Semiconductors

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.D: Energy in Chemical Processes and Everyday Life

Initial Prep Time

Approx. 5 min. per apparatus

Lesson Time

1 – 2 class periods, depending on experiments completed

Assembly Requirements

- None

Materials (for each lab group):

- Horizon Electric Mobility Experiment Set
- Protractor
- Stopwatch
- Colored construction paper
- Various colored light filters
- Heat lamp and/or UV lamp (optional)
- Horizon Renewable Energy Monitor or multimeter (optional)

Semiconductors

Lab Setup

- Your students will need the car frame, red and black wires, the solar panel, and the solar panel support to assemble the solar car.
- 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.
- A heat lamp or UV lamp may be used during experiment #2, if available.
- If you don't have access to a multimeter or Horizon Renewable Energy Monitor, omit the Measurements section of this activity.

Safety

- Students should use protective gloves if changing recently-used bulbs as certain types can become quite hot.

Notes on the Solar Panel:

- Direct sunlight, or a strong electric light, is necessary for operation. Overcast and indirect sunlight may not provide sufficient energy. Be sure any artificial light source is close to the solar panel.

Common Problems

- Check your electrical connections if the car fails to operate properly.

Semiconductors

Goals

- ✓ Use a solar panel to generate electricity from light
- ✓ Understand how semiconductors in the solar panel change light to electricity

Background

Metalloids are strange elements. They exhibit characteristics of both metals and nonmetals, defying categorization in either category. Silicon and germanium, the metalloids in Group 14, have become some of the most important elements to our modern world: they're the most commonly used semiconductors.

A semiconductor is a material that conducts electricity weakly due to high resistance. However, unlike metals, their resistance decreases when heated. From the first experiments with semiconductors in the 1830s by Michael Faraday, it was obvious that they behaved differently. They quickly became vital materials for radios and telephones. Since the late 20th century, they've enabled the mass production of computers and solar panels.

In a solar panel, silicon semiconductors use the photovoltaic effect to convert sunlight to electricity. Photons of light strike valence electrons in the semiconductor, causing them to travel through the material and generating an electric current that can be collected and used as a power source for all kinds of applications, from satellites and spaceships to pocket calculators.

During this activity, we will use the semiconductors in a solar panel to generate an electric current and use that current to power a small motor and determine how the semiconductors work.

Procedure

1. Look at the top of the car frame to see where you should attach the solar panel support. Make sure the solar panel support fits securely onto the top of the frame.
2. Place the solar panel on top of the support.
3. Connect the wires from the motor to the red and black plugs nearest to them on the front of the frame.
4. Use the other red and black wires to connect the solar panel to the other plugs on the front of the frame.
5. Make sure the car is in direct sunlight, and it should start to run.
6. Use the stopwatch to time how long it takes your car to complete the track.

Semiconductors

Observations

Experimentation

1. With the front wheels lifted, try tilting the solar panel so that it changes the angle of the light that hits it. Can you tilt it far enough that the motor stops running? Does it matter which direction you tilt the panel? Using a protractor, measure the biggest angle at which you can still run the motor.

Maximum angle will change based on type of light source. A powerful light source may be able to keep an almost perpendicular solar cell running. Students should present data to determine whether one direction of tilt is better or worse than another.

2. You can use colored plastic gels, or different lightbulbs, to change the color of light hitting the solar panel. Do certain colors work better than others? Try using the solar panel to run the motor while the panel is hit with different wavelengths of light and record your observations below:

Light Color:	Time to fill H2:	Observations:

Semiconductors

3. Raise the front wheels off the ground and use a piece of paper or other method to shade parts of the panel. Using a ruler, measure the farthest distance in from the edge of the solar panel that you can move the covering before the motor stops running.

Side:	Distance:	Observations:

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. Raise the front wheels off the ground and measure the current in Amps and the voltage in Volts while tilting the panel to get the highest values. Record your measurements below:

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

Current: ______________ A

Voltage: ____________ V

2. Measure the current in Amps and the voltage in Volts while shading the solar panel. What is the lowest current and voltage that will still run the motor?

Current: ______________ A

Voltage: ____________ V

Semiconductors

3. Use different colors of light with your solar panel as before. Measure the current in Amps and the voltage in Volts while running the motor. What color gave the highest values? Record your answers below:

Color: ______________

Current: _____________ A

Voltage: ___________ V

Analysis

1. Make a scientific claim about silicon semiconductors based on what you observed while running the solar car.

Claim should reference physical or chemical characteristics of silicon semiconductors.
Example: "Silicon solar cells are best at conducting electrons with a visible light wavelength."

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

Evidence should cite data in Observations and/or Experimentation sections.
Example: "The car completed the track in 15 seconds when the solar panel was under visible light. Infrared took 26 seconds and ultraviolet took 24 seconds."

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

Reasoning can draw from Background section and/or other materials used in class.
Example: "Longer times mean the semiconductors didn't conduct electrons as well."

4. Design an experiment that could test the effects of temperature extremes on the silicon in the solar cell. Describe your experiment below:

Many answers are possible, but students should include ways of changing/measuring the temperature and monitoring the solar cell electrical output. There should be clear control and experimental groups in the description.

Semiconductors

Conclusions

1. Based on your observations, do you think a solar panel would be useful for generating electric energy from any type of light? Explain your reasoning.

"Yes" or "no" are both acceptable answers, so long as students are able to point to specific data from their experiments to back up their assertion.

2. What would you say is the most important factor in determining how much electric energy a solar panel produces?

Student answers should reference data collected in all experiments.

3. Based on your observations, what color of light is absorbed most easily by the solar panel?

Answers will depend on the variety of colors used.