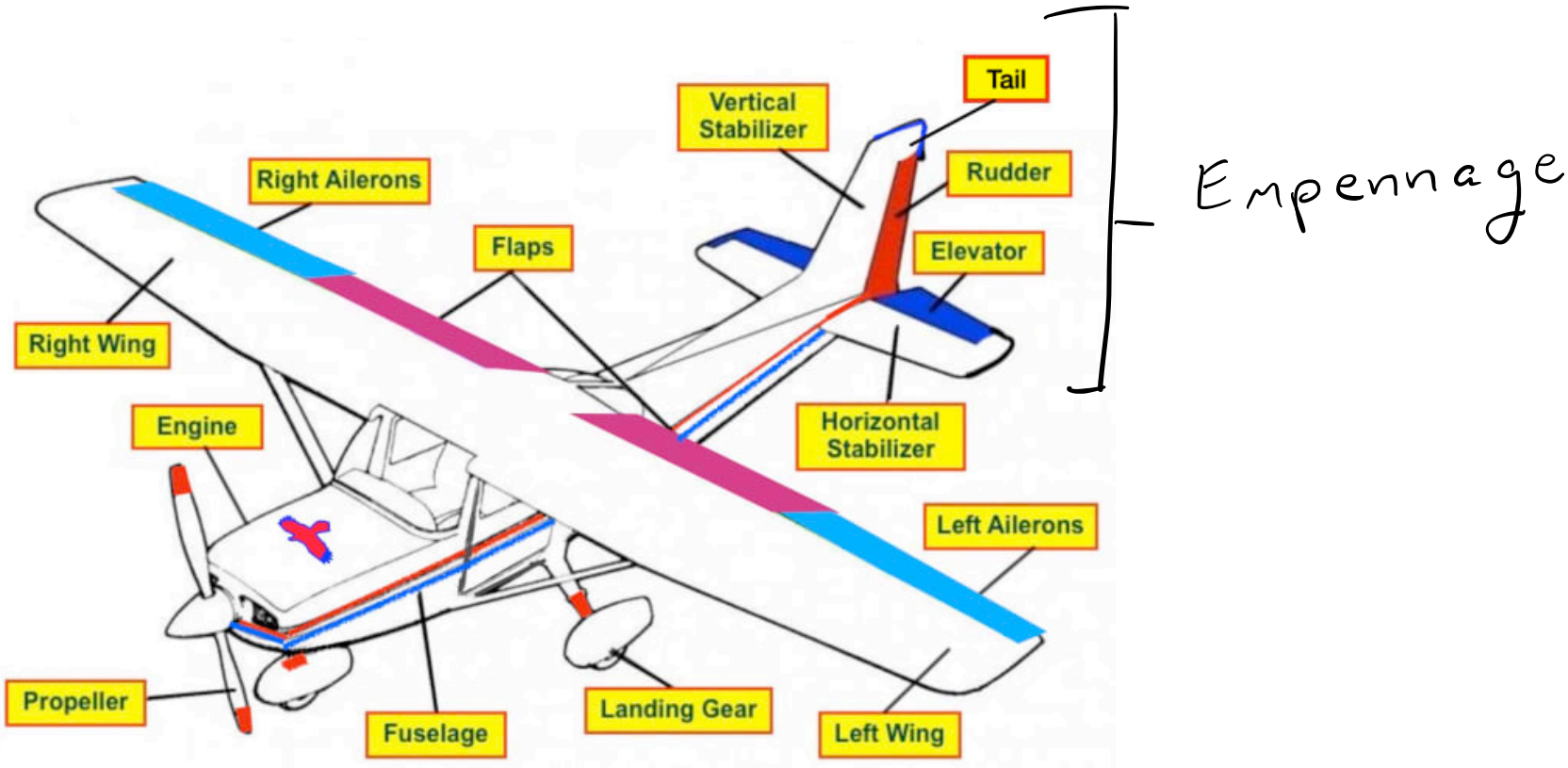
## Motivation

Forms foundational knowledge for more advanced aerodynamic topics and provides a useful mental model for pilots so they can better anticipate and understand the operation of an airplane.

# Overview

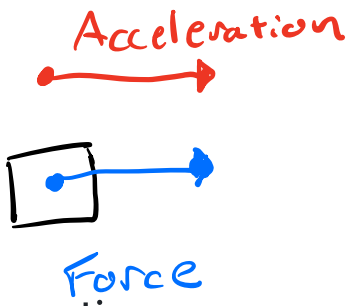
- Airplane components
- Newton's laws of motion
- Four forces of flight
- Lift theories
- Basic airfoil
- Lift on an airfoil
- Angle of attack
- Lift equation
- Thrust vs drag
- Parasite drag
- Induced drag
- Wingtip vortices
- Ground effect
- Parasite drag vs induced drag
- Wing design

