

Aerodynamics: Lift and Drag

Objective

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

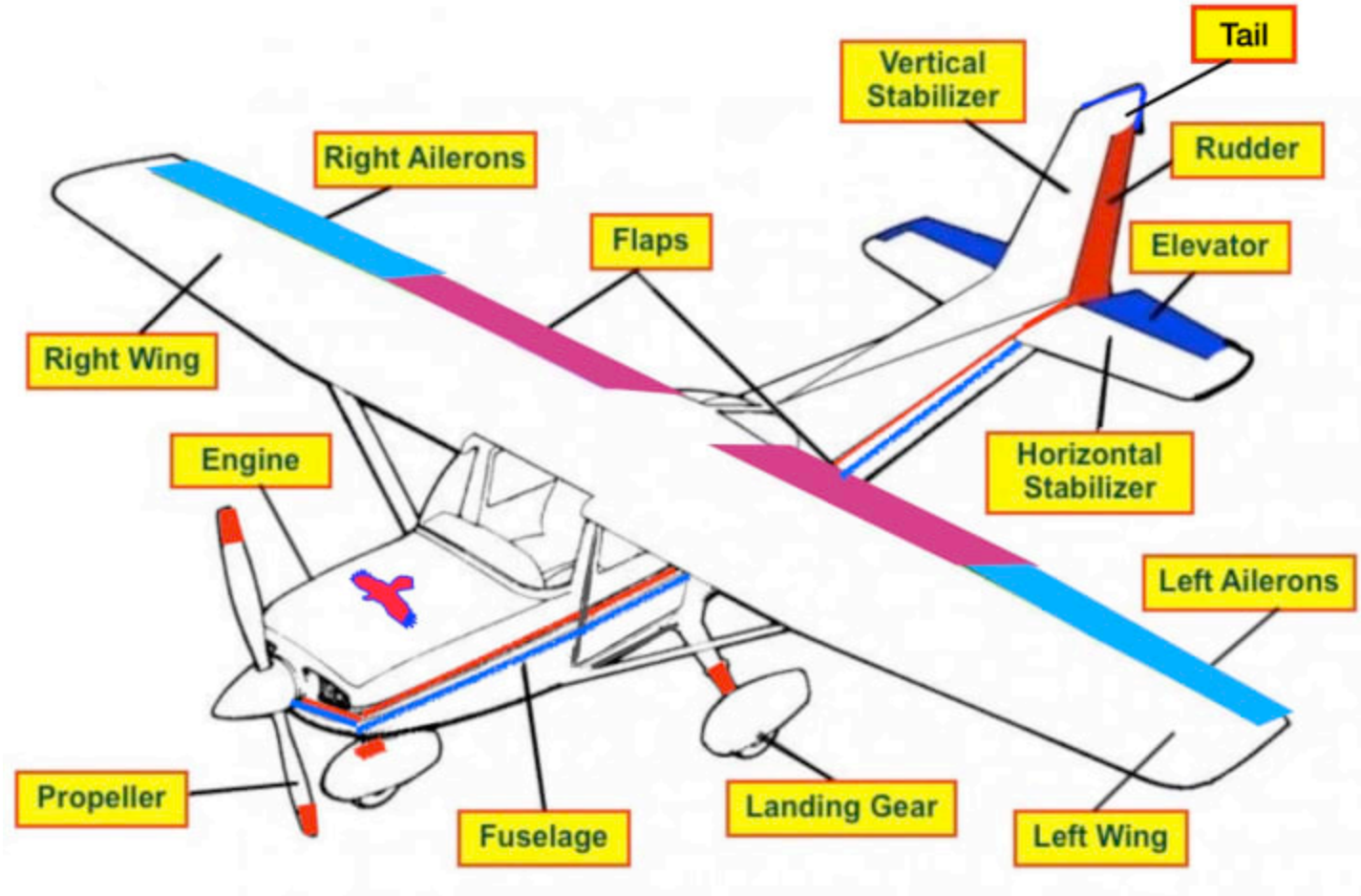
Motivation

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

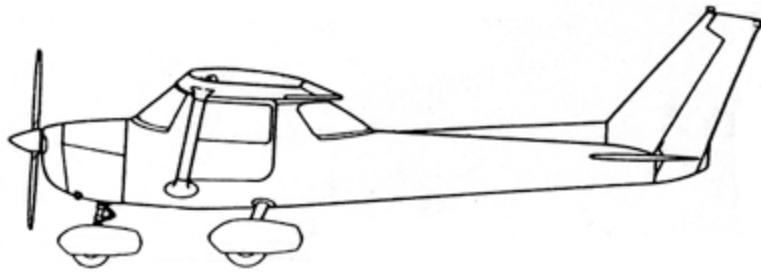
Components of an Airplane



Newton's Laws of Motion

1. Objects in motion want to stay in motion
2. $F_{\text{net}} = \text{mass} * \text{acceleration}$
3. For every action there is an equal and opposite reaction

