Thermoelectric Generators

Next Generation Science Standards

NGSS Science and Engineering Practices:

- ☐ Asking questions and defining problems
- ☐ Developing and using models
- ☑ Planning and carrying out investigations
- ☑ Analyzing and interpreting data
- ☑ Using mathematics and computational thinking
- ☑ Constructing explanations and designing solutions
- ☐ Engaging in argument from evidence
- ☑ Obtaining, evaluating, and communicating information

NGSS Cross-cutting Concepts:

- ☐ Patterns
- ☐ Cause and effect
- ☐ Scale, proportion, and quantity
- ☐ Systems and system models
- ☑ Energy and matter
- ☐ Structure and function
- ☑ Stability and change

NGSS Disciplinary Core Ideas:

- ☑ PS3.A: Definitions of Energy
- ☑ PS3.B: Conservation of Energy and Energy Transfer

Initial Prep Time

Approx. 5 min. per apparatus, plus time to heat and chill water

Lesson Time

1 – 2 class periods, depending on experiments completed

Assembly Requirements

- None

Materials (for each lab group):

- Horizon Thermal Power Science Kit
- Various beakers
- Hot plate or other heating device
- Ice
- Stopwatch
- Horizon Renewable Energy Monitor or multimeter (optional)

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Lab Setup

- This activity gives you the option of assembling the thermoelectrical system before class or allowing students to assemble it themselves. Skip the Assembly section of the activity if you want to preassemble the apparatus.
- Lab includes small parts that can go missing easily. Set up a resource area for each lab table or for the entire class to minimize lost pieces.
- We recommend that you keep large amounts of hot and cold water in a central location and have students collect small amounts of them for their lab groups as necessary. This will minimize the number of heating elements required.
- If you don't have access to a multimeter or Horizon Renewable Energy Monitor, omit the Measurements section of this activity.

Safety

- Hot water can easily cause burns. Students should wear protective gloves or mitts when handling containers of hot water.
- The glass thermometers are fragile and will break into very sharp pieces if handled too roughly.
- Safety goggles should be worn at all times.

Notes on the Thermal Power Science Kit:

- The thermoelectrical system will work best with large temperature differences (>150ºF) between the water used in the hot and cold sides. For best results you should have a good refrigeration source (or lots of ice) and heat source on hand.

Common Problems

- The fan motor sometimes needs a quick tap or flick to get it to start spinning.

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Goals

- ✓ Produce electricity with a thermoelectric generator
- ✓ Observe the effects of thermal energy
- ✓ Make calculations based on data

Background

Heat is a way of transporting thermal energy from one object to another. Since it's caused by the motion of atoms and molecules, it's constantly spreading to nearby particles through collisions and causing fluids to circulate and transfer its energy to new places.

Under the right conditions, moving heat can also generate electricity using the thermoelectric effect. Thomas Johann Seebeck discovered that whenever heat moves between two different semiconducting materials, electric charges move as well. Semiconductors are unique substances that are used in computer chips and in numerous ways inside many electronic devices.

When two different semiconductors are next to each other, the thermoelectric effect transfers electric charge from one to the other as heat moves between them. Since heat moves naturally from hot objects to cold objects, getting it to move really quickly between them creates a larger, useable electric current.

A thermoelectric generator is thus a way to create useful energy from heat, which is usually thought of as wasted energy in most mechanical processes.

During this activity, we will use the thermoelectric effect to allow us to visualize heat transfer through the generation of electricity.

Assembly:

IIf generator is already assembled, go to the Procedure section.

1. Look at the thermoelectrical system (the two connected containers with red and black wires on the top). Which of the other parts do you think will attach to it?
2. How does the thermoelectrical system fit into its base? Does it matter how you attach them?
3. Why do you think the seals are colored red and blue? The thermoelectrical system's wires are also different colors. Do you think there's a right and wrong side to put each seal? Write down anything you've observed in the Observations section below.

Procedure

1. Fill two beakers with water, one hot and one cold.
2. Before you fill your generator, be sure to put cold water in the side with the red wire and hot water in the side with the black wire, or all of your results will be backwards!

