# Physics and Sailing

FOR SAILSIM

# Overview

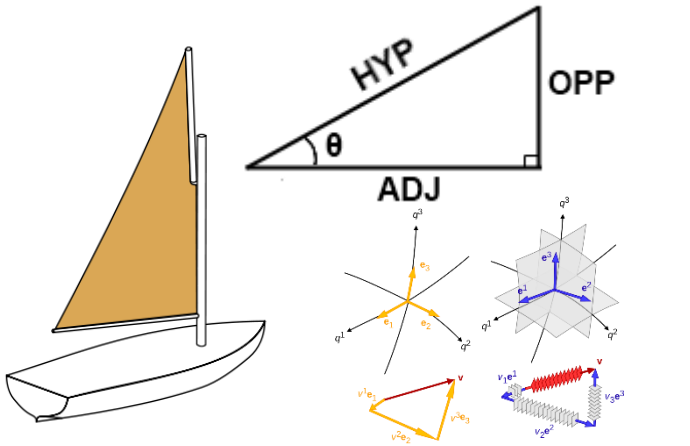
The goal here is to become familiar with the basic physics behind sailing

Each page introduces a topic, with some explanation notes included in the footer of the .pptx file

Some prerequisite topics that will be helpful

- Algebra
- Vector Fundamentals
- Basic Trigonometry (SOH-CAH-TOA)
- Newton's Laws of Motion

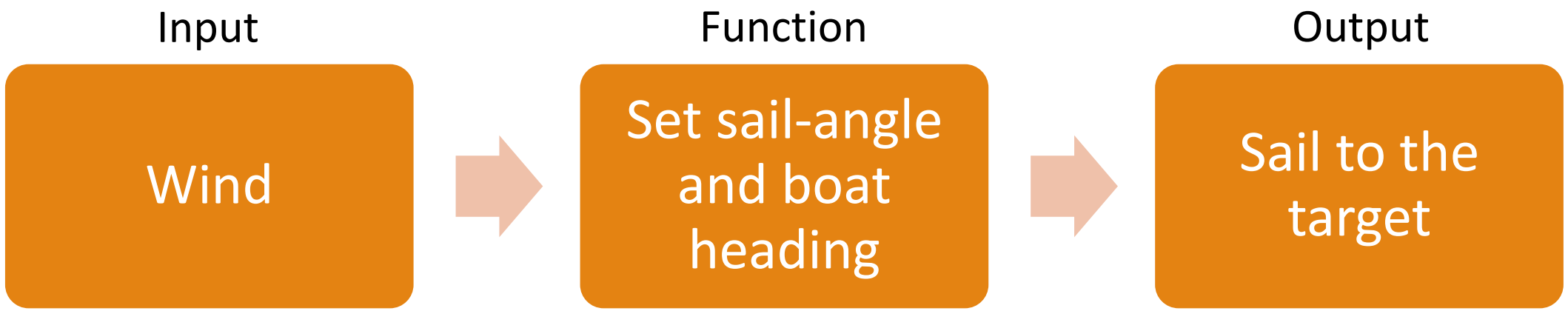
Important Topic




Important notes about this topic

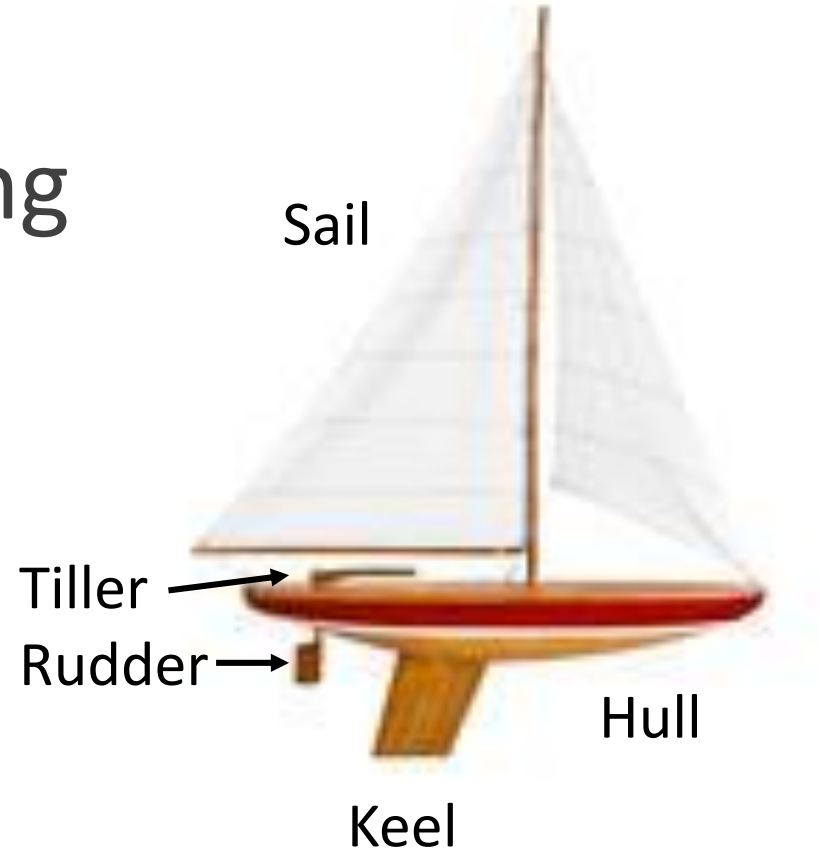
# What's the Problem?

Apply techniques in math, physics, and computer science to discover a "solution" to the sailing "problem"



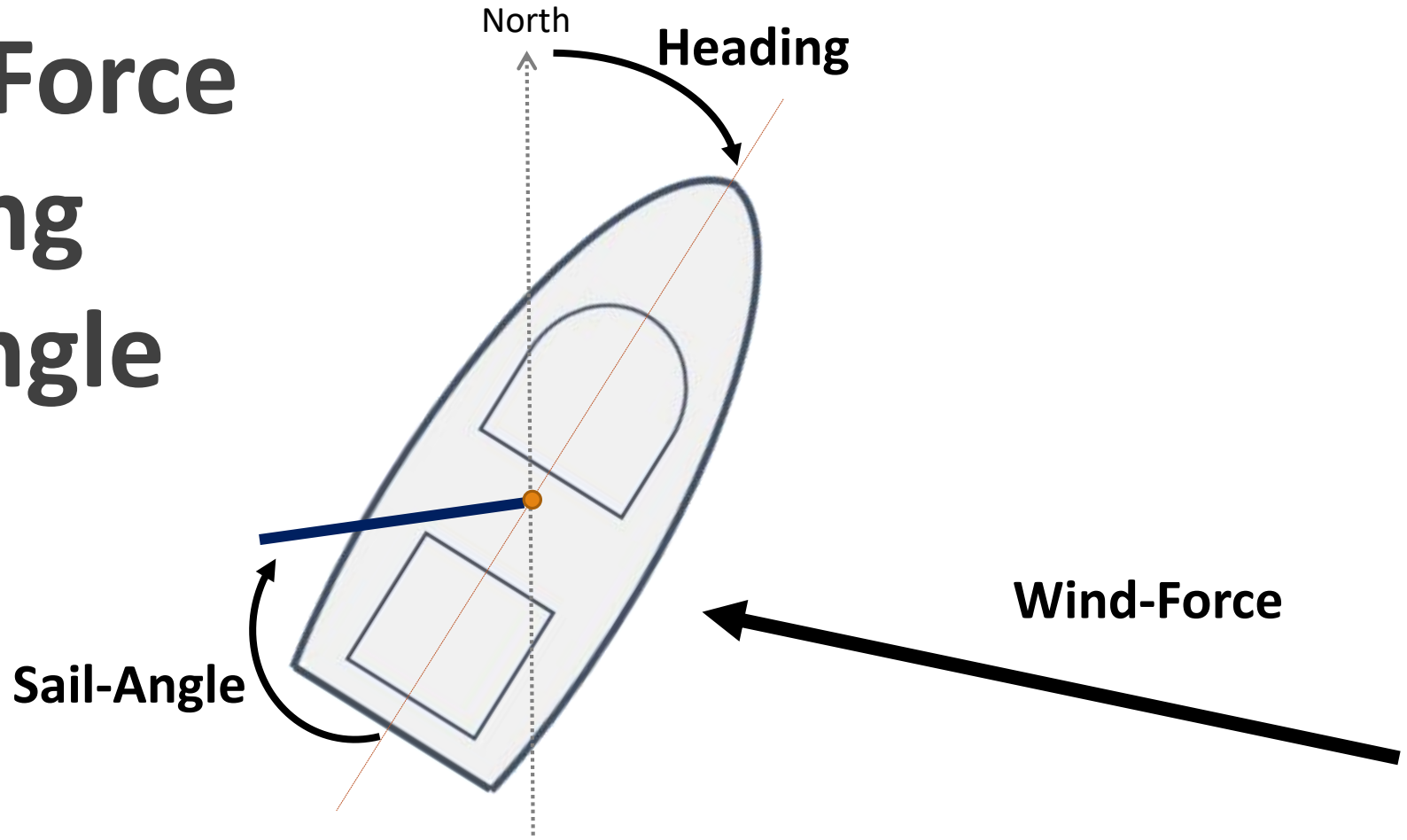
# 4 Key Parts of a Sailboat

- **Sail** ⇒ Power
- **Tiller and Rudder** ⇒ Steering
- **Hull** ⇒ Buoyancy
- **Keel** ⇒ Balance