# Components of an Airplane

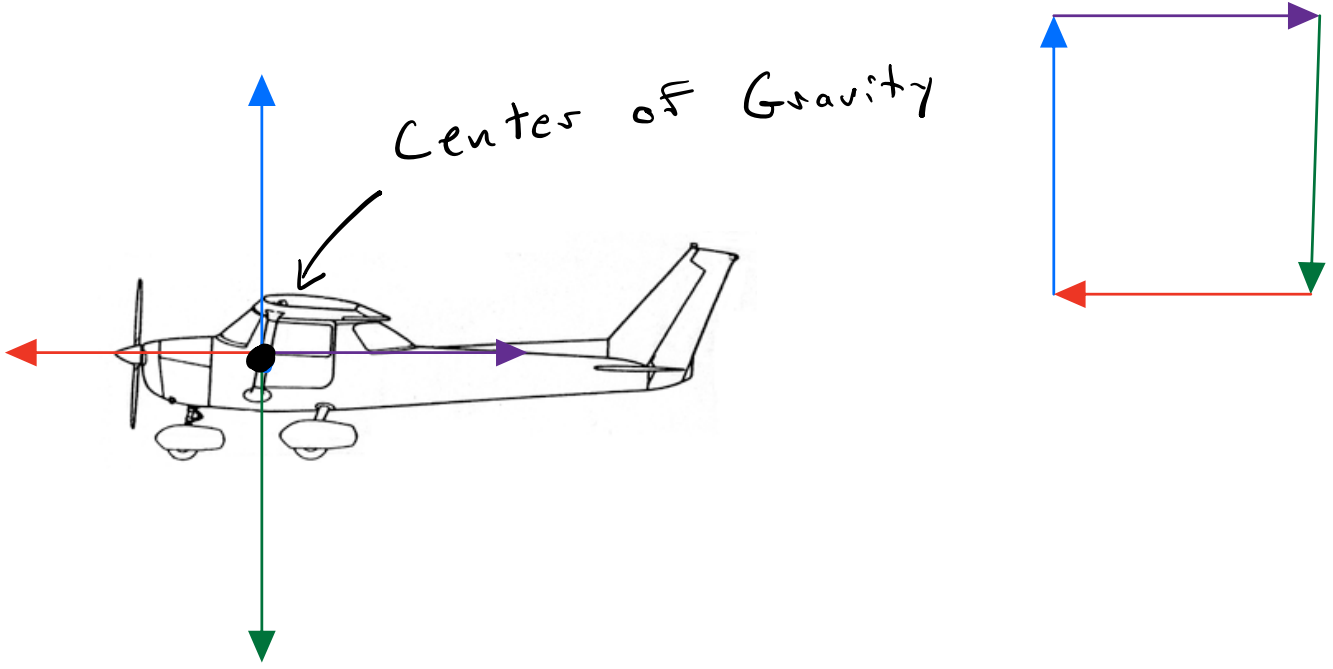


# Newtons Laws of Motions

1. Objects in motion want to stay in motion
2. Fnet = mass * acceleration
3. For every action there is an equal and opposite reaction