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3. Open the tops of the two containers to fill your generator with hot and cold water.
4. Close the lids and insert the thermometers into the seals, pushing them down gently but firmly until they're almost touching the bottom of the containers.
5. Start the stopwatch and record the temperatures of each thermometer in the table below.
6. Connect the red and black sockets on the generator to the fan with the red and black wires and observe what happens.
7. Disconnect the wires from the fan and connect the generator to the LED lights instead. Observe what happens.
8. After 2 minutes have gone by, record the temperature again, then repeat steps 6 and 7.
9. Repeat step 8 until you've filled in the table below.

Observations

Experimentation

1. What happens to the system over time? Record your data from the Procedure section here:

Time (min):	Hot Temp (°C):	Cold Temp (°C):	Observations:
0			
2			
4			
6			
8			
10			

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2. What happens to the system when you increase the temperature of the hot water? Run your generator as before and record your data below:

Time (min):	Hot Temp (°C):	Cold Temp (°C):	Observations:
0			
2			
4			
6			
8			
10			

3. What happens to the system when you decrease the temperature of the cold water? Run your generator as before and record your data below:

Time (min):	Hot Temp (°C):	Cold Temp (°C):	Observations:
0			
2			
4			
6			
8			
10			

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4. Now try colder cold water and hotter hot water. What happens when you run the generator now? Record your data below:

Time (min):	Hot Temp (°C):	Cold Temp (°C):	Observations:
0			
2			
4			
6			
8			
10			

Measurement

For this section, you will need a multimeter or the Horizon Renewable Energy Monitor. For an introduction to using a multimeter, click here.

1. Record the highest current in Amps and highest voltage in Volts produced while the generator is powering the motor. Record your answers below:

(Answers in this section will vary, but check that they are within reason, i.e. not >1A.)

Current: ______________ A

Voltage: ____________ V

2. Record the highest current in Amps and highest voltage in Volts produced while the generator is powering the LEDs. Record your answers below:

Current: ______________ A

Voltage: ____________ V

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3. Voltage is equal to the current in amps multiplied by the resistance in ohms (V = IR), so according to your data what is the resistance of the motor in ohms?

Resistance: ____________ Ω

4. What is the resistance of the LEDs in ohms?

Resistance: ____________ Ω

5. Power is current multiplied by voltage (P = IV). What is the maximum power in watts that your thermoelectric generator created?

Power: ____________ W

Analysis

1. Make a scientific claim about what you observed while running your generator.

Claim should reference the generator's electrical capabilities.
Example: "The largest amount of current the generator can produce is 0.255 Amps."

2. What evidence do you have to back up your scientific claim?

Evidence should cite data in Observations and/or Experimentation sections.
Example: "The highest current output of the generator was measured when the hot water was close to boiling and the cold water was close to freezing."

3. What reasoning did you use to support your claim?

Reasoning can draw from Background section and/or other materials used in class.
Example: "Since we can't fill the generator with steam or solid ice, the generator have a larger difference in temperature than the one we observed, so that must be its maximum output."

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4. Design an experiment that would test how to keep the thermoelectric generator running for a longer period of time. Describe your experiment below:

Many answers are acceptable, as long as students describe the steps they would take to make the generator run longer and include obvious control and experimental groups in their description. Experiments could involve an external heat source or heat sink, insulation, or other method.

Conclusions

1. What is the relationship between the difference in temperature of the generator's sides and the amount of electric current it produces?

Students should note that the amount of electric current decreases as the difference in temperature equalizes.

2. Do you think the thermoelectric generator would work with substances other than water? Why or why not?

"Yes" and "No" are both acceptable answers, provided students are able to back up their answers with facts that support their argument, such as saying that the generator could hold other liquids, or mentioning that other substances could damage the semiconductors.

3. Could a thermoelectric generator be used as a source of renewable energy? Explain your answer.

Once again, "Yes" and "No" are both acceptable answers, provided students are able to back up their answers with facts that support their argument, such as the availability of many machines that produce heat as a byproduct or the small amount of current produced by thermoelectrics.