Wave Energy Engineer

Building a Model Wave-Energy Generator

Objectives

Students will:

1. Describe a variety of wave-energy devices.
2. Identify which devices are best suited for which ocean space (nearshore or offshore technology).
3. Identify ways that changes in device design can impact efficiency.
4. Use grade-appropriate science and engineering design standards and inquiry skills for problem-solving (Appendix 3).
5. Understand there is no one clear wave-energy device, but rather many devices being developed and tested.

Method

Students will design and test their own model wave-energy device.

Model Wave-Energy Devices

Kinetic energy is the type of energy that exists within motion. Waves are in constant motion and therefore possess a consistent form of energy. Wave-energy devices are being developed to harness that energy and convert it to electricity. There are several different technologies being developed. See "A Primer on Wave Energy Devices," "WEC Model Literature," and "Devices in action: Website Resource" (Appendix 2). When developing devices for the ocean, engineers must consider

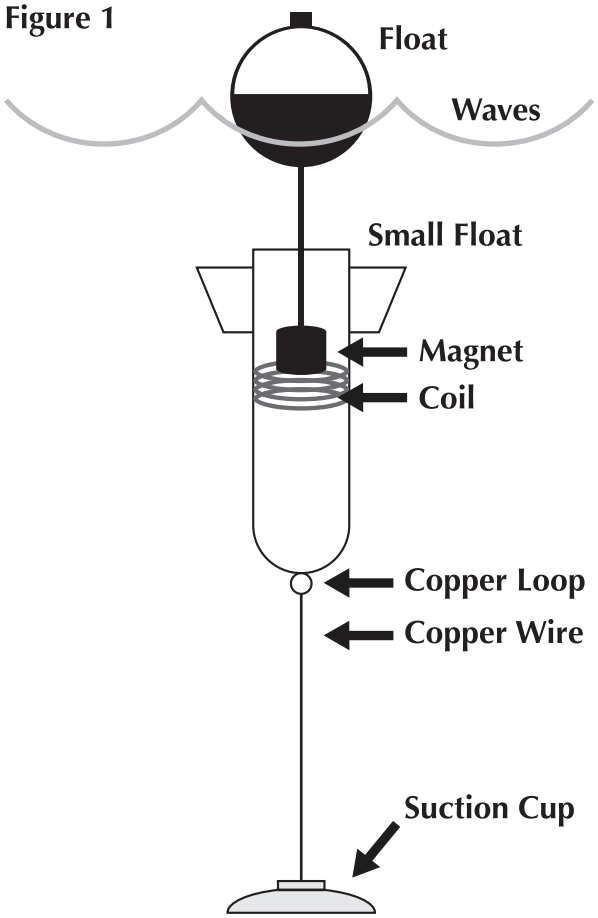
- the cost of building and maintaining the device
- using materials that will withstand the harsh ocean environment
- safe and effective anchoring and mooring systems
- developing devices that will produce electricity efficiently
- environmental and social impacts

This document explains the construction and operation of a model wave-energy generator used to convert ocean wave energy into electrical energy. Applicable theories can be found in Appendix 1. The actual model is that of a wave-energy point absorber (see "A Primer on Wave Energy Devices"). In this model, a magnet moves in a straight line, passing through a coil of wire to generate a current.

Device Construction

There are several ways to approach the construction of the model. Figure 1 illustrates an example of one possible way to construct a model device. Part of this activity is about finding innovative approaches, so it's a good idea to allow for as much trial and error as possible throughout the construction process. Another great opportunity for innovations comes from sharing ideas about what works under what conditions. So it's good to allow for comparison and revision throughout the process, as well.

Figure 1



Step 1: Create a coil by winding the wire around the test tube. Generally, a minimum of 100 coils is needed to produce a measurable electrical current. Fasten the wire to the tube with trasnparent adhesive tape, leaving a couple feet of wire free on both ends of the coil to make connections. To ensure effective connections, remove the insulation from the ends of the wire. This can be done by sanding the end of the wire with medium-grit sandpaper. When the wire end becomes a bright copper color, the insulation is removed. This can be tested with the ohm meter. If there is zero resistance between the ends of the coil wires, the insulation has been stripped and your wire is ready.

Step 2: Attach a loop of copper wire to the bottom of the test tube (copper is not magnetic). This will attach to a suction cup on the bottom of the wave tank and keep the tube from drifting out of position.

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Step 3: To keep the tube upright in the tank, attach a flotation collar. Wrap the top of the tube in buoyant material and secure with tape.