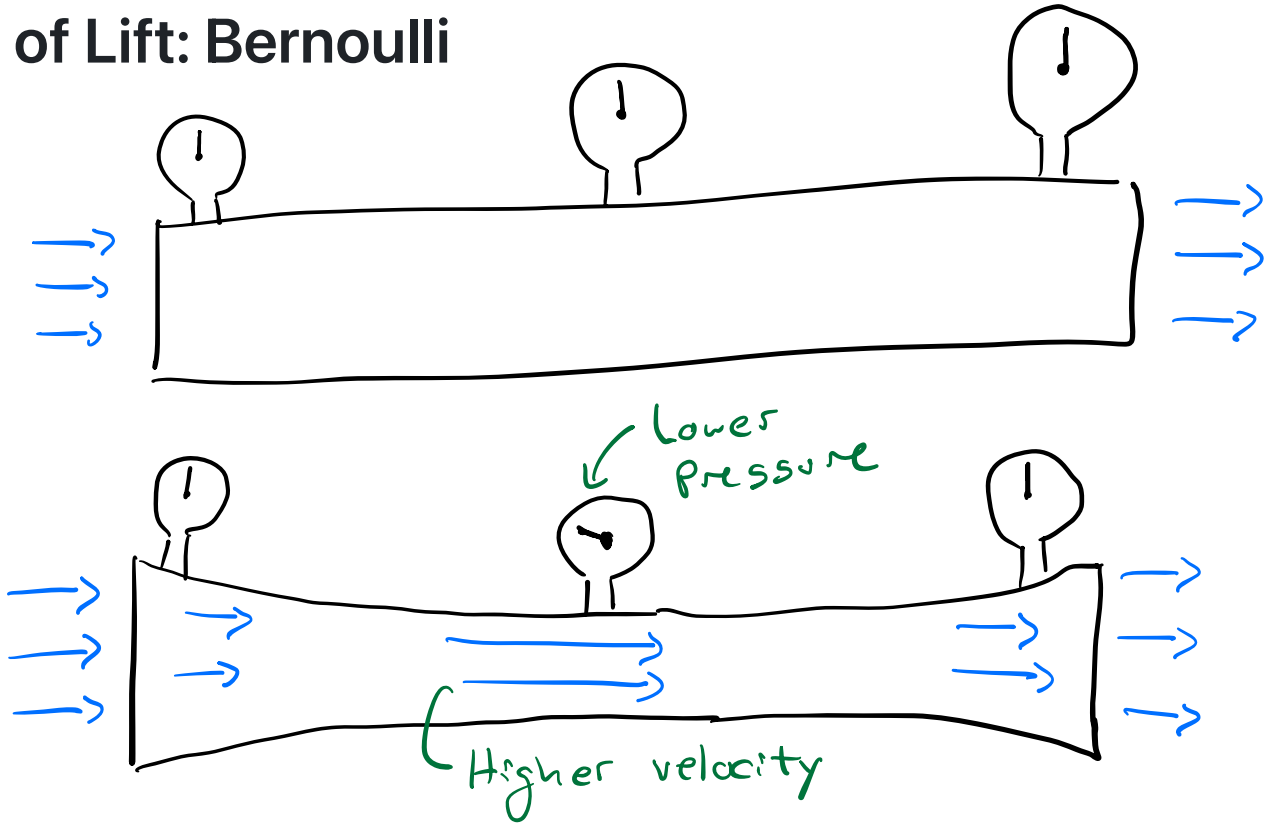


# Four Forces in Flight



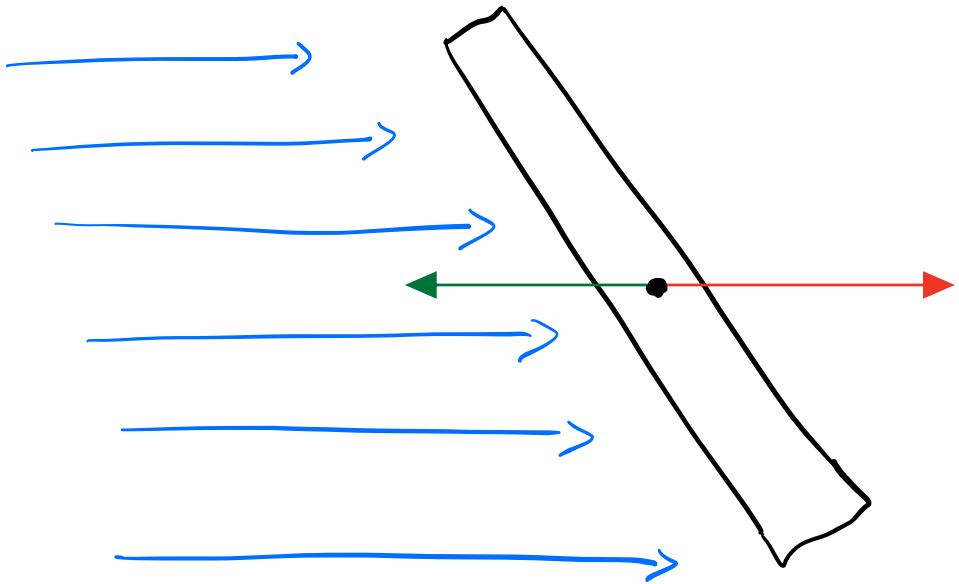

Fnet = 0 for unaccelerated flight

# Principles of Lift: Bernoulli



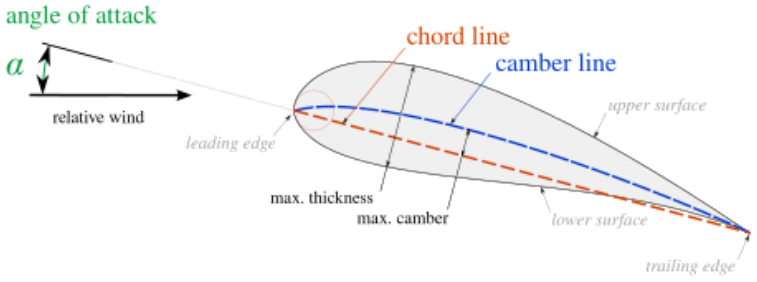

Higher speed = lower pressure

