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### Lesson Focus

Lesson focuses on watercraft engineering and sailing. Students explore what marine engineers and naval architects do, and work in teams to design a sailboat out of everyday objects that can catch a breeze from a fan, stay afloat with a set load, and sail one meter. Students work in teams of "engineers" to design a boat with a sail structure, test their boat, evaluate the work of other "engineering" teams, and present reflections to the class.

### Lesson Synopsis

The Sail Away lesson not only explores how engineers design watercraft, but also challenges student to work as teams of engineers to develop a watercraft that holds a set weight, captures wind from a fan for power, and can move one meter without sinking. Teams design their boats, build them, test them, evaluate the crafts of other teams, and present their project reflections to the class.



### Age Levels

8-18.

### Objectives

- ◆ Learn about marine engineering and sailing principles.
- ◆ Learn about engineering product planning and design.
- ◆ Learn about meeting the needs of society.
- ◆ Learn about teamwork and working in groups.

### Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- ◆ watercraft engineering
- ◆ problem solving
- ◆ teamwork

### Lesson Activities

Students explore what marine engineers and naval architects do, and work in teams to design a sailboat out of everyday objects that can catch a breeze from a fan, stay afloat with a set load, and sail one meter. Students work in teams of "engineers" to design a boat with a sail structure, test their boat, evaluate the work of other "engineering" teams, and present reflections to the class.

#### Sail Away

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## **Resources/Materials**

- ◆ Teacher Resource Document (attached)
- ◆ Student Worksheets (attached)
- ◆ Student Resource Sheet (attached)

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## **Alignment to Curriculum Frameworks**

See attached curriculum alignment sheet.

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## **Internet Connections**

- ◆ TryEngineering ([www.tryengineering.org](http://www.tryengineering.org))
- ◆ WB-Sails DynaSim (<http://www.wb-sails.fi/en/sail-technology/dynasim>)
- ◆ The Physics of Sailing (<http://newt.phys.unsw.edu.au/~jw/sailing.html>)
- ◆ International Sailing Federation ([www.sailing.org](http://www.sailing.org))

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## **Recommended Reading**

- ◆ Introduction to Marine Engineering, Second Edition (ISBN: 0750625309)
- ◆ The Complete Sailor: Learning the Art of Sailing (ISBN: 0070571317)
- ◆ Toy boats, 1870-1955: A pictorial history (ISBN: 0684159678)

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## **Optional Writing Activity**

- ◆ Write an essay or a paragraph about how marine engineers have to incorporate the range of water temperatures across the globe when designing a cruise ship that will travel all around the world.

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## For Teachers: Teacher Resource

### ◆ Lesson Goal

The Sail Away lesson not only explores how engineers design watercraft, but also challenges student to work as teams of engineers to develop a watercraft that holds a set weight, captures wind from a fan for power, and can move one meter without sinking. Teams design their boats, build them, test them, evaluate the crafts of other teams, and present their project reflections to the class.

### ◆ Lesson Objectives

- ◆ Learn about marine engineering and sailing principles.
- ◆ Learn about engineering product planning and design.
- ◆ Learn about teamwork and working in groups.

### ◆ Materials

- ◆ Student Resource Sheet and Worksheets
- ◆ Construction Materials: One set of materials for each group of students: empty wax coated milk or juice carton, scissors, standard weight (several coins of same denomination or film canister filled with sand), paper, cardboard, glue, tape, string, sail materials (aluminum foil, plastic wrap, silk, fabrics, balloons), toothpicks, popsicle sticks, rubber bands, wire, tape. Each team has identical materials.

### ◆ Procedure

1. Show students the various Student Reference Sheets. These may be read in class, or provided as reading material for the prior night's homework.
2. If internet access is available, have students review physics of sailing and sailing simulators on the following websites:
  - ◆ WB-Sails DynaSim (<http://www.wb-sails.fi/en/sail-technology/dynasim>)
  - ◆ The Physics of Sailing (<http://newt.phys.unsw.edu.au/~jw/sailing.html>)
3. Divide students into groups of 2-3 students, providing a set of materials per group.
4. Explain that students must work in teams of "engineers" who have been given the challenge of designing a sailboat that will catch wind from a fan, hold a set weight, and travel 4 feet without sinking.
5. Students will first meet, plan, and draw their boat design on paper.
6. Next, students construct their boats.
7. Students take turns testing their boats on a waterway created by the teacher. The teacher runs the fan to ensure testing consistency. Student must see if their sail design captures wind, and is able to travel one meter on the water without sinking.
8. Students complete evaluation and reflection sheets, and then present their reflections to the class.