Step 4: Cut a piece of fishing line about a foot long. Tie one end to the magnet necklace clasp. Then stick the clasp to a magnet(s). The magnet clasp makes it easier to change magnets when doing comparative tests. The other end is tied to a fishing bobber.

Factors Affecting Voltage

- Number of turns in the coil
- Length of the coil: as the coil is "stretched out" with the number of turns remaining the same, the voltage will be reduced
- Diameter of the coil: as the diameter of the coil grows larger, the voltage will be reduced
- Amount of current flowing in the coil: as the current increases, it creates an opposing magnetic field, reducing the voltage
- Clearance between the magnet and the inside of the test tube: as clearance is reduced, fluid friction with the water is increased and the magnet speed and voltage are reduced
- Strength of the magnet
- Length of the stroke of the magnet through the coil: controlled by wave height
- Speed of the magnet through coil: controlled by wave period

Making a Plastic Storage-Container Wave Tank

Step 1: Using a black marker, draw measured lines on the side of the tank to help estimate wave height.

Step 2: Attach suction cups to the bottom of the tank to serve as anchors for the tubes. This will keep the tubes from being carried away by the waves. Place the suction cups 3 to 4 inches from one end of the tank, where the waves will be highest. Make sure the suction cup is free to attach to the wire loop on the test tube.

Step 3: Position tank on sturdy table in preparation for testing. Cut two pieces of 1-inch dowel about 2 feet long and place them under the tank, like rollers.

Step 4: Make waves gently move the tank back and forth on the rollers. It will take a bit of practice to make decent waves without slopping the water out of the tank. The tank will have a natural period of oscillation. Once you find it, the waves will be much easier to control.

Step 5: Put the coil into the tank.

Step 6: Fasten the loop on the tube to a suction cup in the bottom of the tank. Attach a flotation collar to the top to keep the tube upright in the tank.

Step 7: Connect the wires from the tank to the meter.

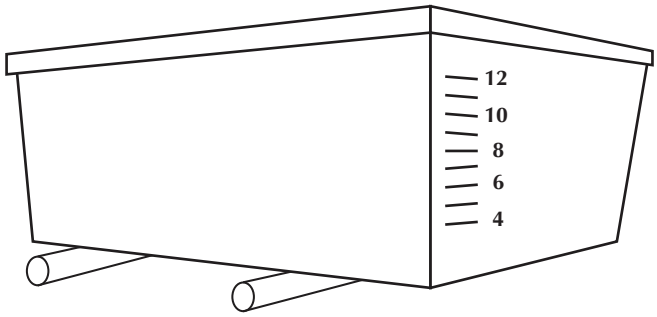
Step 8: Fill the tank up to about 2–3 inches above the top of the test tube.

Step 9: Put the float and magnet assembly into the tank, with the magnet inside the tube.

Step 10: Adjust the line so that the magnet is just above the bottom of the coil. The waves will go both above and below the fill level.

Step 11: Move the tank back and forth on the rollers. Try to make the waves as uniform as possible.

Step 12: Observe the needle on the meter. It should move in time with the waves.



Extension Ideas

Design an experiment looking at one variable (use the factors effecting voltage). Students can come up with a hypothesis and alter the one variable, holding all other variables constant, and test.

Assign cost to materials. Potential cost-cutting material could include found material or recyclable material. Material could be given a life span to be considered in the cost efficiency.

Create a poster prototype of design that addresses cost, environmental impacts, and socioeconomic impacts.

Parts List

- Acrylic test tubes—16mm, 24mm, and 38mm. Most of the work will be done with the 16mm test tubes, so order enough of these to go around. The larger tubes are used only to investigate the effect of a larger coil diameter. You will probably need only a few of these.
- Rare-earth cylinder magnets, type D68 (3/8-inch diameter by 1/2 inch long) and type D48 (1/4-inch diameter by 1/2 inch long). NOTE: Sizes larger than 1/2 inch are not recommended, due to the risk of injury from these extremely powerful magnets.
- Small magnetic necklace clasps.
- Magnet wire, enamel coated, in the range of 20- to 30-gauge.
- Electric meter—zero center, -50-0-50 millivolts or -500-0-500 micro amps or similar. Having the zero in the center allows the needle to track the voltage or current as it alternates between negative and positive.
- 20-gallon storage container (wave tank).
- Fishing bobbers, 2–3 inches. The kind that fasten to the line with a spring-loaded hook make adjustments easier.
- Fishing line, monofilament or braided, 5- to 10-pound test. Heavy sewing thread will also work fine.
- Fishing sinkers, 1 ounce
- Empty soda bottle, 2 liters
- Two 1" dowels, 2' long
- Lead split shot, 1/4 inch
- 16- or similar gauge steel wire
- Copper wire
- Rubber bands
- Glue gun and glue sticks
- Packing foam
- Fingernail polish
- Medium sandpaper
- Needle-nosed pliers
- Yardstick
- Black marker
- Paper or cloth towels

Appendix 1

Theories Applicable to Wave-Energy Development

The Laws of Thermodynamics

Energy is the ability to bring about change or to do work, and thermodynamics is the study of energy. There are two basic laws of thermodynamics that rule how energy behaves and can be used.

