Soap-Motor Boat

Introduction

Move a boat with a drop of soap.

Concepts

- Surface tension
- Cohesion
- Marangoni effect

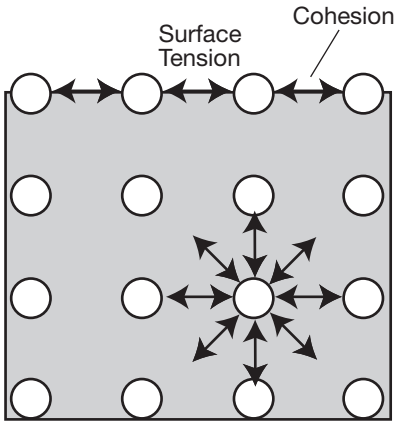

Figure 1.

Background

Liquid water has an unusually strong surface tension because of its strongly polar water molecules. A surface tension develops because the molecules at the interface between the water and air are attracted to the water molecules below them but not to the air molecules above (Figure 1). The attraction of like molecules toward each other is known as *cohesion*. Since no water molecules are above the surface to counteract the cohesive attraction from below, the water molecules at the surface are attracted to each other with a stronger net force. The unbalanced forces on the surface water molecules form an invisible elastic "skin" on the surface of the water.

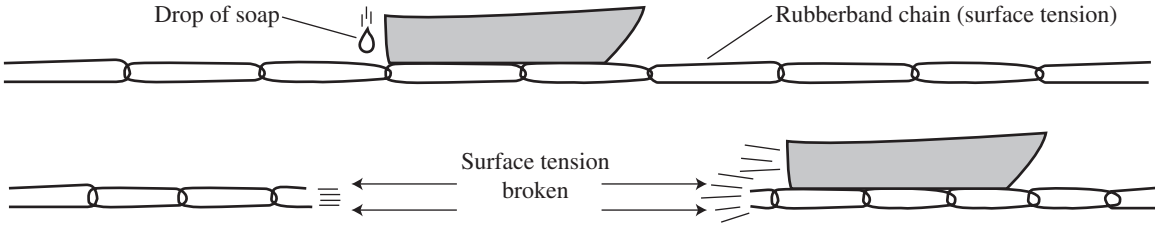

Figure 2.

The higher attractive forces at the surface of water can be modeled in terms of linked, stretched rubber bands (Figure 2). Stretched rubber bands have a high potential energy, and when a rubber band relaxes, the potential energy is converted into kinetic energy—or energy of motion. In terms of the rubber band model, when a drop of soap is added to the surface of the water, the soap molecules create an area of low surface tension, acting like scissors cutting the links between the stretched rubber bands. When the link is broken, the rubber bands relax and quickly retract. The flow of liquid away from a region of lower surface tension is known as the *Marangoni effect*. The retracting surface molecules (rubber bands) are quickly pulled away from the drop of soap and the boat at the surface goes along for the ride—like a surfboard on a wave.

Materials

Aluminum foil, 5 cm × 8 cm
Demonstration tray or large pan
Dish soap, 1 drop
Paper towel
Scissors
Water

Safety Precautions

The materials in this activity are considered safe. Please follow normal laboratory safety guidelines.

Preparation

1. Fill a demonstration tray or large trough about ¼- to ½-full with water.
2. Cut aluminum foil into 5 cm × 8 cm rectangles.

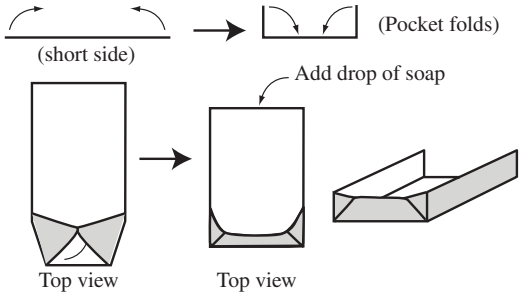

Figure 3.

Procedure

1. Obtain the aluminum foil rectangle and bend it in the form of boat similar to Figure 3. *Note:* The back of the boat can remain open and it will not sink on the water. Any boat design will work.
2. Place the aluminum foil boat at one end of the water-filled tray with its bow pointing towards the "open water."

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Observe the motion of the boat.

3. Remove the boat from the water and dry off the bottom.
4. Add a small drop of dish soap to the back edge of the boat. Make sure the soap is at the edge.
5. Place the boat back in the water-filled tray with its bow pointing towards the open water. Observe the motion of the boat.

Disposal

The aluminum foil may be disposed of in the regular trash or be recycled.

Tips

- The boat can have larger dimensions. 5 cm × 8 cm are only preliminary guidelines. Boats may also be cut from foam beverage cups.
- The "soap-motor" will only last for about 30 seconds, depending on the size of the tray and the amount of surface the boat can travel over. The boat rides along the surface, pushed by the breaking surface tension, and eventually the water's surface tension will be in equilibrium and no longer provide any force. At this point, the boat may sink as well, depending on its design.
- The motion of the boat can also be described in terms of Newton's third law of motion, or action–reaction. As the low surface tension soap molecules touch the water, they immediately shoot away from the boat. The resulting action pushes (reaction) the boat in the opposite direction (just like burning rocket fuel exiting the back of a rocket pushes the rocket up).
- Challenge students to create a boat that will travel in a clockwise or counter-clockwise direction.

NGSS Alignment

This laboratory activity relates to the following Next Generation Science Standards (2013):

Disciplinary Core Ideas: Middle School
- MS-PS1 Matter and Its Interactions
  - PS1.A: Structure and Properties of Matter
- MS-PS2 Motion and Stability: Forces and Interactions
  - PS2.A: Forces and Motion
  - PS2.B: Types of Interactions
- MS-PS3 Energy
  - PS3.A: Definitions of Energy
  - PS3.B: Relationship Between Energy and Forces

Disciplinary Core Ideas: High School
- HS-PS1 Matter and Its Interactions
  - PS1.A: Structure and Properties of Matter
- HS-PS2 Motion and Stability: Forces and Interactions
  - PS2.B: Types of Interactions
- MS-PS3 Energy
  - PS3.A: Definitions of Energy

Science and Engineering Practices
- Asking questions and defining problems
- Planning and carrying out investigations
- Constructing explanations and designing solutions

Crosscutting Concepts
- Cause and effect
- Energy and matter
- Structure and function

Materials for the *Soap-Motor Boat* are available from Flinn Scientific, Inc.

Catalog No.	Description
A0019	Aluminum Foil, Household Type, 1 roll
C0241	Cleaner, Dishwashing, 22 oz.
AP5429	Demonstration Tray, Large
AP9176	Plastic Utility Pan

Consult your *Flinn Scientific Catalog/Reference Manual* for current prices.