Four Forces in Flight



$F_{\text{net}} = 0$ for unaccelerated flight

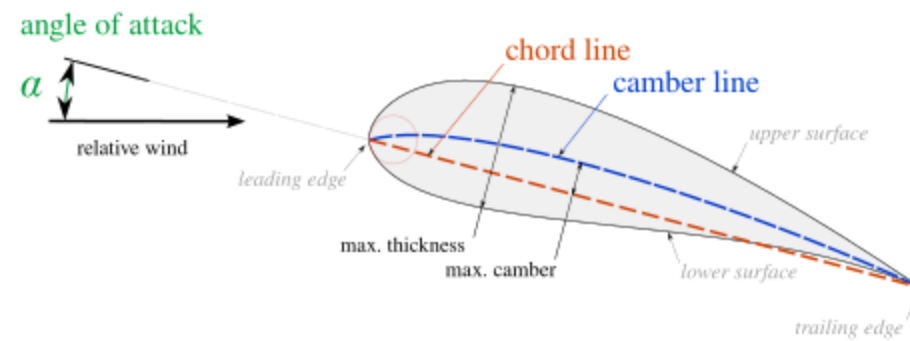
Principles of Lift: Bernoulli

Higher speed = lower pressure

Principles of Lift: Barn door / Newton

Equal and opposite reaction

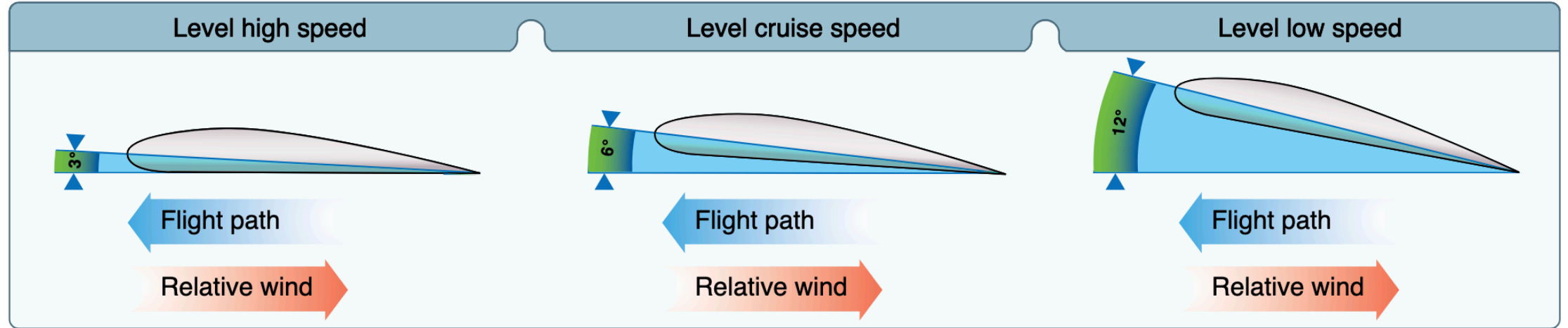