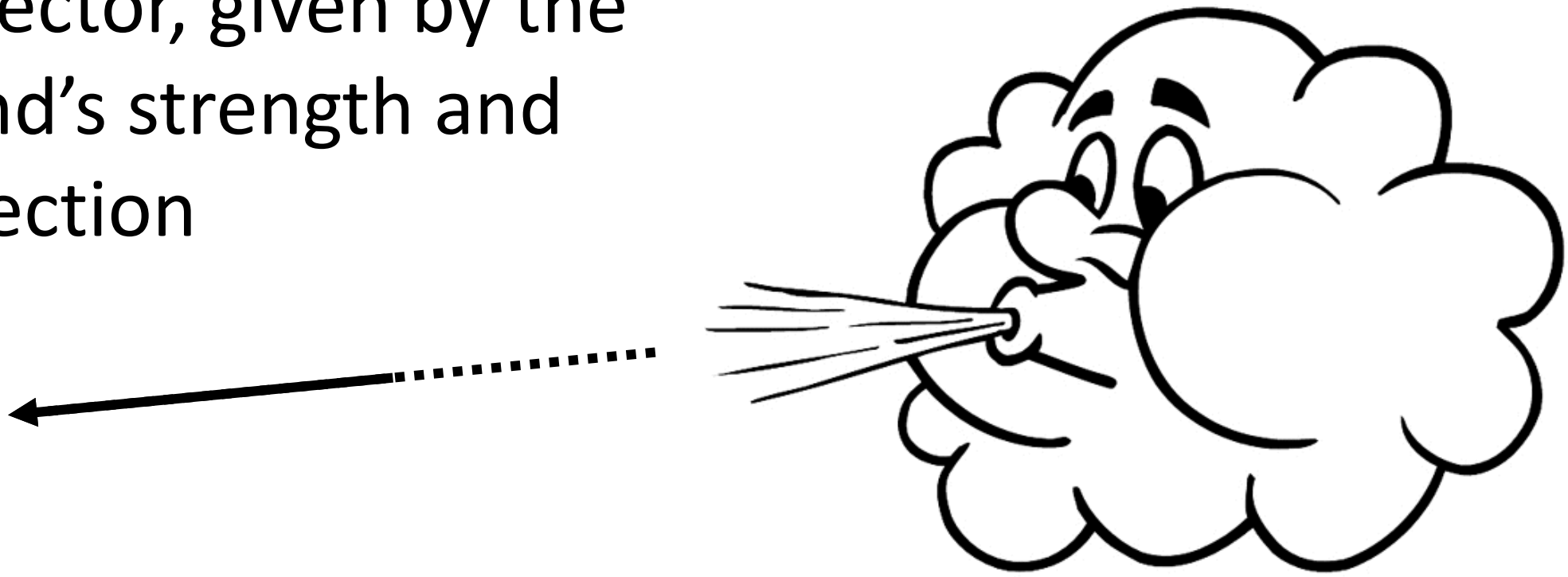
# The Three Ingredients for Sailing

- **Wind-Force**
- **Heading**
- **Sail-Angle**



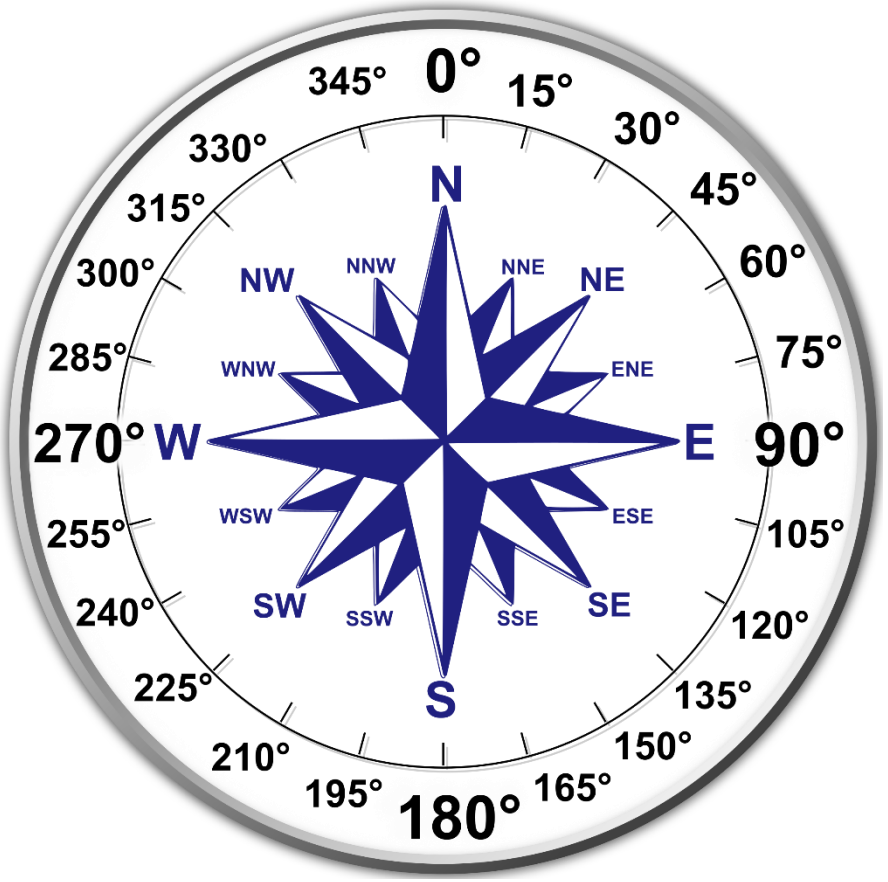
# Ingredient #1: Wind-Force

A vector, given by the wind's strength and direction



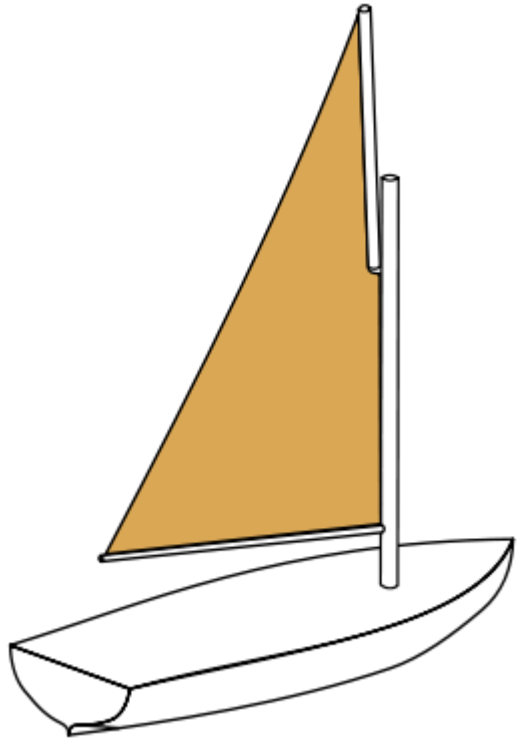
# Ingredient #2: Heading

In navigation, heading is measured in degrees of **clockwise** rotation from north