# Principles of Lift: Barn door / Newton

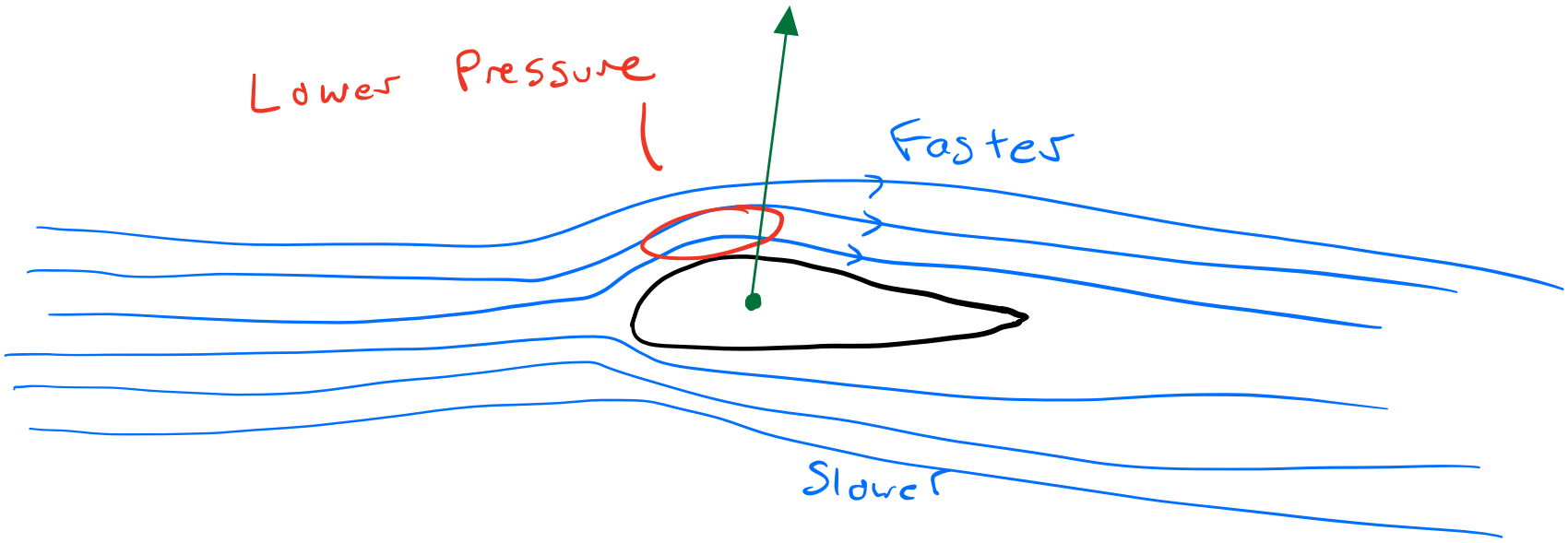


Equal and opposite reaction

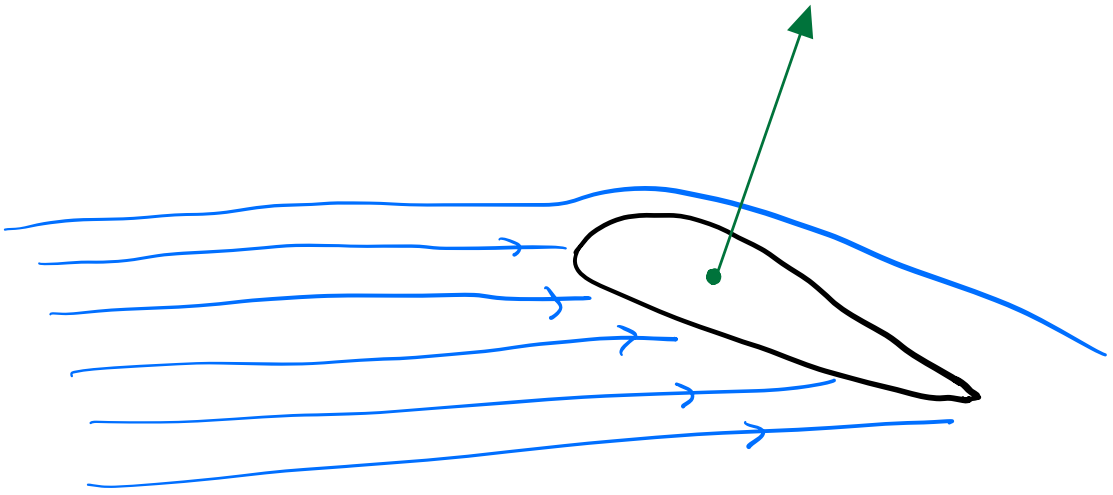
# Basic Airfoil



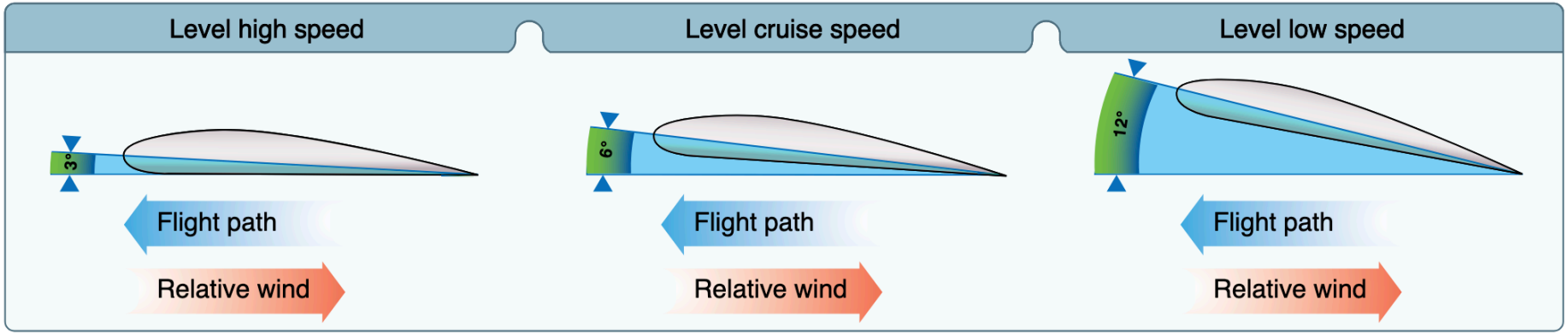
# Lift on an Airfoil: Bernoulli



# Lift on an Airfoil: Newton



# Angle of Attack

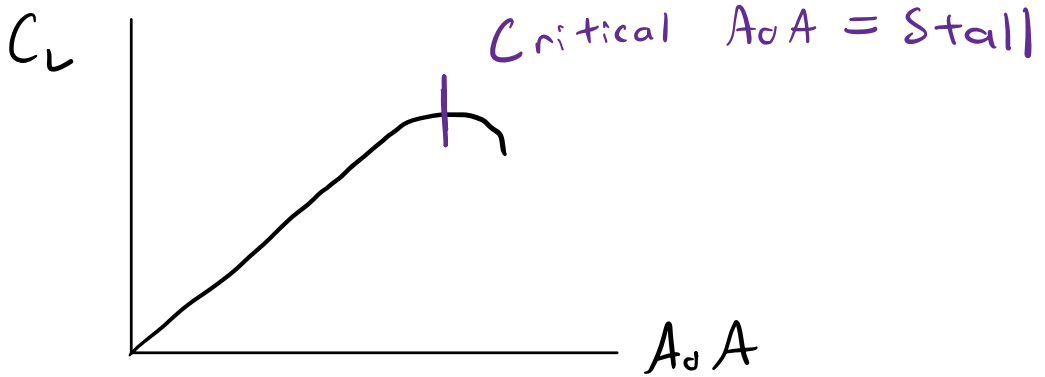


