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Steamship *Portland*

All Steamed Up

Focus
Energy conversions and simple machines

Grade Level
7-8 (Physical Science)

Focus Question
What energy conversions and simple machines are involved in the operation of a steam engine?

Learning Objectives
Students will be able to explain the basic operation of a steam engine.

Students will be able to identify and describe the energy conversions involved in the operation of a steam engine.

Students will be able to identify at least three simple machines in a steam engine and explain their function.

Materials
For the miniature steam engine
- ❒ Unused, gallon-size metal paint can with lid
- ❒ Unused, quart-size metal paint can with lid
- ❒ Soft copper tubing, 1/4" inside diameter, 6 m long
- ❒ Soft copper pipe, 1/2" insider diameter, 15 cm
- ❒ Hard plastic tubing, 1/8" – 1/4" diameter, 35 cm
- ❒ Metallic tape
- ❒ 2 wine corks
- ❒ Circular metal electrical junction box
- ❒ Electrical cable clamp to fit holes in junction box
- ❒ 2 hose clamps, 1/2" – 1-1/4"
- ❒ Metal mesh screen, 12 cm x 24 cm
- ❒ Charcoal
- ❒ Wooden skewer, about 20 cm long
- ❒ Wooden dowel, 3/8" diameter, 1.5 cm
- ❒ Screwdriver
- ❒ Electric drill with 1/2" diameter metal bit
- ❒ Tin snips
- ❒ Pliers
- ❒ Hammer
- ❒ Scissors

For students invented machines:
- ❒ Mechanical pencil sharpeners, one for each student group
- ❒ Meter sticks, one for each student group
- ❒ Duct tape
- ❒ Coathangers, one for each student group
- ❒ Chairs, one for each student group

Audio/Visual Materials
None

Teaching Time
Two or three 45-minute class periods

Seating Arrangement
Groups of 2-3 students

Maximum Number of Students
30

Key Words
Steamboat
Mechanical energy

Kinetic energy
Potential energy
Chemical energy
Electromagnetic energy
Nuclear energy
Electrical energy
Thermal energy
Energy conversion
Simple machines

Background Information

On Thanksgiving Saturday, November 26, 1898, the passenger steamship *Portland* left Boston Harbor with 192 passengers and crew bound for Portland, Maine. During the night, New England was hit by a monster storm with northeasterly winds gusting to 90 mph, dense snow, and temperatures well below freezing. At 5:45 a.m. on the morning of November 27, four short blasts on a ship's steam whistle told the keeper of the Race Point Life-Saving Station on the tip of Cape Cod that a vessel was in trouble. Seventeen hours later, life jackets, debris, and human bodies washed ashore near the the Race Point station, confirming that the *Portland* and everyone aboard had been lost in one of New England's worst maritime disasters.

For 90 years, the location of the *Portland* wreck was unknown, despite intense and continuing public interest. Then in April 1989, members of the Historical Maritime Group of New England found wreckage more than 300 feet deep that they were certain had been the *Portland*. Because of the depth, however, the discoverers were unable to obtain photographs or other evidence that could confirm their find. Thirteen years later, on August 29, 2002, the U.S. Commerce Department's National Oceanic and Atmospheric Administration (NOAA) confirmed that the wreck of the *Portland* had been found within NOAA's Stellwagen Bank National Marine Sanctuary. Using side-scan sonar and a remotely operated vehicle (ROV), scientists obtained high-quality video and side-scan images in a joint research mission of the Stellwagen Bank National Marine Sanctuary and the National Undersea Research Center at the University of Connecticut.

Built in 1889, the *Portland* was a state-of-the art vessel. Eighty-two years earlier, Robert Fulton had demonstrated the potential of steamboat technology when the *Clermont*, the first steamboat built in the United States, successfully completed its trial run from New York to Albany. Unlike sailing vessels, steamboats could travel great distances on reliable schedules, and for this reason quickly became the preferred means of transportation along major waterways of the United States. Steamboats had a major influence on nineteenth century life in the United States and contributed to the development of tourism, transportation of perishable foods and supplies, settlement of frontier areas, and growth of the U.S. mail service.