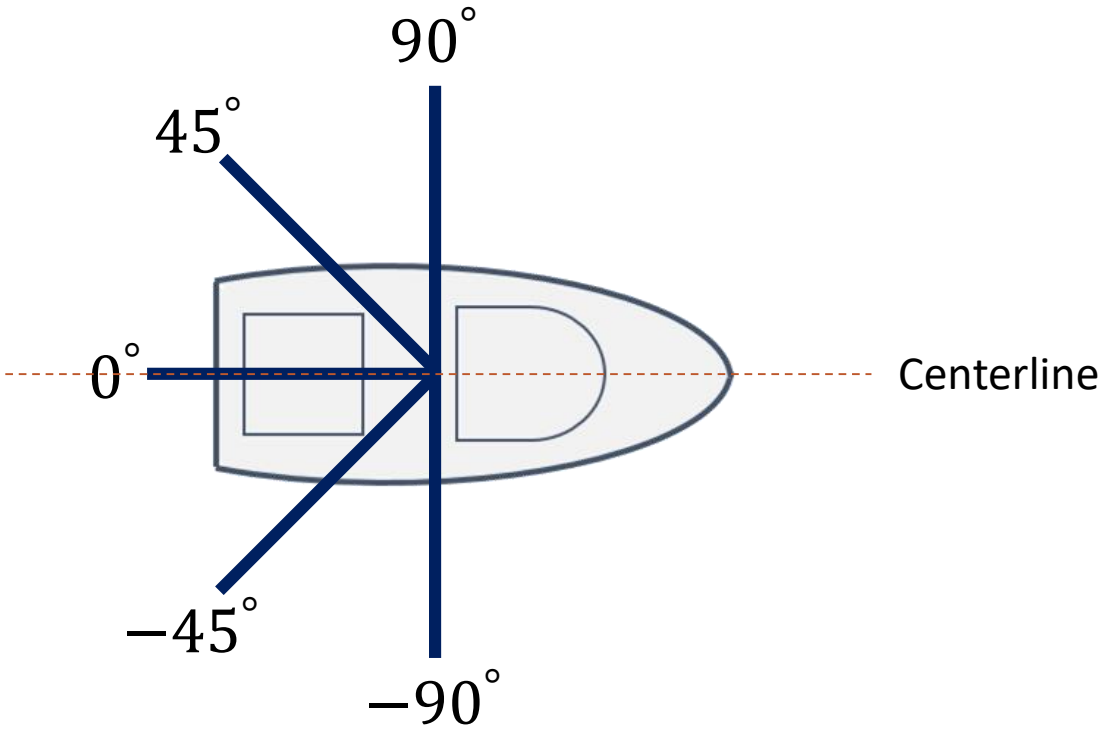


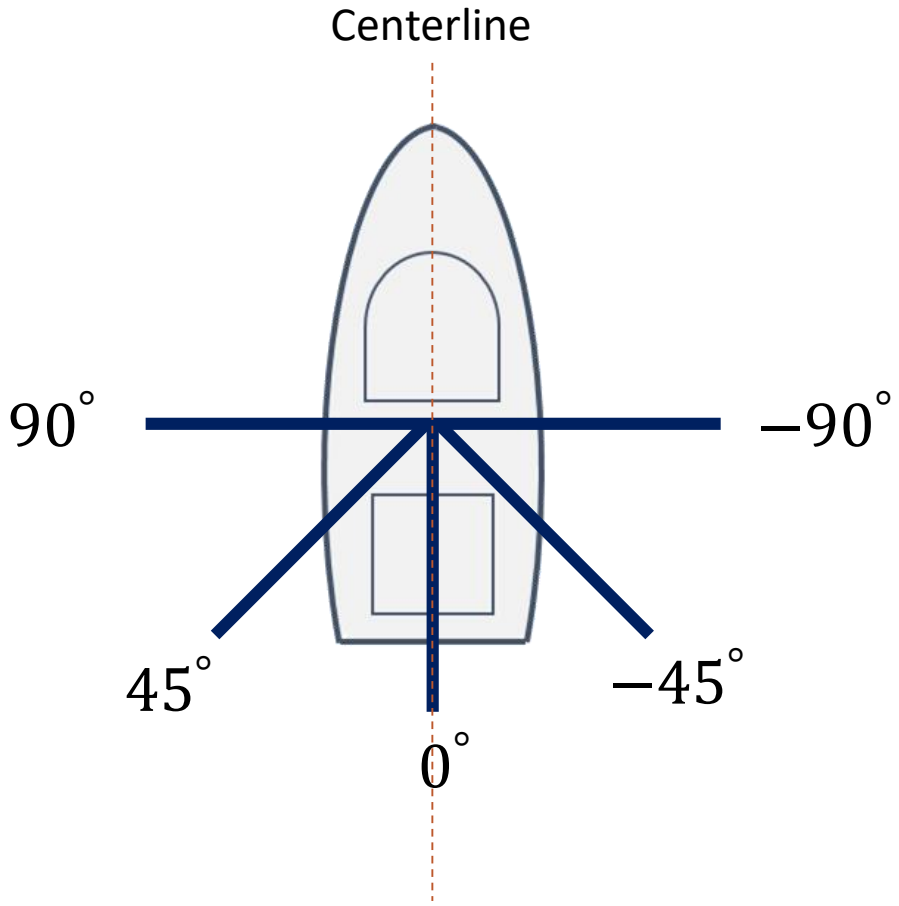
# Ingredient #3: Sail-Angle

Actually, there are two important components: **Relative** and **Absolute** Sail-Angles