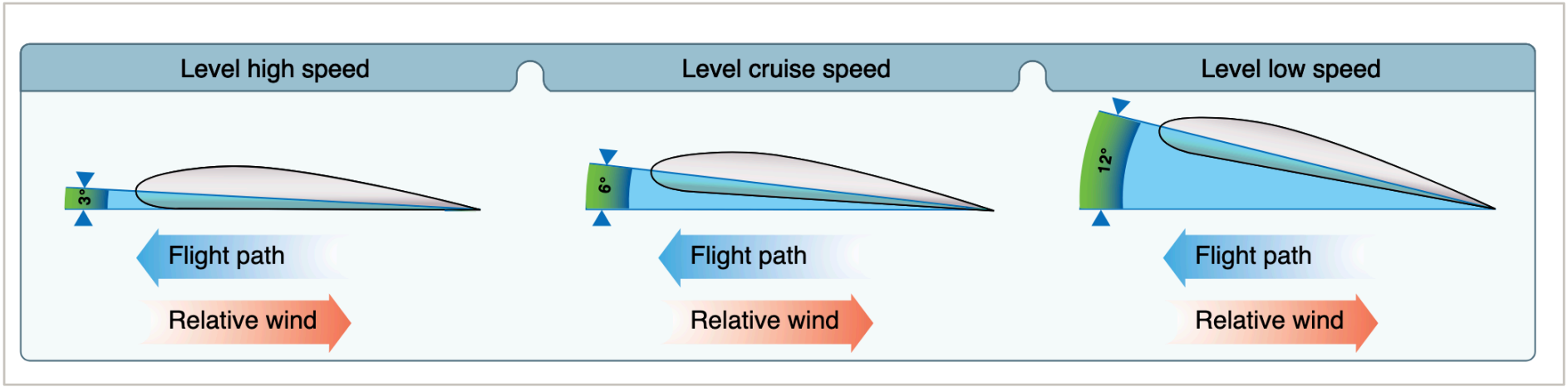
## Lift Equation

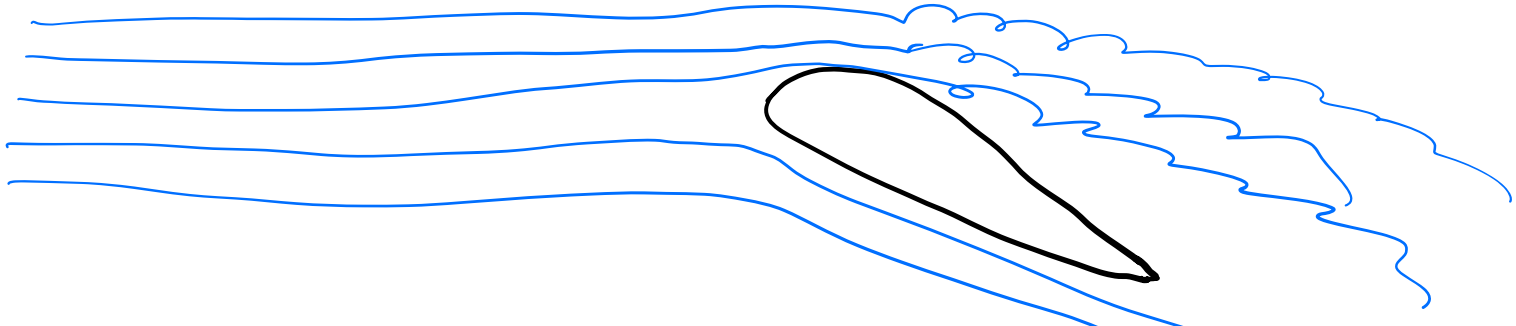
$$\text{lift} = \frac{\frac{1}{2}\rho V^2 S C_l}{2}$$

$$\text{Where:} \rho = \text{air density} V = \text{velocity} S = \text{surface area} C_l = \text{coefficient of lift}$$