Because they were propelled by large paddlewheels, steamboats could maneuver in waters that were too shallow for sailing ships. By the 1870's, many people routinely boarded steamboats to travel between port cities. But the paddle-wheelers had a serious flaw: they were built long and narrow (the *Portland* was 281 feet long and 62 feet wide), and this shape combined with a shallow draft (the *Portland*'s keel was only 11 feet below the water line) made these ships extremely unstable in high seas. When the *Portland* steamed out of Boston Harbor into a strong northeasterly wind, the captain could not turn back: to have done so would have placed the ship broadside to wind and waves that would surely have capsized her. The only choice was to continue to head northeast into the waves, and hope to ride out the storm. Four hours after her departure, a vessel believed to have been the *Portland* was seen near Thatcher Island, about 30 miles northeast of Boston. But the *Portland* was apparently unable to make much more progress against the storm: she sank about 18 miles southeast of Thatcher Island, perhaps because of the intense, constant pounding that may have lasted for 24 hours or more. The loss of the *Portland* underscored the inherent instability of sidewheel paddleboats. Sidewheelers were gradually replaced by propeller-driven boats, which have a lower center of gravity.

In this lesson, students will study some of the science behind steamboats, and participate in constructing a model steam engine.

Learning Procedure

[Note: Portions of this lesson were adapted from Newton's Apple show number 1403, "Riverboats." Visit http://www.ktca.org/newtons/14/riverboats03.html for a complete teacher guide for this show.]

1. Download a copy of "Full Steam Ahead!" from http://www.blm.gov.education/00_resources/articles/steel_rails_and_iron_horses/posterback.html. Visit http://oceanexplorer.noaa.gov for up-to-date information on the 2003 Steamship *Portland* expedition.

   You may also want to download:
   - "The Portland Gale" from http://www.hazegray.org for more information on the *Portland* and the monster storm of 1898; and/or
   - "Historic Shipwrecks of the Gulf of Mexico: A Teacher's Resource," which has useful background materials on steamboats (http://www.gomr.mms.gov/homepg/lagniapp/shipwreck/).

2. Briefly review the story of the *Portland* and the gale of 1898. Introduce the basic elements of a steam engine: a source of steam (usually a boiler fired by wood, coal, or other combustible fuel), a device that is moved by the steam (such as a piston inside a cylinder or a turbine), and a means for converting the motion of the device into useful work. Steam engines of the 1800's had many more features that made them more efficient.

3. Work with students to construct the miniature steam engine described in "Full Steam Ahead!" Many students would have difficulty completing this project on their own, but everyone can be involved with some aspects if the project is undertaken as a group effort. You may want to enlist one or more parents or students with shop skills to assist. Have students prepare brief written reports on energy transformations that take place during operation of the miniature steam engine, and possible sources of energy to power steam engines.

4. Lead a discussion of the energy sources and transformations that take place during operation of the miniature steam engine. Chemical energy (in fuels) is converted by combustion to thermal energy; thermal energy is converted to mechanical energy by the increasing the motion of water molecules; and this mechanical energy is transferred by the action of steam on the dowel piston. Ask students what other conversions might be possible. One of the most common conversions is to connect a steam engine to an electric generator, which converts mechanical energy into electrical energy.

   Discuss possible sources of energy for steam engines. These include fossil fuels (which were originally produced by photosynthesis using electromagnetic energy from the sun, since these fuels are the remains of once-living plants and animals), wood (also a product of photosynthesis), nuclear reactions, or sunlight (one type of solar generator uses a parabolic mirror to focus the sunlight onto a pipe containing water that is heated to produce steam).

5. Point out that the miniature steam engine produces a back-and-forth type of motion. Tell students that early steam engines used steam to move a piston inside a cylinder. This produced a back-and-forth motion, which was okay for pumps, but not as useful for propelling boats or turning machinery. Tell students that their assignment is to design a machine that will convert a back-and-forth motion into a rotary motion that will operate a pencil sharpener. They are to use a chair tipping back and forth on two legs to simulate the piston motion of a steam engine.

Tell students they will be provided with meter sticks, tape, coathangers, and chairs, and are free to bring other materials from home. Have each group brainstorm their machine during one class period, and complete their invention during the first half of the next class period. Have each group explain their machine, discuss the problems they encountered, and how these problems were overcome.

6. Show students an illustration of a simple steam engine (there are lots of these on the web; e.g., at http://www.mgsteam.btinternet.co.uk/hditwork.htm; you can also find an animated explanation of how a steam engine works at http://www.howstuffworks.com/steam1.htm). Tell students that many devices were built to convert back-and-forth motion to rotary motion. The *Portland* used what is known as a "walking beam engine" to make this conversion. A large diamond-shaped beam was mounted on an A-frame structure. One end of the beam was connected to a rod attached to the piston of the steam engine. The other end of the beam was attached to a second rod that drove a crankshaft, which in turn caused the paddlewheels to rotate, propelling the ship through the water. Discuss how many simple machines you can find in the illustration. Levers, wheels and axles should be obvious. Some students may realize that parts of the engine are probably held together with various types of screws. Pulleys could be involved in transferring mechanical energy from the engine to a driven machine. Tell students that after the *Portland* disaster, sidewheel paddle boats were gradually replaced by ships driven with propellers, which are a special type of screw.