### ◆ Tips

1. Waterway might be a shallow long container, a plastic planter, or child's pool.
2. Teams may need to replace or redesign their sail after testing; allow students extra time and materials to redo their boat and try again.

### ◆ Time Needed

Two to four 45 minute sessions.

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## **Student Resource:** **Marine Engineering, Sailing, and Physics**

### ◆ **What is Sailing?**

Sailing is the skillful art of controlling the motion of a sailing ship or sailboat, across a body of water. The force of the wind on the sails propels sailing vessels. Today, for most people, sailing is recreation, an activity pursued for the joy of being on the water and pursuing the mastery of skills needed to maneuver a sailboat in varying sea and wind conditions. Throughout history sailing has been instrumental in the development of civilization. The earliest representation of a ship under sail appears on an Egyptian vase from about 3500 BC.

### ◆ **Sail Aerodynamics**

Sails propel the boat in one of two ways. When the boat is going in the direction of the wind (i.e. downwind), the sails may be set merely to trap the air as it flows by. Sails acting in this way are aerodynamically stalled. In stronger winds, turbulence created behind stalled sails can lead to aerodynamic instability, which in turn can manifest as increased downwind rolling of the boat. Spinnakers and square-rigged sails are often trimmed so that their upper edges become leading edges and they operate as airfoils again, but with airflow directed more or less vertically downwards. This mode of trim also provides the boat with some actual lift and may reduce both wetted area and the risk of 'digging in' to waves. The other way sails propel the boat occurs when the boat is traveling across or into the wind. In these situations, the sails propel the boat by redirecting the wind coming in from the side towards the rear. In accordance with the law of conservation of momentum, air is redirected backwards, making the boat go forward. This driving force is called lift although it acts largely horizontally. The lift generated by a sail can be resolved into two main components; forward force and sideways force. These forces act against opposing forces generated by the hull and the keel. On a sailing boat, a keel or centerboard helps to prevent the boat from moving sideways. The shape of the keel has a much smaller cross section in the fore and aft axis and a much larger cross section on the athwart axis (across the beam of the boat). The resistance to motion along the smallest cross section is low while resistance to motion across the large cross section is high, so the boat moves forward rather than sideways.



### ◆ **Marine Engineers and Naval Architects**

Marine engineers and naval architects are involved in the design, construction, and maintenance of ships, boats, and related equipment. They design and supervise the construction of everything from aircraft carriers to submarines, and from sailboats to tankers. Naval architects work on the basic design of ships, including hull form and stability. Marine engineers work on the propulsion, steering, and other systems of ships. Marine engineers and naval architects apply knowledge from a range of fields to the entire design and production process of all water vehicles.



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***Student Worksheet:  
Build Your Own Watercraft***

**◆ Engineering Teamwork and Planning**

You are a team of marine engineers given the challenge of designing a sailboat using everyday materials that can hold a set weight and move 4 feet along a classroom waterway harnessing wind energy from a fan.

**◆ Planning and Design Phase**

Each team has been provided with a set of materials. Review these as a group and draw your plan for a boat design in the box below. Think about how the weight your boat must carry should be distributed in the boat for stability during motion. Also think about what your sail material will be and how it will be attached to the boat securely.

**Sail Away**

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**Student Worksheet:**  
**Build Your Own Watercraft (continued)**

◆ Construction Phase

As a team, build your boat, and then complete the questions below:

1. How similar was your design to the actual boat you built.

2. If you found you needed to make changes during the construction phase, describe why you made revisions.

3. Did you find you needed to add extra materials to your boat during the construction phase? If so, what parts did you need to add?

◆ Testing Phase

Your teacher has created a waterway for testing your watercraft. Test your boat! If you find your sail or boat design doesn't work the first time, you'll have an opportunity to redesign your boat and try again. Don't worry if it fails the first time. Part of engineering is testing and designing products until the optimal design is achieved.

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## ***Student Worksheet: Evaluation and Presentation***

### ◆ Evaluation Phase

Answer the following questions to summarize your experience with the Sail Away activity. Work in teams to come up with group opinions.

1. Were you able to create a boat that could hold weight, catch the wind, and travel one meter?
2. If yes, did you need to rework your boat during the testing process? What did you need to change about your boat to make it meet the challenge?
3. Do you think your design could scale upward and work as a full size sailboat? Why or why not?
4. What aspects of other team's boats did you find interesting? Where there aspects of other designs you wish you had incorporated into your own team's boat?
5. How different were all the final boats? What did that tell you about problem solving?
6. If you had a chance to do this project again, what would your team have done differently?
7. Do you think you would have been able to create a successful boat if you had not been working in a group? What did the group interaction add to the design and problem solving process?

