Physical Sciences | Middle School | 5 hours

Unit Plan - Description

For this activity, students will learn about hydrogen fuel cells and what makes them a sustainable energy resource. They will explore the different components of a hydrogen fuel cell car, assemble it, and conduct experiments to see how it works. The primary content includes basic chemical reactions, transfer and conservation of energy, and designing and constructing engineering solutions.

Focus

Students will engage with multiple resources to understand how energy is transformed during chemical reactions and the relationship between chemical and electrical energy.

Behaviors

SWBAT construct a functioning electrolytic cell and explain its chemical reaction.

SWBAT explain how machines conserve energy.

SWBAT understand the difference between renewable and nonrenewable sources of energy.

NGSS Science and Engineering Practices

- Asking Questions and Defining Problems
- 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 Crosscutting Concepts

- Patterns
- Cause and Effect
- Scale, Proportion, and Quantity
- Energy and Matter
- Structure and Function
- Stability and Change

NGSS DCIs

MS-ETS1.B, MS-PS1.A, MS-PS1.B, MS-PS2.B, MS-PS3.B, MS-PS3.C

Energy Literacy Framework

1.1, 1.3, 1.4, 1.5, 1.6, 1.7, 1.8, 4.1, 4.2, 4.6, 4.7, 6.1, 6.4, 6.5, 6.8

Common Core ELA and Math

RST.6-8.1, RST.6-8.3, WHST.6-8.7, MP.2, 6.RP.A.2, 6.RP.A.3, 6.SP.B.5

Classroom and Homework Activities

1. Lab Activity sheet
2. Intro. to Electrodes
3. Stating a Scientific Claim
4. Measuring Current in a Circuit

Electronic and Online Activities

1. Electrolysis video
2. Hydrogen Fuel Cell video
3. Department of Energy website
4. Energy Conservation game

Procedure

Over the course of multiple lessons, students will engage with a variety of resources dealing with fuel cells and renewable energy resources. Electronic and online resources will be available to supplement in-class resources as well as instructor-led small- and whole-group discussions. Formative assessment will be conducted with oral questions during activities and students will complete a final written assessment at the close of the activity.

Lab Setup

- For this activity, you have the option of assembling the cars beforehand or allowing your students to assemble them by following the guiding questions in the “Assembly” section.
- If you choose to let your students assemble the cars themselves, it is recommended that you complete steps 1 through 3 of the “*Hydrocar Assembly Guide*” in advance so that your students don’t need to use screwdrivers or cut lengths of tubing.
- If you choose to assemble the cars beforehand, be sure to allow time before class to assemble each car. You’ll need AA batteries, scissors, a ruler, a small Philips-head screwdriver, and plenty of distilled

water to assemble them. See the "*Hydrocar Assembly Guide*" for complete assembly instructions.

- Please note that the PEM fuel cell's membrane should be kept from drying out. It's best to seal it in a plastic bag between uses. Before students use the cell, be sure it's filled with water and that the two small pieces of tubing are attached.
- Some of the parts of the car are quite small (such as tube caps) and can be lost easily. Setting up resource areas on lab tables with labeled containers for each group's pieces can prevent loss of these small parts and help keep the parts of each group's kit separate.

⚠ Safety

- Battery packs can short out and heat up if the red and black contacts touch each other while the unit is in the "on" position. Be sure to keep them "off" when not in use.
- Using regular tap water instead of distilled water will severely shorten the lifespan of the fuel cells. Distilled water can be found at most pharmacies or drug stores.
- Running electric current through dry fuel cells or attaching the battery packs backwards can destroy the fuel cells. Be sure to always connect red to red and black to black.
- Beware of water spills, and don't be surprised if someone tries to start a syringe water fight.

Notes on Using This Kit

- Though the car can detect and steer around objects that it bumps into, it won't detect the edge of a table. It may be best to put them on the floor when it's time to have them run.
- There is an on-off switch on the body of the car. Check that students have it set in the "on" position if they can't get their car to run.