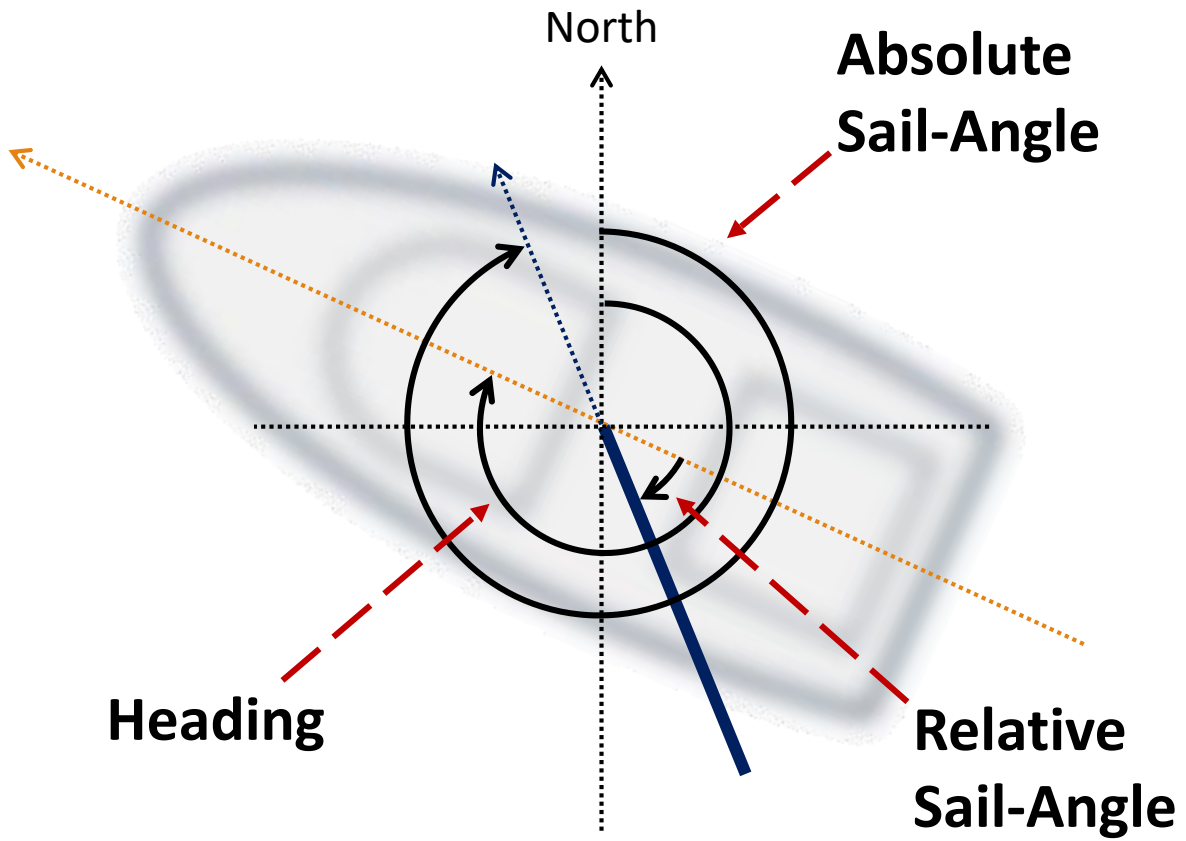
# Relative Sail-Angle



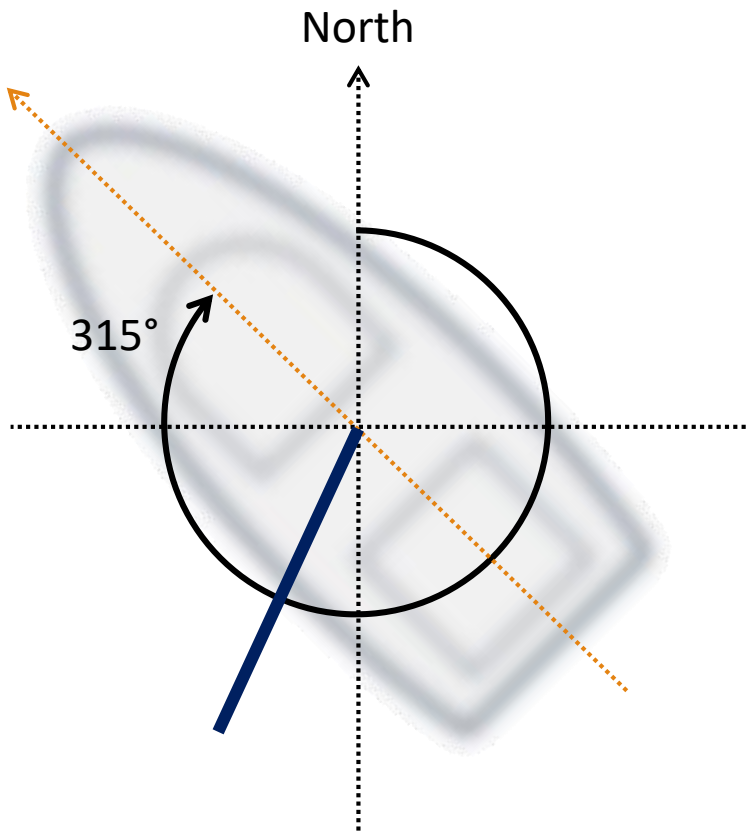



# Absolute Sail-Angle

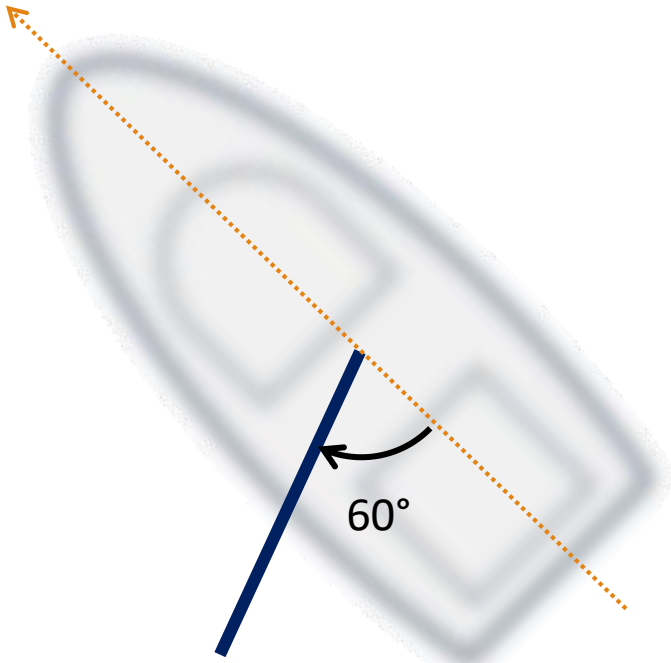
The sail's compass bearing, independent of the boat's heading