Basic Airfoil



Lift on an Airfoil: Bernoulli

Lift on an Airfoil: Newton

Angle of Attack



Lift Equation

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

Where: ρ = air density V = velocity S = surface area C_l = coefficient of lift

Critical Angle of Attack

Thrust and Drag

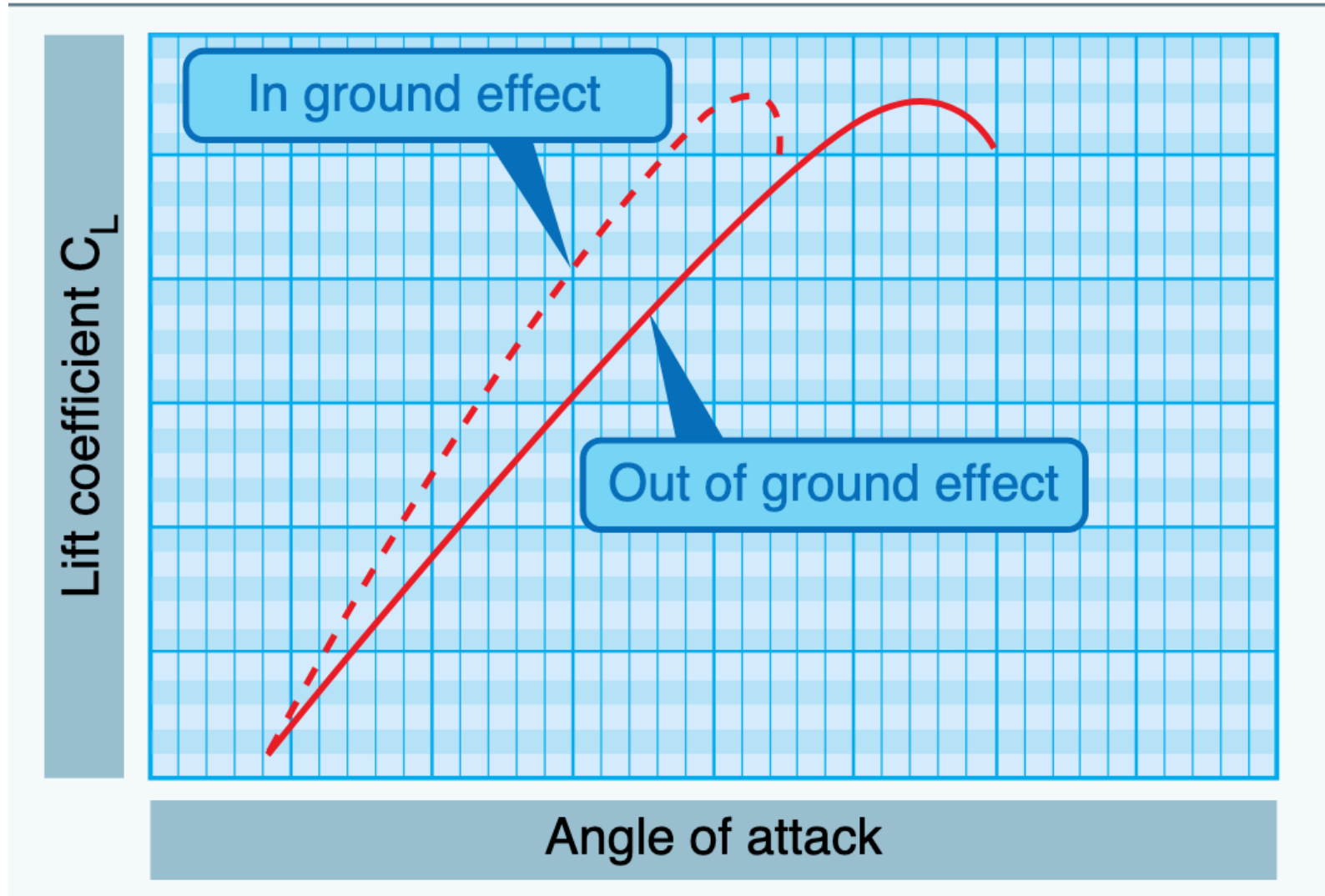
Thrust = drag in unaccelerated flight

Parasite Drag

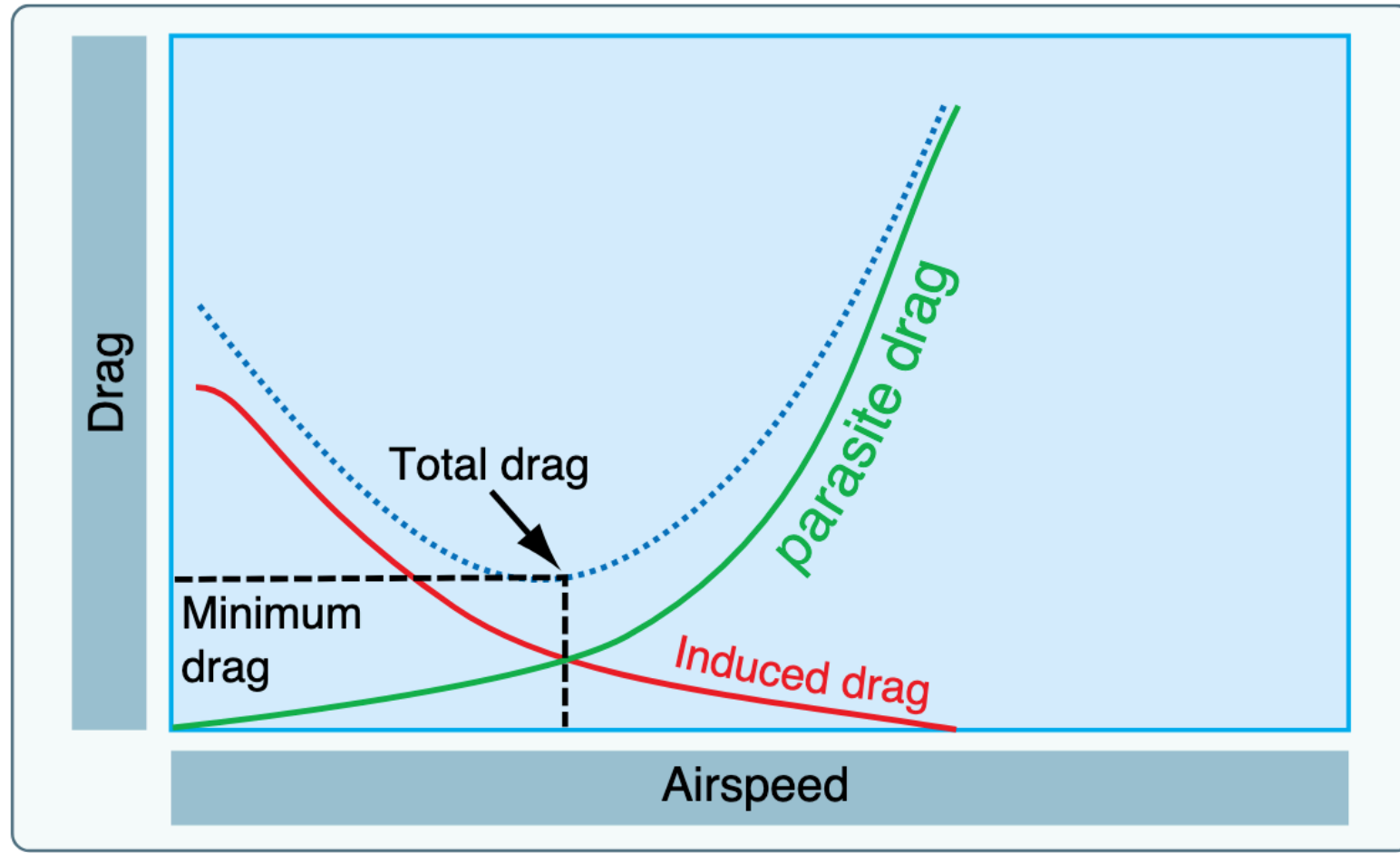
Induced Drag

Ground Effect

AoA in Ground Effect



Thrust vs Drag



Summary

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