

WheTopic: How a Sailboat Works

Primary Goal: Students will learn about the different forces on a boat and how they all work together. They will understand how sail aerodynamics affects boats with different designs.

Lesson Objectives:

- Students should understand how modern sailboats gain propulsion from the wind
- In addition to the sails, how other forces such as wind, water, hull, and keel all interact with one another

Lesson Outline:

- I. Introduction
 - a. The interaction of the wind, sails, hull, water, and keel all effect a boats propulsion
 - b. Take this time to review each of these terms
 - c. *C.A. Marchaj*: “The sailing craft must be considered as a complex system consisting of two interdependent parts – aerodynamic and hydrodynamic”
- II. Sails
 - a. Push vs. Pull: The Two Modes of Sailing
 - i. When the wind comes from behind the boat, the sails simply trap the wind and it *pushes* the sails, like a parachute. This is what most people think of when they think of sailing (mention square-rig)
 - ii. When the wind is coming abeam of or in front of the boat, the sails are able to generate *pull*
 - b. Sails generate energy from the wind (flow of air) by “bending” it as it goes by. The bending of the flow of air causes a low pressure on one side of the sail and a high pressure on the other side
 - i. As the high pressure air attempts to catch up, it generates lift on the sail which causes a force forward and sideways
 - c. When a sailboat is moving directly downwind, it can never move faster than the wind because, at the wind speed, the sails would feel no wind. In fact, a boat going downwind can never attain the wind speed because there’s always some resistance to its motion through the water.
- III. Keel
 - a. Why doesn’t the boat drift sideways? → the keel
 - b. The keel exerts a sideways force on the water, which causes the boat to slightly tip, or “heel”. But by transforming the side force created by the wind in the sails into a force that counteracts, the boat is able to go forward.

Supplemental Resources:

Quest Video: [The Physics of Sailing](#)

Veritasium Videos: (1) [How Does a Sailboat Actually Work?](#) (2) [How Does a Wing Actually Work?](#)

DSN Animations: [What are the Parts of a Sailboat?](#)

Exercises/Activities:

Bring a large fan to class. Have students take turns holding their hand, palm open, and flat to the blowing air. Explain that this force is what happens when a boat is going downwind. Then have the students slightly cup their palm and slowly turn it towards the fan. Have the students note the gradual change when they rotate and cup their hand and relate that to the similar forces on a sail.