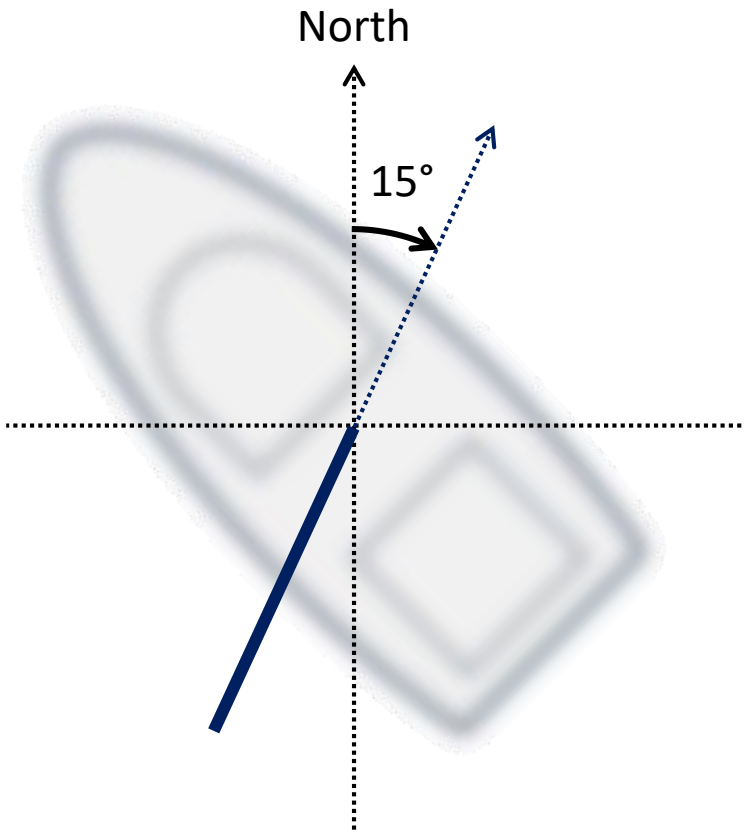
# Absolute Sail-Angle Broken Down




Boat Heading



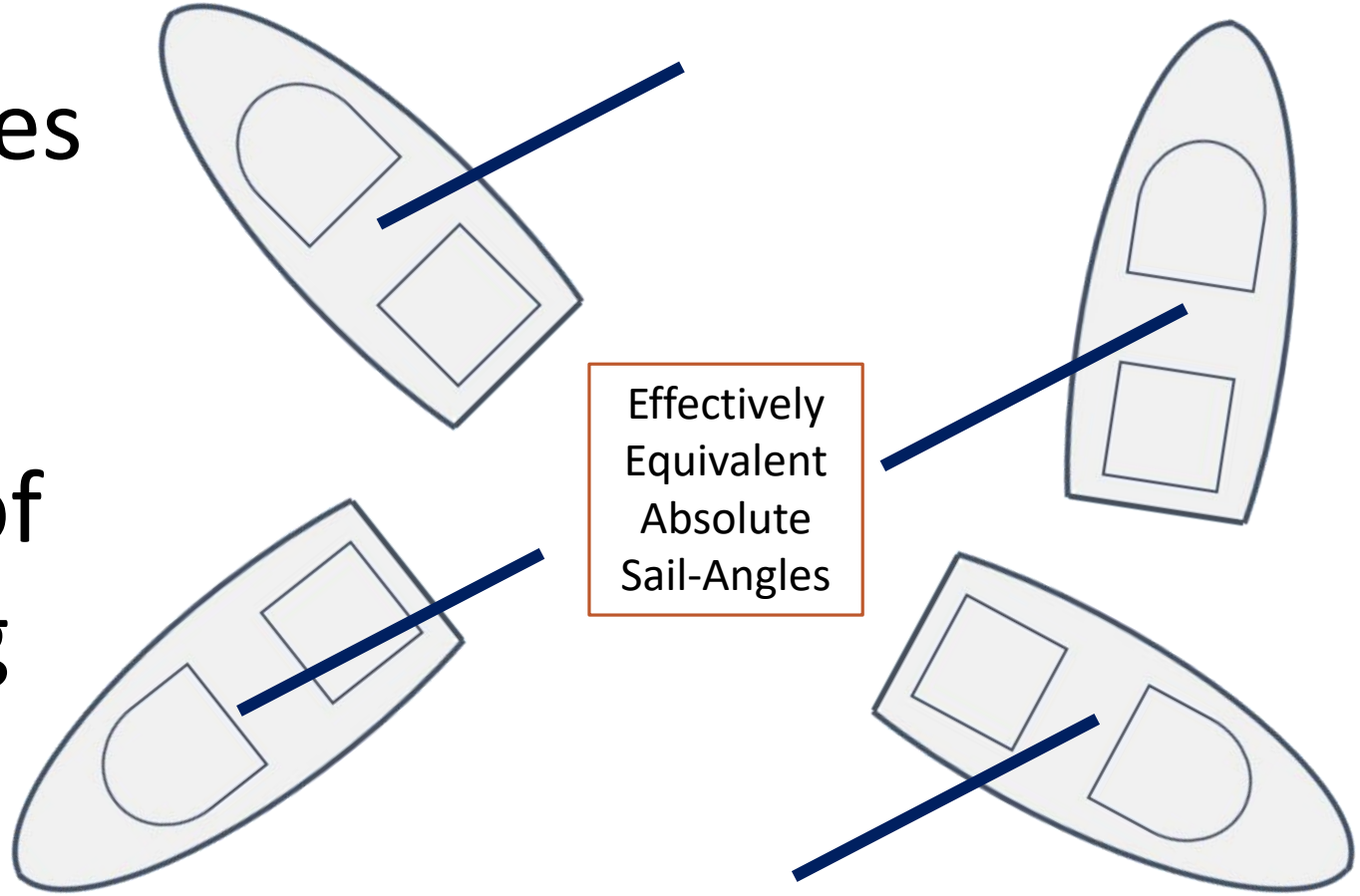

Relative Sail-Angle




Absolute Sail-Angle

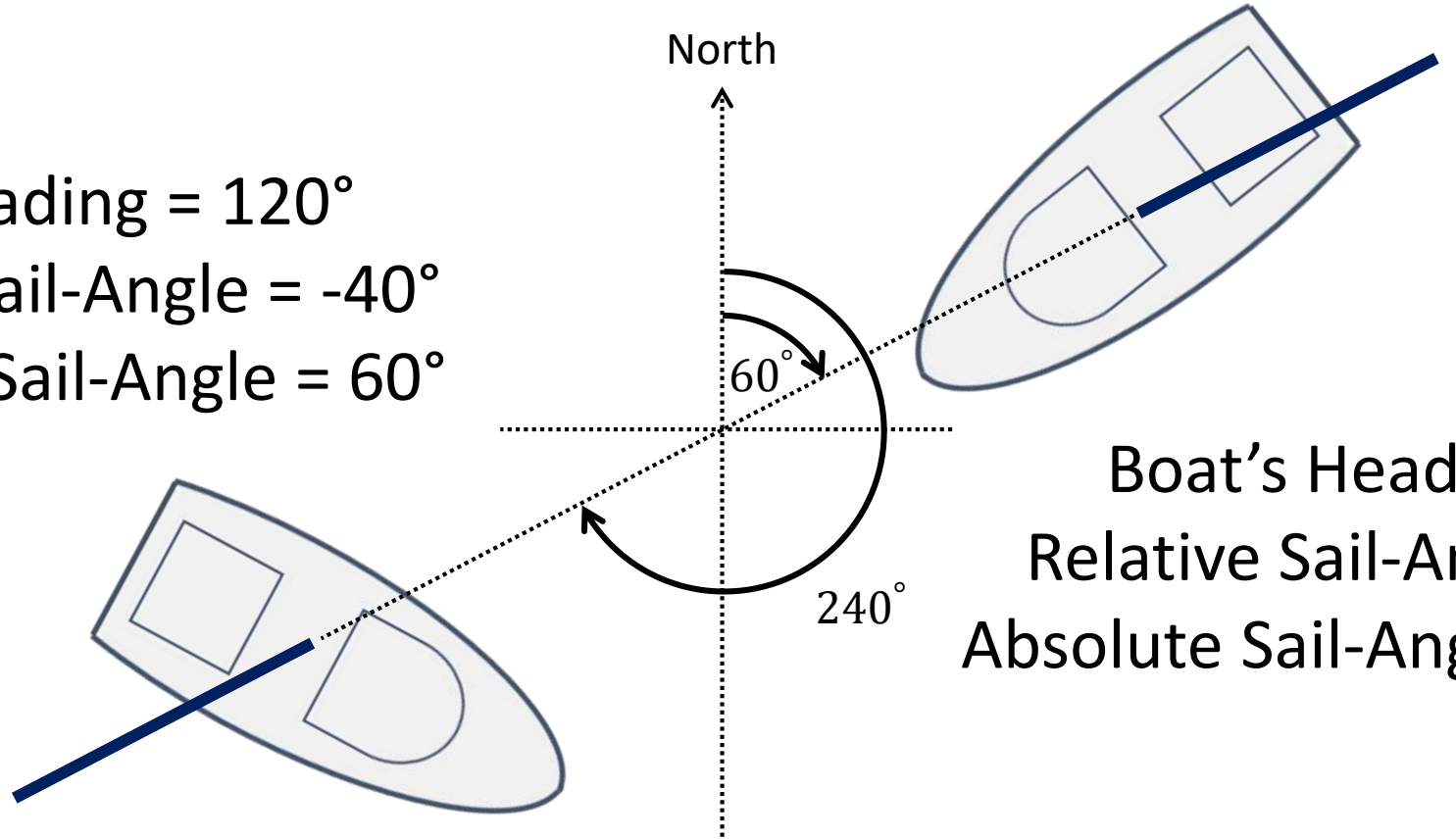
# Equivalent Absolute Sail-Angles

Absolute Sail-Angles that differ by 180° are effectively the same, regardless of the boat's heading



# Equivalent Absolute Sail-Angles Example

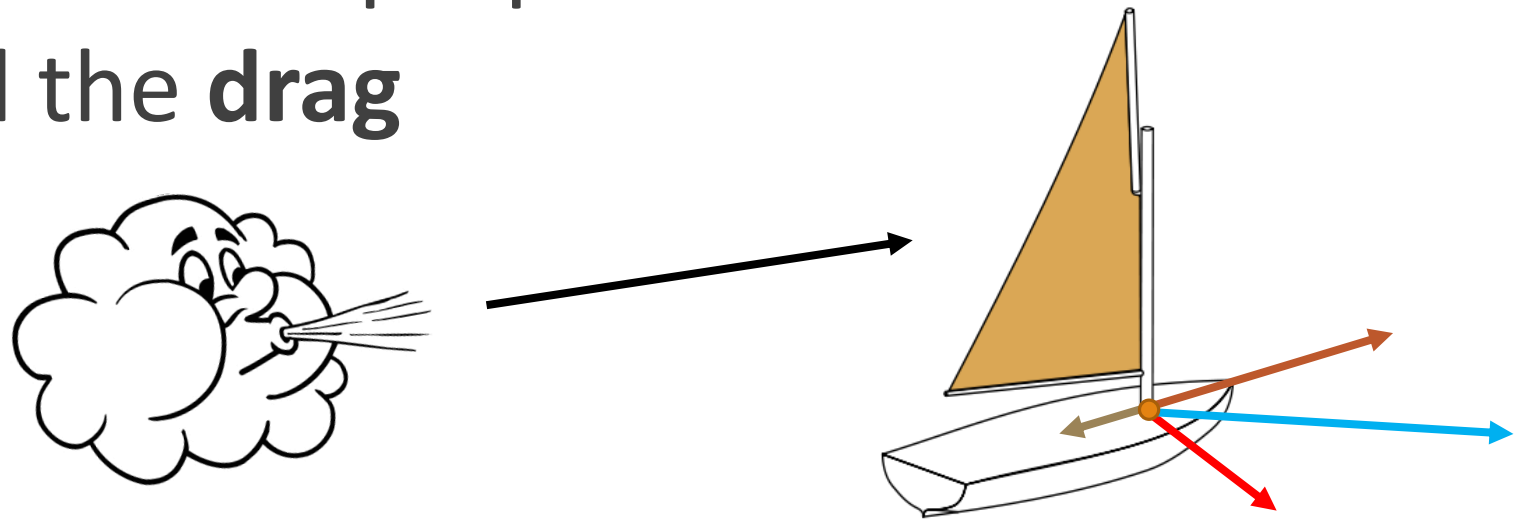
Boat's Heading = 120°
Relative Sail-Angle = -40°
Absolute Sail-Angle = 60°