   You may want to briefly discuss the history of the steam engine. James Watt is often credited with developing the first steam engine, but Hero of Alexandria (who lived more than 2,000 years ago) documented many of the principles upon which the steam engine is based. The first operating steam engine was built in 1712 by English engineer Thomas Newcomen (visit http://technology.niagarac.on.ca/people/mcsele/newcomen.htm for a description of the Newcomen engine). Newcomen's engine was simpler than the systems described above: steam from the boiler was let into the space between the inside of the cylinder and the piston. The other end of the piston was attached to the pump by means of a rod. Water was sprayed onto the cylinder to cool the steam. As the steam cooled, its volume decreased, and caused a vacuum to form inside the cylinder. The piston was sucked down into the cylinder by the weight of the air on top of it, then was pulled back by the weight of the pump attached to the rod. Steam was let into the chamber again, and the cycle repeated (this is a good opportunity to review what students know about the relationships between temperature and volume of gases).

   You can demonstrate the principle by filling a 2-liter plastic soda bottle one-fourth full with hot (not boiling) water, and screwing the cap on tightly. When you immerse the bottle in ice cold water, warm air inside the bottle contracts, producing a partial vacuum. Air pressure forces the side of the bottle in to fill the vacuum, just as air pressure forces the piston of a Newcomen engine into the partial vacuum created when the steam-filled cylinder is cooled.

7. You may want to have students investigate other simple machines, such as
   - cam and follower
   - eccentrics
   - scotch yoke
   - universal joint
   - loose-link coupler
   - Geneva wheel
   - Watt's sun-and-planet gear (invented by James Watt as a substitute for the common crankshaft, which had already been patented by someone else)

The BRIDGE Connection

http://www.vims.edu/bridge/archive1200.html/

The "Me" Connection

Have students to write a short essay describing 10 ways that they use simple machines in everyday life.

Connections to Other Subjects

English/Language Arts, Social Studies, Mathematics

Evaluation

Written reports prepared in Step 3 and oral presentations in Step 5 provide an opportunity for assessment.

Extensions

Log on to http://oceanexplorer.noaa.gov to keep up to date with the latest *Portland* Expedition discoveries.

Watch the History Channel production of "Great Ships: The Riverboats" and/or the "Steamboats 'A Comin! " episode of "The Mighty Mississippi," (both available from http://store.aetv.com/html/) and check out study guides for these programs at http://www.historytv.com/classroom/admin/study_guide/archives/thc_guide.1378.html.

Resources

Bachelder, P. D. and M. P. Smith. 2003. Four Short Blasts. The Gale of 1898 and the Loss of the Steamer *Portland*. The Provincial Press. Portland, ME.

http://www.hazegray.org/ – Website with information on naval ships, photos, etc., and a page about the *Portland* Gale of 1898

http://score.rims.k12.ca.us/activity/bubbles/ – Marine archaeology activity guide based on investigations of the wreck of a Spanish galleon; from the Schools of California Online Resources for Education website

http://www.historytv.com/classroom/admin/study_guide/archives/thc_guide.1378.html – Study guide for history channel program on steamboats on the Mississippi

http://www.howstuffworks.com/steam1.htm – Animated explanation of how a steam engine works

http://www.gomr.mms.gov/homepg/lagniapp/shipwreck/ – US Department of the Interior Minerals Management Service publication, "Historic Shipwrecks of the Gulf of Mexico: A Teacher's Resource"

http://www.usatoday.com/weather/movies/ps/perfectstorm.htm – USA Today website with information about extreme storms

http://pao.cnmoc.navy.mil/educate.neptune/quest/wavetide/waves.htm – Naval Meteorology and Oceanography Command website with information on waves and tides

http://school.discovery.com/lessonplans/programs/tidalwave/index.html – Discovery Channel School lesson plans on tsunamis (tidal waves)

Levy, R. 1991. Making mechanical marvels in wood. Sterling Publishing Co. New York. – Description of many simple machines and how to make working models of them

National Science Education Standards

Content Standard A: Science As Inquiry
- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

Content Standard B: Physical Science
- Motions and forces
- Transfer of energy

Content Standard D: Earth and Space Science
- Structure of the Earth system

Content Standard E: Science and Technology
- Abilities of technological design

Content Standard F: Science in Personal & Social Perspectives
- Natural hazards
- Science and technology in society

For More Information

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