Common Problems

- The solar cell works best with direct sunlight, and could take up to 20 minutes to fill the hydrogen container on the car. If pressed for time, use the battery pack instead.
- If the water level doesn't change after purging the cells, make sure the gaps on the base of the inner cylinders are open so that water can fill them.

Using the Comprehension Questions Formative Assessment Tool

- As your students are working on their activities and you circulate from group to group, use the grid system to keep track of how well individual students are understanding the material.
- You can use a code to quickly assess each individual's level of mastery after talking with them, for example: (B)elow Grade Level, (A)t Grade Level, (E)xceeds Grade Level.
- Feel free to adopt your own code, and be sure to write them in pencil so you can adjust them as your students improve over time. Use this tool to take stock of your students' progress at a glance and provide resources to those who need it.
- You can even add your own questions to gauge your students' knowledge of other areas of your curriculum.

Resource Availability

- The electronic and print resources included in this mini-unit are designed to be accessible by students at all levels of achievement. We suggest that you make as many resources as possible available to your students as they engage with the new content so they have multiple opportunities to familiarize themselves with the information.
- If you have additional resources or feel that some of our resources cover material outside the scope of your class, feel free to customize as needed.

Creating New Materials

- We include all our instructional files as modifiable files so that you can customize them to your own class. We've aligned our activities with the Next Generation Science Standards and the US Department of Energy's Energy Literacy Framework. If you need to add content to comply with a specific state standard or the scope and sequence of your course, feel free to do so.
- In fact, if you develop a great new experiment or additional student resource, let us know! We regularly select the best teacher-submitted lessons, labs, and activities and share them with other educators all over the world. Winners are all listed on our website and receive free Horizon Educational Kits for their classrooms.

Analysis

Make a *scientific claim* about your car: what affected how far or how fast it could go? To help you write a claim statement, see "Stating a scientific claim"

• Level 1 example answer: "Our car ran for 47 seconds."
• Level 2 example answer: "Friction affected how far our car went."
• Level 3 example answer: "When we reduced friction our car ran for longer."

What *evidence* can you use from your **observations** and your **data table** to back up your claim?

• Level 1 example answer: "First the car ran for a long time, then it ran for a shorter time."
• Level 2 example answer: "The car ran for 36 seconds during the first test, and for 22 seconds during the second test."
• Level 3 example answer: "The car ran for 49 seconds when it ran in a straight line, but for only 26 seconds and moved slower when it ran into objects."

State the *reasoning* you used to make your claim.

• Level 1 example answer: "The table is a smoother surface than the carpet, so the car was faster."
• Level 2 example answer: "Friction stops the car from moving."
• Level 3 example answer: "A lower mass requires less force to move it, so if the car produces the same amount of energy every time, it should move a lighter mass for a longer time."

Use the data you collected to *design an experiment* that you could run to test whether the temperature of the water would affect the speed of the car. Explain the steps of your experiment here:

- **Level 1 example answer: "Have a car with hot water and a car with cold water and see which is faster."**
- **Level 2 example answer: "Measure the temperature of the water, then see how long the car runs. Run the car again with water that's a different temperature."**
- **Level 3 example answer: "Fill the car with water that's ice cold and measure how long it runs. Run it again with water at room temperature and measure how long it runs. Run it once more with water that's been heated up and measure how long it runs. Compare the times to see if the hot or cold water produced a different run time than the regular room temperature water."**

Use your knowledge of the properties of hydrogen and oxygen to *design an experiment* that you could run to prove that hydrogen and oxygen are the gases produced by the reaction in the fuel cell. Explain the steps of your experiment here:

- Level 1 example answer: "Hydrogen and oxygen are both gases, so if the fuel cell makes gases it must be hydrogen and oxygen."
- Level 2 example answer: "Hydrogen burns and you can breathe oxygen, so if you can breathe one of the gases and the other one lights on fire they must be hydrogen and oxygen."
- Level 3 example answer: "There are two hydrogens for every one oxygen in water, so the cylinder that fills twice as fast must have hydrogen in it, which we could prove by seeing if the gas inside was flammable. Oxygen will make a flame burn brighter, so a match should have a much bigger flame in the presence of oxygen."