The First Law of Thermodynamics (Conservation) states that energy is always conserved; it cannot be created or destroyed. In essence, energy can be converted from one form into another.

The Second Law of Thermodynamics states that "in all energy exchanges, if no energy enters or leaves the system, the potential energy of the state will always be less than that of the initial state." *Information retrieved from: www.nrel.gov/education/pdfs/educational_resources/high_school/re_intro.pdf [last accessed 12-2-13].*

Faraday Law of Induction states that any change in the magnetic environment of a coil of wire will cause a voltage (emf) to be "induced" in the coil. No matter how the change is produced, the voltage will be generated. The change could be produced by changing the magnetic field strength, moving a magnet toward or away from the coil, moving the coil into or out of the magnetic field, rotating the coil relative to the magnet, etc. *Information retrieved from: hyperphysics.phy-astr.gsu.edu/hbase/electric/farlaw.html [last accessed 12-2-13].*

Appendix 2

Wave-Energy Devices in Action: Website Resources *[last accessed 12-2-13]*

- Northwest National Marine Renewable Energy Center http://nnmrec.oregonstate.edu/
- http://www.emec.org.uk/marine-energy/wave-devices (Give the site a minute to warm up, and see the devices in action with specific information detailed on each device)

YouTube Videos *[last accessed 12-2-13]*
(Note: if you scroll down past each video, there is background information on most of the devices.)

- Innovation Nation—Wave Energy-Magnetic Field http://www.youtube.com/watch?v=phc9_h31JfE
- Ocean Power Technologies PB150 PowerBuoy Animation http://www.youtube.com/watch?v=EsRzTl6Q24E
- Indian Piston Device (no sound) http://www.youtubecom/watch?v=tt_lqFyc6Co
- Giggawattz Ocean Wave Energy Converter http://www.youtube.com/watch?v=QP-G6sfbQq4

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YouTube Videos *continued [last accessed 12-2-13]*

- Theoretical Wave Energy Farm
  http://www.youtube.com/watch?v=vS-s9QzPGDg
- Brazilian pilot project (subtitled)
  http://www.youtube.com/watch?v=GA_UgVm9bvU
- Blue Energy—Ocean Power (Piston Pump & Racks)
  http://www.youtube.com/watch?v=fYfs-qYGzvs
- Giant Sea Snake Renewable Electricity Generation
  http://www.youtube.com/watch?v=mcTNkoyvLFs
- Pelamis at Aguçadoura
  http://www.youtube.com/watch?v=JYzocwUfpNg

Appendix 3

Oregon Department of Education Science and Engineering Design Standards

This list provides the content standards for Science and Engineering Design for 4th grade through high school that can be met with the "Wave Energy Engineer: Building a Model Wave-Energy Generator" curriculum.

Engineering Design Standards

4.4D.1 Identify a problem that can be addressed through engineering design using science principles.

4.4D.2 Design, construct, and test a prototype of a possible solution to a problem using appropriate tools, materials, and resources.

7.4D.2 Design, construct, and test a possible solution using appropriate tools and materials. Evaluate proposed solutions to identify how design constraints are addressed.

8.4D.2 Design, construct, and test a proposed solution and collect relevant data. Evaluate a proposed solution in terms of design and performance criteria, constraints, priorities, and trade-offs. Identify possible design improvements.

H.4D.2 Create and test or otherwise analyze at least one of the more-promising solutions. Collect and process relevant data. Incorporate modifications based on data from testing or other analysis.

H.4D.4 Recommend a proposed solution, identify its strengths and weaknesses, and describe how it is better than alternative designs. Identify further engineering that might be done to refine the recommendations.

Science Standards

4.1P.1 Describe the properties of forms of energy and how objects vary in the extent to which they absorb, reflect, and conduct energy.

6.2P.2 Describe the relationships between: electricity and magnetism, static and current electricity, and series and parallel electrical circuits.

8.2P.2 Explain how energy is transferred, transformed, and conserved.

H.2P.3 Describe the interactions of energy and matter including the law of conservation of energy.

H.2P.4 Apply the laws of motion and gravitation to describe the interaction of forces acting on an object and the resultant motion.

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