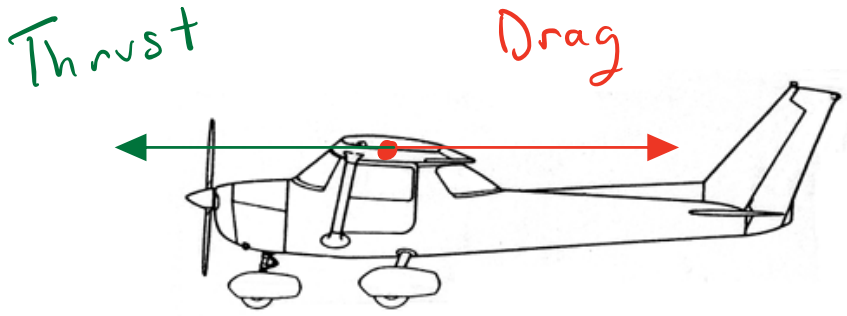
# Critical Angle of Attack



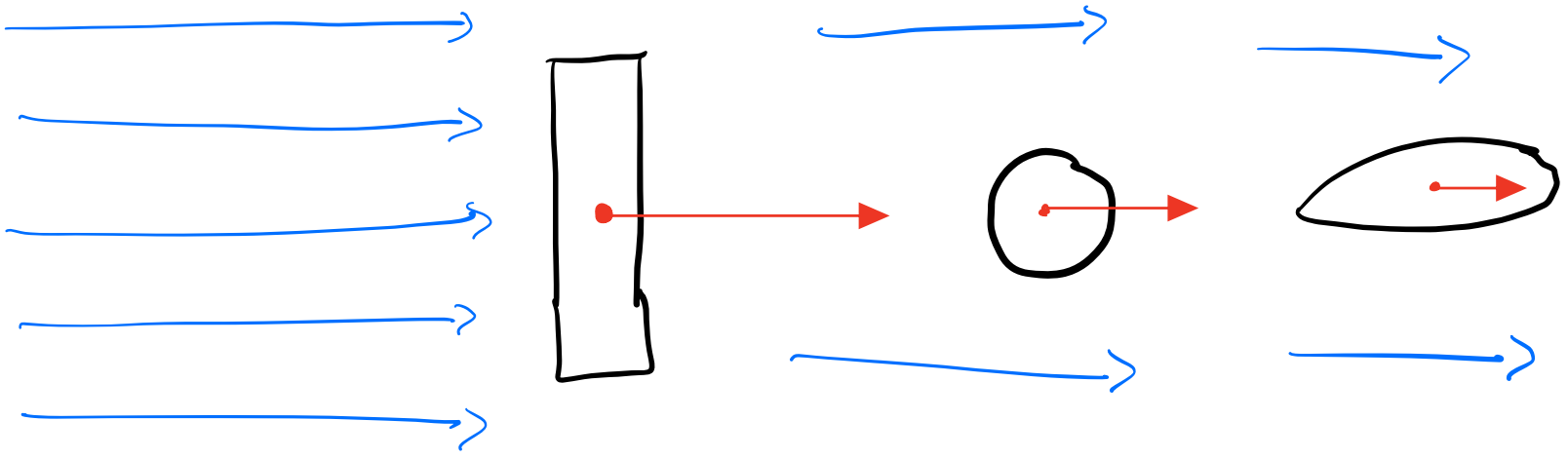



# Thrust and Drag

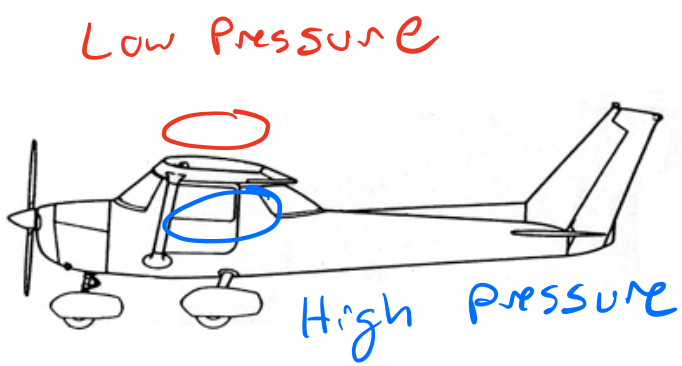


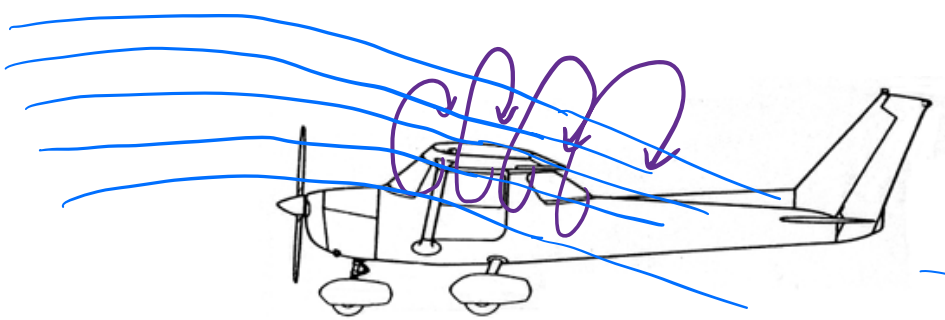