Conclusion

1. What is the most important change that affected how long the car will run? *Develop an argument* to support your position using evidence you observed during this activity and defend your argument if there are different points of view in your group.

Level 1 example answer: "The weight of the car was the most important."
Level 2 example answer: "The most important change we made was reducing friction because it made the car run for longer."
Level 3 example answer: "The most important change we made was reducing the weight of the car, which made the car run for 15 seconds longer. All of our other changes didn't make as much of a difference."

2. Do you think hydrogen fuel cells would make a good fuel source for a full-sized car? *Develop an argument* to support your position using evidence you observed during this activity and defend your argument if there are different points of view in your group.

Level 1 example answer: "There are already cars that run on hydrogen, so it would make a good fuel."
Level 2 example answer: "It would make a good fuel because hydrogen doesn't pollute."
Level 3 example answer: "Hydrogen could be a good fuel because it doesn't produce carbon dioxide and there's lots of hydrogen available in water. But hydrogen is also explosive, so there would have to be a way to stop that from happening before it could be used in cars."

3. How many ways was energy transformed during this activity? *Construct an explanation* of the different types of energy you observed during this activity and what caused them to transform.

Level 1 example answer: "Energy is transformed three times during this activity."
Level 2 example answer: "Chemical energy in the fuel cell became electrical energy in the wires, which became kinetic energy when the car moved."
Level 3 example answer: "Electrical energy transformed into chemical energy when it was used to split water, and then went back into electrical energy when we turned on the fuel cell. The electrical energy became kinetic energy to move the car, but also became sound, light, and heat energy because of friction."

4. Was energy created or used up during this experiment? *Construct an explanation* of where energy was moving during this activity and how you know if it was created or used up.

Level 1 example answer: "Energy wasn't created or used up during this experiment."
Level 2 example answer: "Energy was created from hydrogen when the fuel cell made electricity and was used up when the car was moving, but it was the same amount of energy."
Level 3 example answer: "Energy is never created or destroyed, but it changes from one form to another. Energy moved from the battery to the fuel cell and then to the car motor, where it became heat and motion."

Measurement

Is the amount of time the car runs related to the amount of electric current it produces? To find out, we'll need to use an ammeter to measure the amount of current being produced by the fuel cell. Read "Measuring Current in a Circuit" for more information on how to set this up.

With an ammeter connected to the car, connect the circuit to the fuel cell and start the car. What is the amperage produced?

Car running produces _____ amps. (**Student answers should be in the milliamp range**)

Using some of the ways you modified the car in the previous section of this activity, try to make the car run for as long and as short as possible. What happens to the amount of electricity produced?

Longer run time produces _____ amps. Shorter run time produces _____ amps.

Make a *scientific claim* about the cause of the differences you observe. What evidence can back up your claim? What is your reasoning?

Level 1 example answer: "Our car produced 25 milliamps and then 22 milliamps."
Level 2 example answer: "The car produced more current when it ran for longer."
Level 3 example answer: "When the car ran for more time, it produced more current. This happened because the fuel cell continued to power the car for longer, so more electrical energy was needed.

What if your car didn't carry water to produce hydrogen and instead just carried hydrogen gas. How would that car be different? In the space below, sketch what that car might look like and write an explanation of how it would work.

Level 1 example answer: A sketch of a car with a hydrogen tank.
Level 2 example answer: A sketch of a car with a hydrogen tank and fuel cell, both labeled.
Level 3 example answer: A sketch of a car with a hydrogen tank, fuel cell, engine, and an explanation of the flow of fuel, waste, and electrical energy.