Boat's Heading =230°
Relative Sail-Angle = 10°
Absolute Sail-Angle = 240°

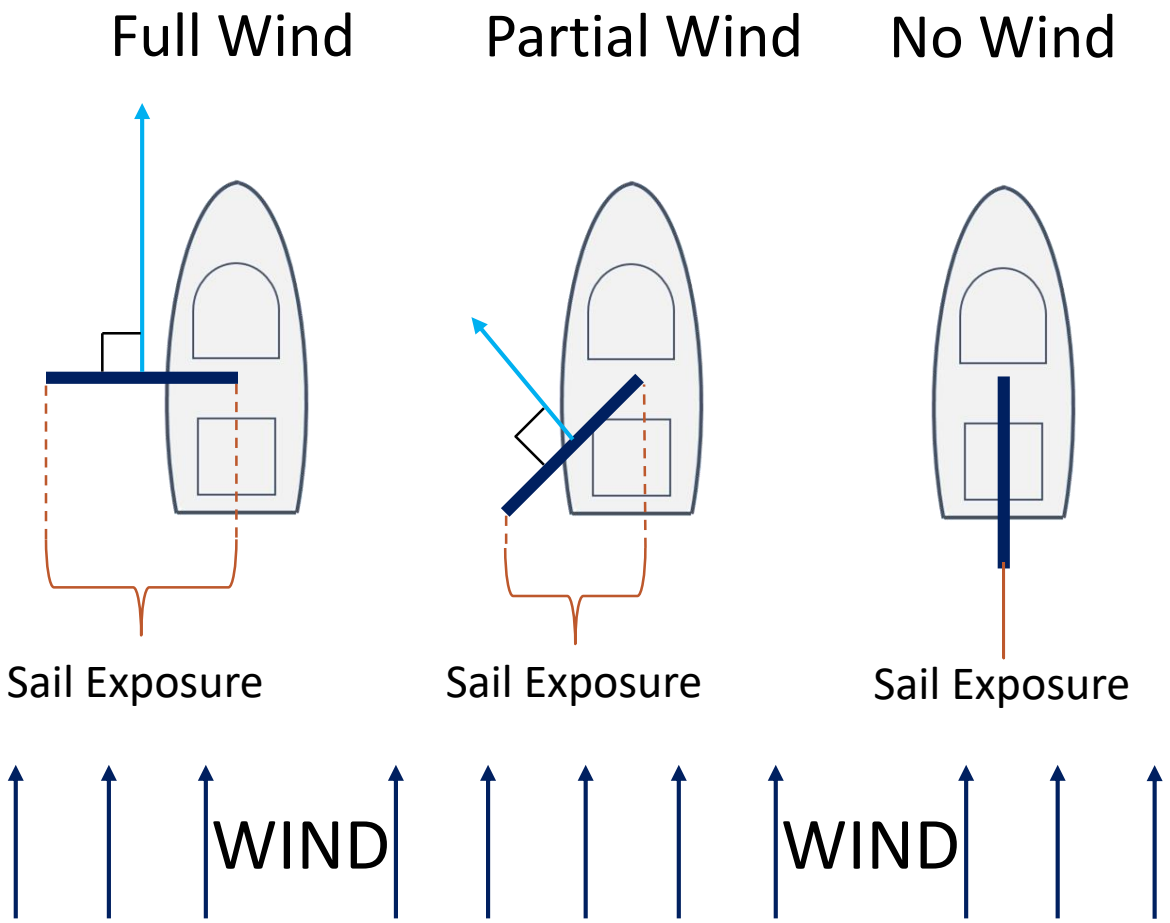
# The sailing recipe

1. Convert **Wind-Force** into **Sail-Force**
2. Decompose the Sail-Force into components parallel and perpendicular to the keel
3. Find the **drag**



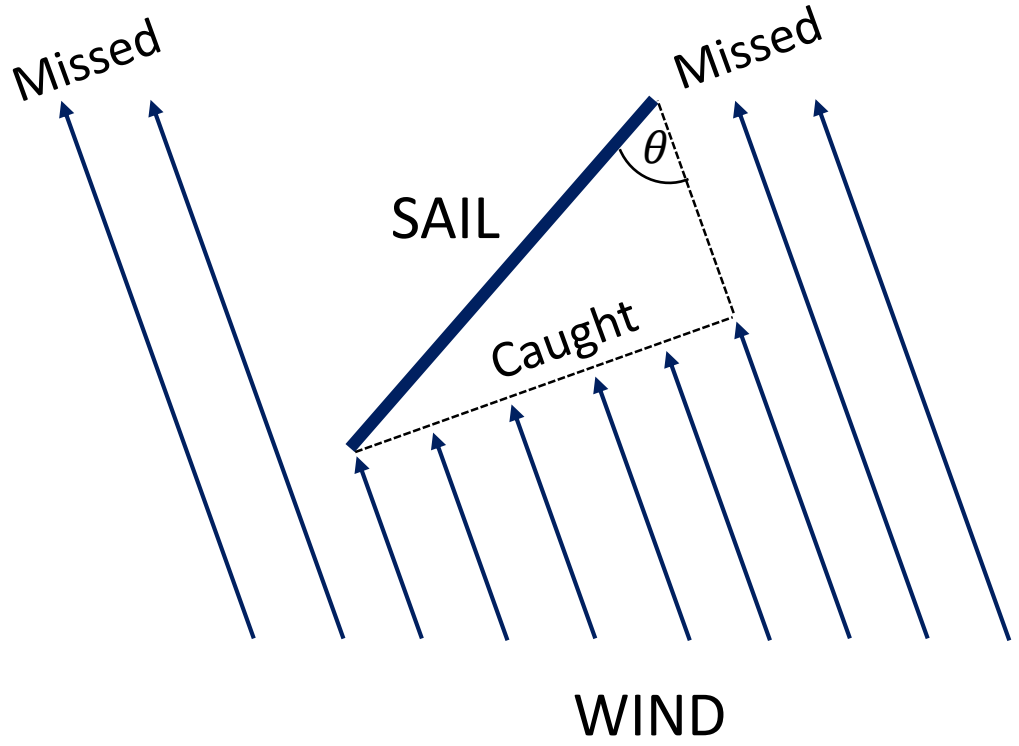
# The Wind-Sail Interaction

The amount of wind the sail will “catch” depends on the angle between the wind and the sail



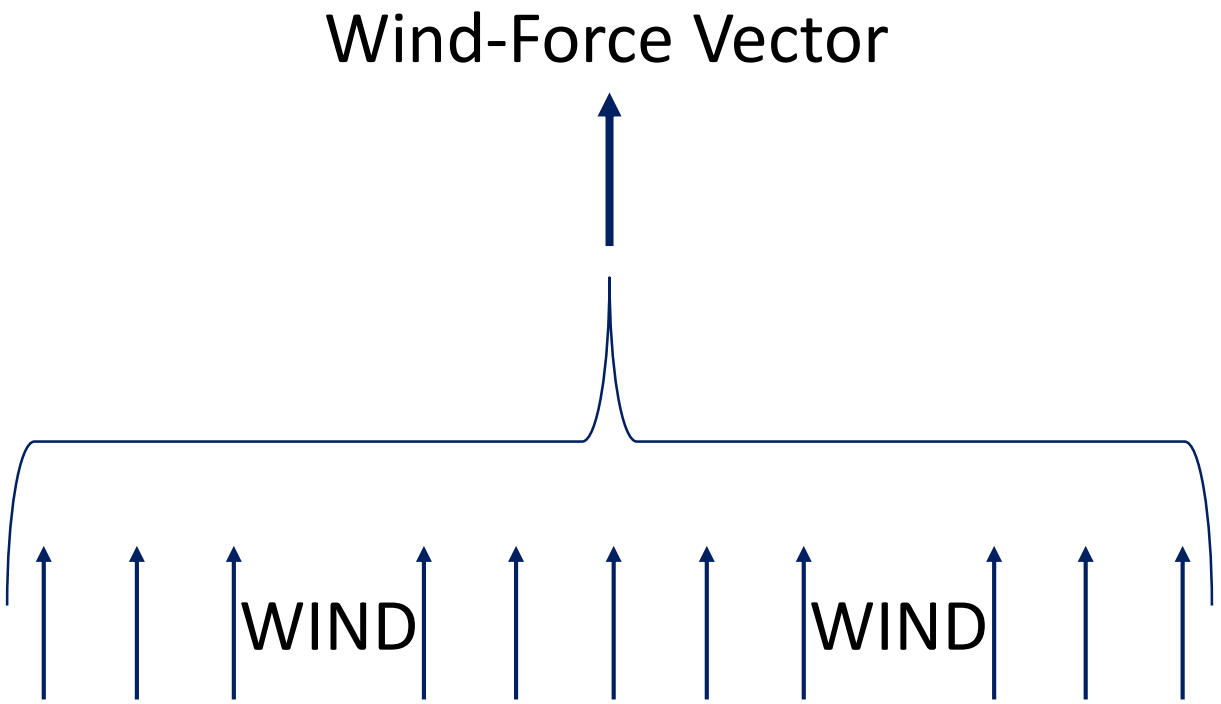
# How Much Wind Does a Sail Catch?