Thrust = drag in unaccelerated flight

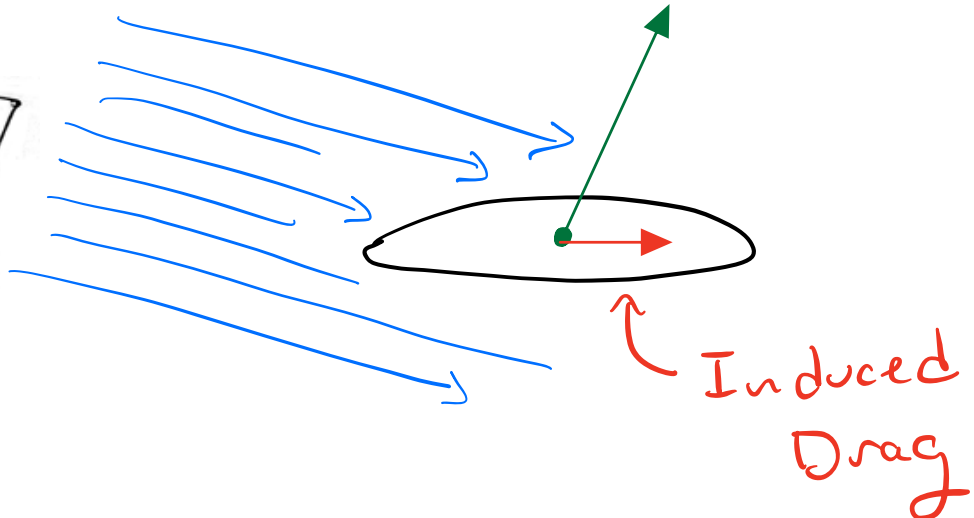
# Parasite Drag



# Induced Drag



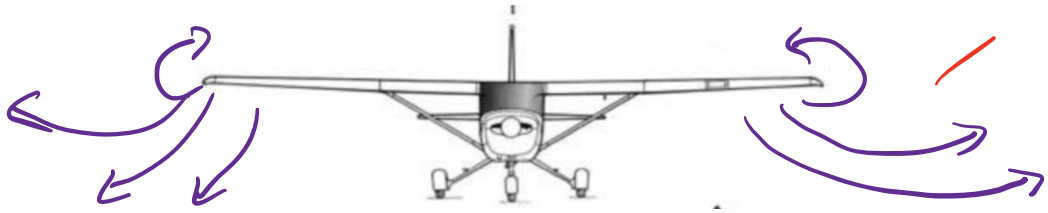


# Ground Effect

½ Wingspan

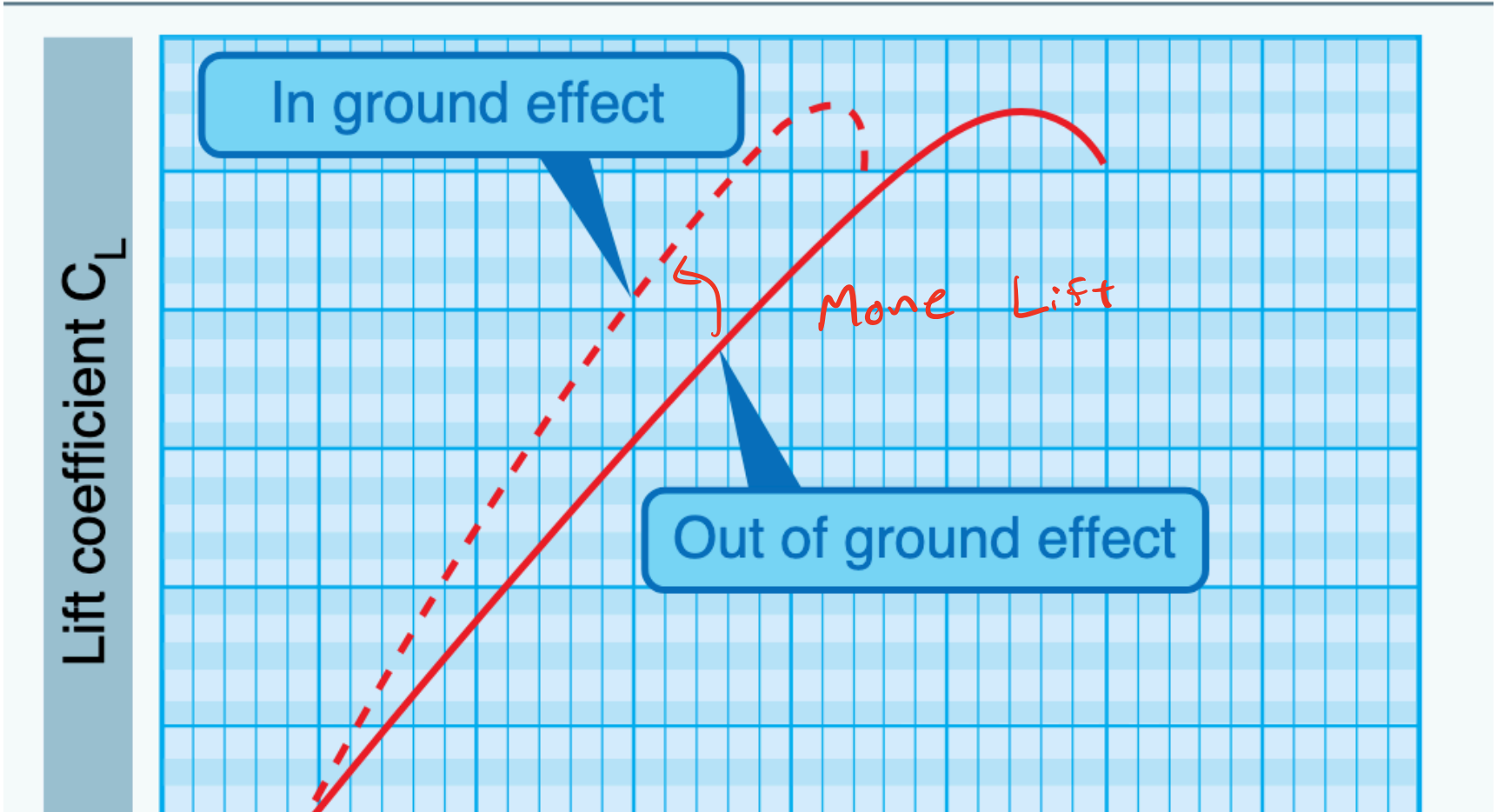
