Heat and Thermal Energy

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)

Heat and Thermal Energy

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 (>150^{0}F) 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

Heat and Thermal Energy

Goals

- ✓ Observe the effects of thermal energy transfer
- ✓ Understand the relationship between thermal energy and temperature

Background

Thermal energy causes atoms and molecules to shake around. What we call temperature is really just an average of the thermal energy of all particles in a system. If you've ever stepped out of a shower, you've felt the effects of thermal energy moving from one place to another.

No matter how hot your shower was, you'll start to feel cold if you don't quickly dry your skin. The fastest-moving molecules of water are evaporating from your skin into the air, taking their large amounts of thermal energy with them. This lowers the average energy of the molecules that remain, the same way that the average height of the people in your classroom would be lower if the tallest people left.

Lowering the average thermal energy of the water still on your skin lowers its temperature. This draws thermal energy out from your skin into the water, since it naturally flows from hotter areas to colder areas. After losing this thermal energy, your skin feels cold. To really feel this, try drying one arm and leaving the other wet after your next shower.

On your skin or anywhere else in the universe, molecules and atoms move faster as they absorb thermal energy. In solids, this means that they bump up against each other and transfer that energy to particles that are moving less. In liquids or gases, particles collide as they move from place to place, transferring energy like billiard balls. Whenever thermal energy moves from one object to another, we call it heat.

Heat moves in three distinct ways.

- Radiation is the way that our Sun transfers heat over millions of miles of space, through electromagnetic waves.
- Two objects that touch each other can transfer heat directly from one to the other through conduction.
- And gases or liquids can move heat around when their temperature causes them to rise or sink, creating convection like in a pot of boiling pasta.

A thermoelectric generator is a way to create useful energy from heat, which is usually thought of as wasted energy in most mechanical processes. It uses moving heat to transport an electric current, which can be used to power electric devices.

During this activity, we will use a thermoelectric generator to allow us to visualize moving heat 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?

Heat and Thermal Energy

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!
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

Heat and Thermal Energy

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			

2. If you put salt in your heated water and ice water, what would you expect to happen to the temperatures you would measure on either side of your generator? How would this affect the fan and LEDs?

Students should note the boiling point elevation and freezing point depression effects of salt.

3. How much salt makes a difference? Copy the largest temperature difference from your previous experiment to the first row, then use water with different amounts of salt and determine the greatest temperature difference you can achieve.

Salt (g):	Initial Hot Temp (°C):	Initial Cold Temp (°C):	Observations:
0			

Heat and Thermal Energy

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. Observe the motor as the current decreases until the motor stops. What is the lowest current and voltage that still runs the motor?

Time (min):	Hot Temp (°C):	Cold Temp (°C):	Current (A):	Voltage (V):	Observations:

3. According to your data above, for every °C difference between the hot and cold sides, how much current and voltage does the thermoelectric generator produce?

Students should be able to calculate this using the data in the table, comparing the current and voltage at one time with the current and voltage at a different time and looking at the change in the temperature difference over that span.

Heat and Thermal Energy

Analysis

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

Claim should reference an aspect of heat, thermal energy, or temperature.
Example: "When the temperatures of the two sides of the generator are the same, no thermal energy is flowing between them."

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

Evidence should cite data in Observations and/or Experimentation sections.
Example: "After 15 minutes we recorded identical temperatures in both sides and the motor stopped running."

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

Reasoning can draw from Background section and/or other materials used in class.
Example: "The thermoelectric effect says that electric current is created when heat moves, so no electric current means there's no moving heat."

4. Design an experiment that would test how to increase the amount of electricity produced by the thermoelectric generator. Describe your experiment below:

Many answers are acceptable, as long as students describe the steps they would take to increase the generator's output and include obvious control and experimental groups in their description. Experiments could involve using different materials in each side, providing an external source of heat, or other method.

Heat and Thermal Energy

Conclusions

1. Does the temperature difference between the hot and cold sides decrease at the same rate all the time? How do you know?

Students should reference their data and note the decrease in difference over at least two time periods.

2. Explain where and how heat is moving in your apparatus while the generator is running.

Students should at least acknowledge that heat moves from the hot side to the cold side, but can also mention the heat escaping into the air, the lab table, and anything else that touches the hot side. How the heat is moving should include convection in the water and air and conduction from water to the semiconductors and to the water on the other side.

3. Once the temperature of the two sides is the same, is heat still flowing between them? Why or why not?

Students could say "No" if they note that the generator isn't producing electricity if the temperatures are equal. They could also answer "Yes" if they consider the microscopic interactions between particles in the generator, where heat is always being transferred as long as the temperature isn't absolute zero.