The portion of the wind-force caught by the sail depends only on the absolute sail-angle and wind direction



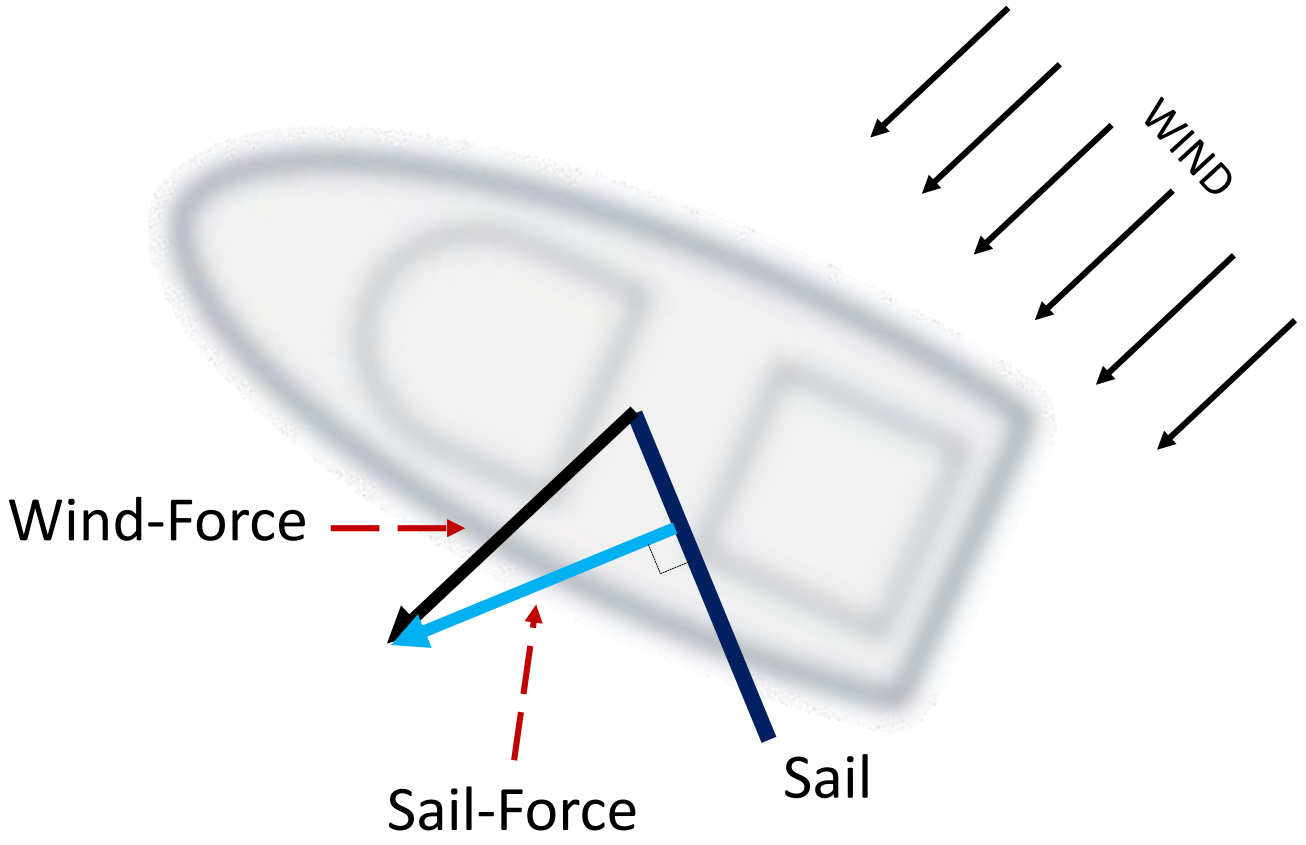
# The Wind-Force Vector

A symbolic way to represent the wind's magnitude (strength) and direction (angle), independent of location



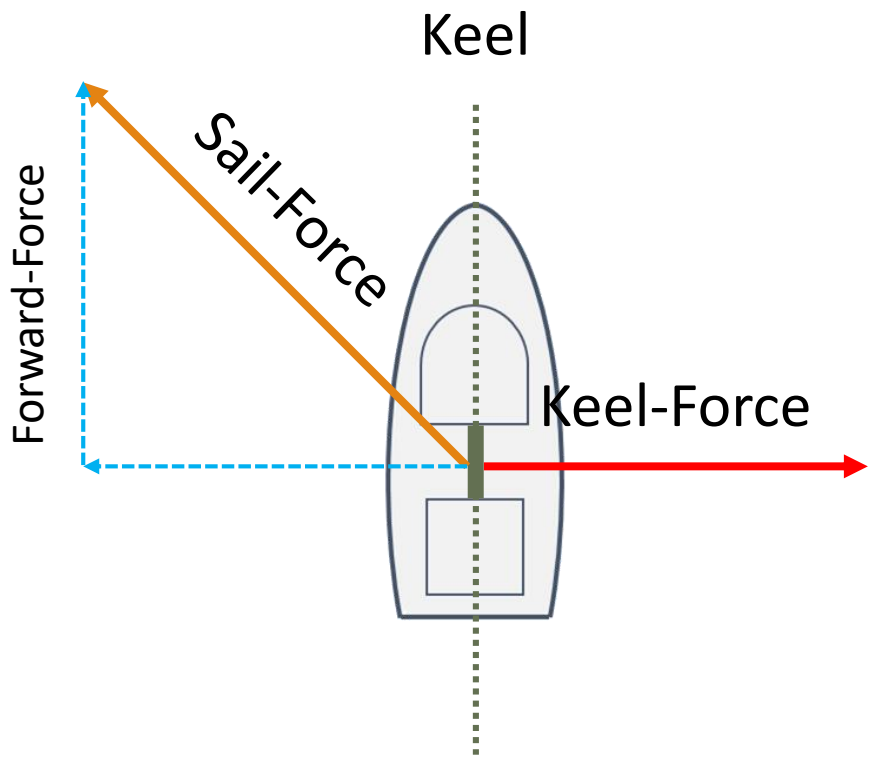
# The Sail-Force

The portion of the wind-force caught by the sail, directed perpendicular to the sail and away from the wind



# Decomposing the Sail-Force

The keel provides resistance, allowing us to decompose the sail-force vector into components perpendicular and parallel to the keel



# Forward-Force and Keel-Force

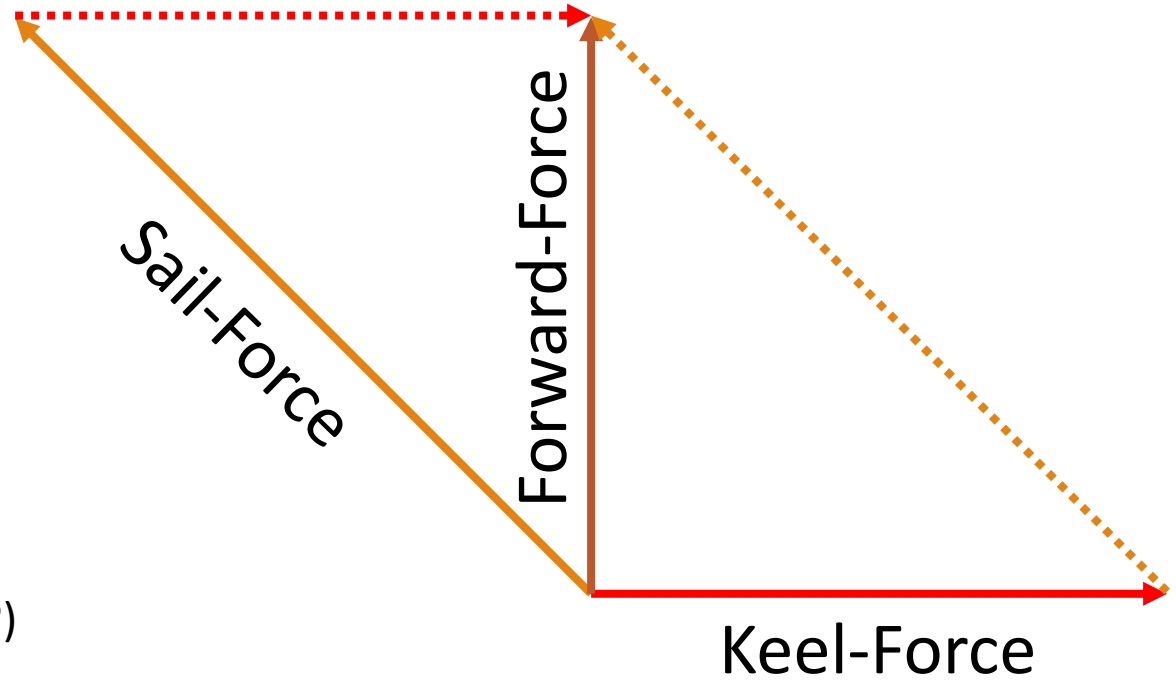
**The Sailing Formula**

Sail-Force

\+ Keel-Force

Forward-Force

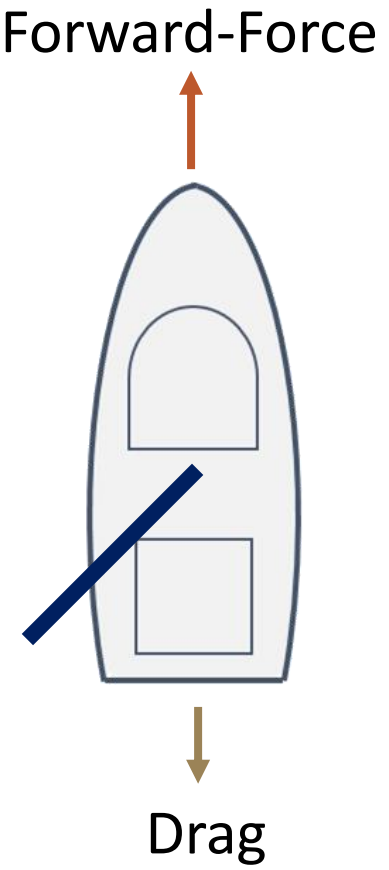
(Remember the parallelogram rule for adding vectors?)