Induced drag ↓

Lift ↑

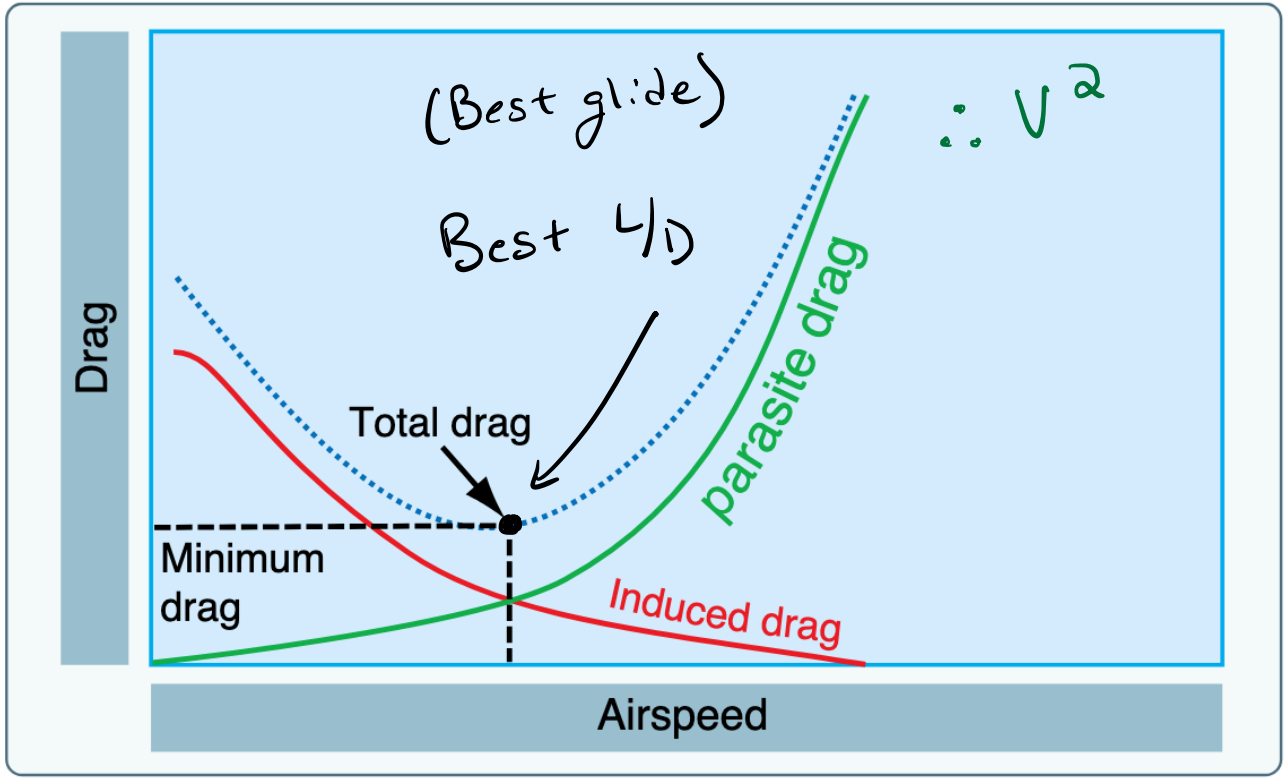


Ground disrupts Vortex

# AoA in Ground Effect



# Thrust vs Drag




Region of Reverse Command

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