### ◆ Presentation

As a group, make a presentation to the class about what you learned during this activity.

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## For Teachers:

### Alignment to Curriculum Frameworks

**Note:** Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards ([http://www.nap.edu/catalog.php?record\\_id=4962](http://www.nap.edu/catalog.php?record_id=4962))
- U.S. Next Generation Science Standards (<http://www.nextgenscience.org/>)
- International Technology Education Association's Standards for Technological Literacy (<http://www.iteea.org/TAA/PDFs/xstnd.pdf>)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (<http://www.nctm.org/standards/content.aspx?id=16909>)
- U.S. Common Core State Standards for Mathematics (<http://www.corestandards.org/Math>)
- Computer Science Teachers Association K-12 Computer Science Standards (<http://csta.acm.org/Curriculum/sub/K12Standards.html>)

#### ◆ National Science Education Standards Grades K-4 (ages 4 - 9)

##### **CONTENT STANDARD A: Science as Inquiry**

As a result of activities, all students should develop

- ◆ Abilities necessary to do scientific inquiry

##### **CONTENT STANDARD B: Physical Science**

As a result of the activities, all students should develop an understanding of

- ◆ Properties of objects and materials
- ◆ Position and motion of objects

##### **CONTENT STANDARD E: Science and Technology**

As a result of activities, all students should develop

- ◆ Abilities of technological design
- ◆ Understanding about science and technology

##### **CONTENT STANDARD F: Science in Personal and Social Perspectives**

As a result of activities, all students should develop understanding of

- ◆ Science and technology in local challenges

##### **CONTENT STANDARD G: History and Nature of Science**

As a result of activities, all students should develop understanding of

- ◆ Science as a human endeavor

#### ◆ National Science Education Standards Grades 5-8 (ages 10 - 14)

##### **CONTENT STANDARD A: Science as Inquiry**

As a result of activities, all students should develop

- ◆ Abilities necessary to do scientific inquiry

##### **CONTENT STANDARD B: Physical Science**

As a result of their activities, all students should develop an understanding of

- ◆ Motions and forces
- ◆ Transfer of energy

##### **CONTENT STANDARD E: Science and Technology**

As a result of activities in grades 5-8, all students should develop

- ◆ Abilities of technological design
- ◆ Understandings about science and technology

##### **CONTENT STANDARD F: Science in Personal and Social Perspectives**

As a result of activities, all students should develop understanding of

- ◆ Science and technology in society

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## For Teachers:

### Alignment to Curriculum Frameworks

#### ◆ National Science Education Standards Grades 9-12 (ages 14-18)

##### **CONTENT STANDARD A: Science as Inquiry**

As a result of activities, all students should develop

- ◆ Abilities necessary to do scientific inquiry

##### **CONTENT STANDARD B: Physical Science**

As a result of their activities, all students should develop understanding of

- ◆ Motions and forces
- ◆ Conservation of energy and increase in disorder
- ◆ Interactions of energy and matter

##### **CONTENT STANDARD E: Science and Technology**

As a result of activities, all students should develop

- ◆ Abilities of technological design
- ◆ Understandings about science and technology

##### **CONTENT STANDARD F: Science in Personal and Social Perspectives**

As a result of activities, all students should develop understanding of

- ◆ Natural and human-induced hazards
- ◆ Science and technology in local, national, and global challenges

#### ◆ Standards for Technological Literacy - All Ages

##### **The Nature of Technology**

- ◆ Standard 1: Students will develop an understanding of the characteristics and scope of technology.
- ◆ Standard 2: Students will develop an understanding of the core concepts of technology.
- ◆ Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

##### **Technology and Society**

- ◆ Standard 6: Students will develop an understanding of the role of society in the development and use of technology.

##### **Design**

- ◆ Standard 8: Students will develop an understanding of the attributes of design.
- ◆ Standard 9: Students will develop an understanding of engineering design.
- ◆ Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

##### **Abilities for a Technological World**

- ◆ Standard 11: Students will develop abilities to apply the design process.

##### **The Designed World**

- ◆ Standard 18: Students will develop an understanding of and be able to select and use transportation technologies.
- ◆ Standard 20: Students will develop an understanding of and be able to select and use construction technologies.

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