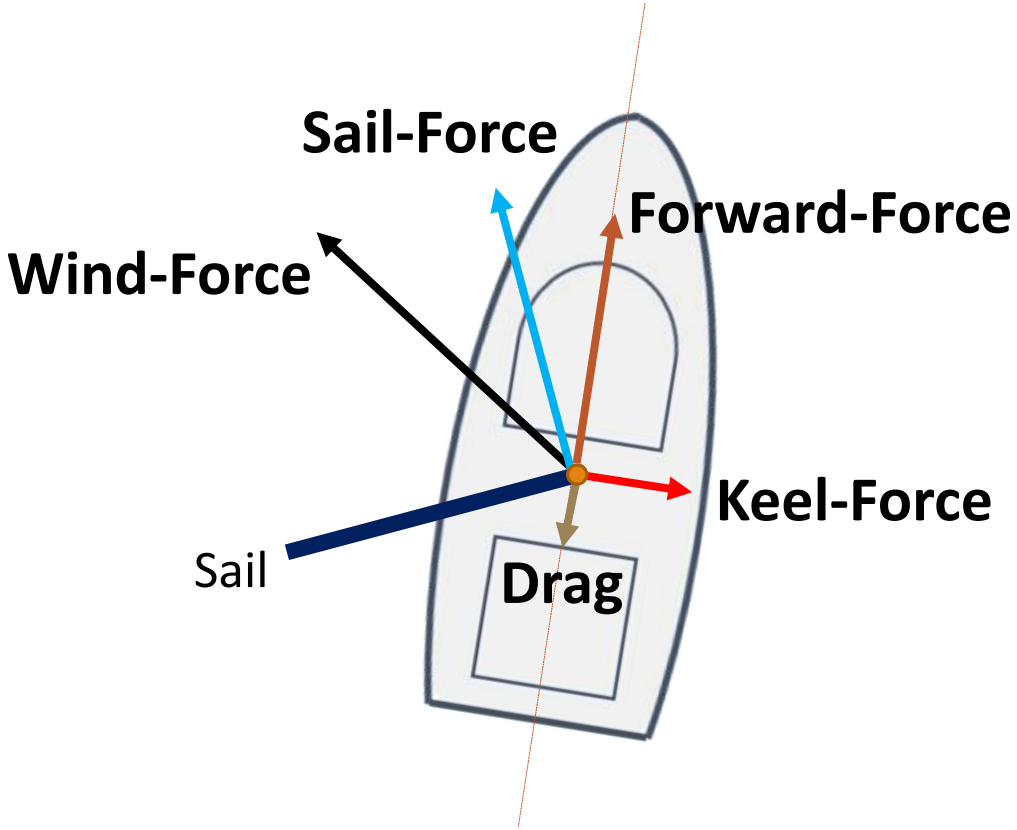
# Resulting Forces

Since the keel-force opposes the sail-force against it, all that remains are

- **Forward-Force**
- **Drag**

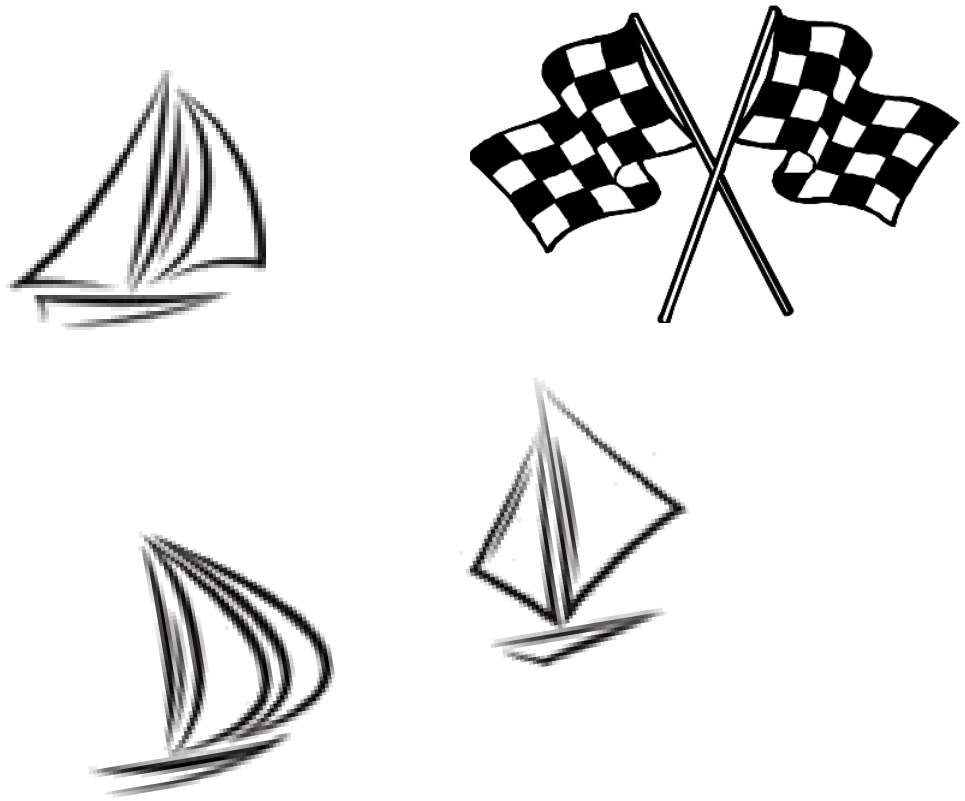


# The Full Picture



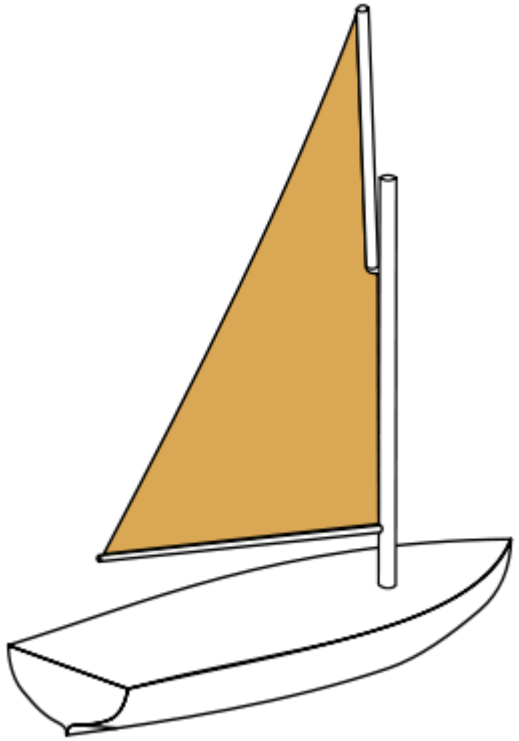
# The Objective

Optimize forward-force while moving toward the target by determining the optimal sail angle and rudder direction

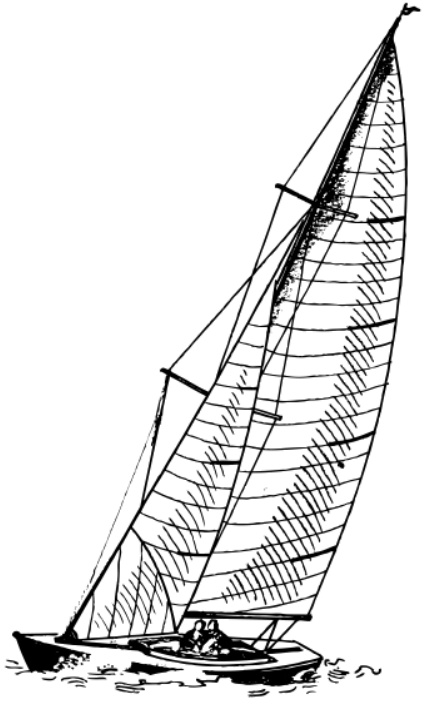


# The Wonderful SailSim Sail Disclaimer

- In SailSim world, sails are flat and frictionless
- Do not attempt to use SailSim physics on a non-virtual sailboat



SailSim = straightforward physics, more fun!



Real World = highly complex physics, still fun, but more work…