Hydrogen Sprint – Fuel Cell Power

Student Objectives

The student:

- will be able to explain how the fuel cell converts hydrogen to electrical energy
- will be able to calculate power output of their fuel cell in various conditions
- will be able to explain the benefits and disadvantages of using fuel cells to generate electricity and power vehicles.

Materials

- Hydrogen Sprint reversible PEM fuel cell–Fuel Cell Store #711303 (1 per group)
- gas collection apparatus (beakers, test tube, water) or gas tanks #623100 from Fuel Cell Store (1 set per group)
- photovoltaic panel, or transformer (.5 amps or less), or battery pack #620500 from Fuel Cell Store (1 per group)
- wires with alligator clips (4 per group)
- rubber tubing, 1/8" inside diameter, enough to connect to gas collection apparatus (2 per group)
- tube clamps (4 per group)
- multimeter (2 per group)
- small motor and propeller (1 per group)
- distilled (or deionized) water
- watch or stopwatch (1 per group)
- sink with a stopper, buckets or large dishpan
- internet connection

Key Words:

amperage (amps)
anode
catalyst
cathode
load
multipurpose meter
nafion
parallel circuit
PEM
platinum
power
series circuit
voltage

Time: 2 class periods

Procedure

1. Students should meet in their Sprint groups (2 - 6 students per group).
2. Review with the students the process and results from the *Fuel Cell–Futuristic Battery* lab activity.
3. Inform the students that they will be working with their Hydrogen Sprint fuel cells to investigate their power output. Remind the students of the proper handling and procedures with their fuel cells–they don't want to foul them and then try to race with them!
4. The students should complete their Laboratory Manuals. Assist as needed.

Internet Sites

http://www1.eere.energy.gov/hydrogenandfuelcells/fuelcell_animation.html

US Department of Energy, Energy Efficiency and Renewable Energy. Fuel Cell animation

Hydrogen Sprint – Fuel Cell Power

			.1	.2	.3	.4	.5	.6	.7	.8
Nature of Matter	**Standard 1**	**SC.A.1.4-**	X				X			
	Standard 2	**SC.A.2.4-**	X							
Energy	**Standard 1**	**SC.B.1.4-**		X			X	X	X	
	Standard 2	**SC.B.2.4-**								

Benchmark SC.A.1.4.1 - The student knows that the electron configuration in atoms determines how a substance reacts and how much energy is involved in its reaction.

Benchmark SC.A.1.4.5 - The student knows that connections form between substances when outer shell electrons are either transferred or shared between their atoms, changing the properties of substances.

Benchmark SC.A.2.4.1 - The student knows that the number and configuration of electrons will equal the number of protons in an electrically neutral atom and when an atom gains or loses electrons, the charge is unbalanced.

Benchmark SC.B.1.4.2 - The student understands that there is conservation of mass and energy when matter is transformed.

Benchmark SC.B.1.4.5 - The student knows that each source of energy presents advantages and disadvantages to its use in society.

Benchmark SC.B.1.4.6 - The student knows that the first law of thermodynamics relates to the transfer of energy to the work done and the heat transferred.

Benchmark SC.B.1.4.7 - The student knows that the total amount of usable energy always decreases, even though the total amount of energy is conserved in any transfer.

Hydrogen Sprint – Fuel Cell Power

ampere (amp) - a unit of electrical current or rate of flow of electrons. One volt across one ohm of resistance causes a current flow of one ampere. One ampere is equal to 6.25×10^{18} electrons per second passing a given point in a circuit.

anode - the negative terminal or chamber, as in a fuel cell

cathode - the positive terminal or chamber, as in a fuel cell

catalyst - a substance that modifies and increases the rate of a reaction without being consumed in the process

load - any device or appliance that is using power in an electrical circuit

multipurpose meter - an instrument to measure electrical output in amps and volts and resistance in ohms

Nafion - Nafion® is DuPont's trademark of a sulfonated tetrafluorethylene polymer modified from Teflon®. Nafion is used as an ion-exchange membrane for applications such as PEM fuel cells.

parallel circuit - an electrical circuit in which each device connects to the same two points of the circuit or the same two terminals of the electric source

PEM - Proton Exchange Membrane–refers to the most common type of fuel cell

platinum - a heavy precious grayish white noncorroding malleable metallic element that fuses with difficulty and is used especially in chemical ware and apparatus, as a catalyst, and in dental and jewelry alloys

power (DC) - in DC circuits, power is given by the product of the voltage and current
$P = V \times I$ (where P is the power in watts)

series circuit - an electrical circuit that is characterized by a single pathway throughout the circuit. The current passing through the resistance of each electrical load is the same, and all current passes through every device of the circuit.

voltage - a measure of the force or 'push' given the electrons in an electrical circuit; a measure of electric potential. One volt produces one amp of current when acting against a resistance of one ohm.

Hydrogen Sprint – Fuel Cell Power

You will be working with the fuel cell you will be using in your Hydrogen Sprint vehicle and investigating the power output of your cell and variations in its power output.

Be careful not to foul your fuel cell. Remember:

- use only deionized or distilled water in your fuel cell
- do not exceed .5 amps *input* to your cell, whether from photovoltaics, battery or electric transformer
- when connecting a power source to your fuel cell make sure you connect positive (red) to positive and negative (black) to negative
- make sure you are feeding the hydrogen and oxygen into the correct sides of your fuel cell
- hydrate the membrane of your fuel cell at least 10 minutes before using it.

Gas Collection

Attach a short piece of tubing and a clamp to each of the top gas ports (one on each side) on your fuel cell. Attach a longer piece of tubing and a clamp to each of the bottom gas ports (one on each side) of your fuel cell. Set up your tanks or gas collection apparatus and fill with distilled water. Submerge the free end of each long tube in a tank of water. Open all four clamps. Inject distilled water into the top tubes (one at a time) until water saturates the membrane and fills up the long tubes. Close the top clamps. Fill the gas collection part of your tank (or a test tube) with water and invert over the tube ends in the tank of water.

Attach your fuel cell to your power supply–photovoltaic panel, transformer or battery pack–checking the polarity (positive to positive, negative to negative). After a few seconds you should see gas pushing through the longer tubes and into the tanks. Continue collecting gas until your tank is full or to the amount specified by your teacher. Close the bottom tube clamps while you set up for the next portion of the investigation.

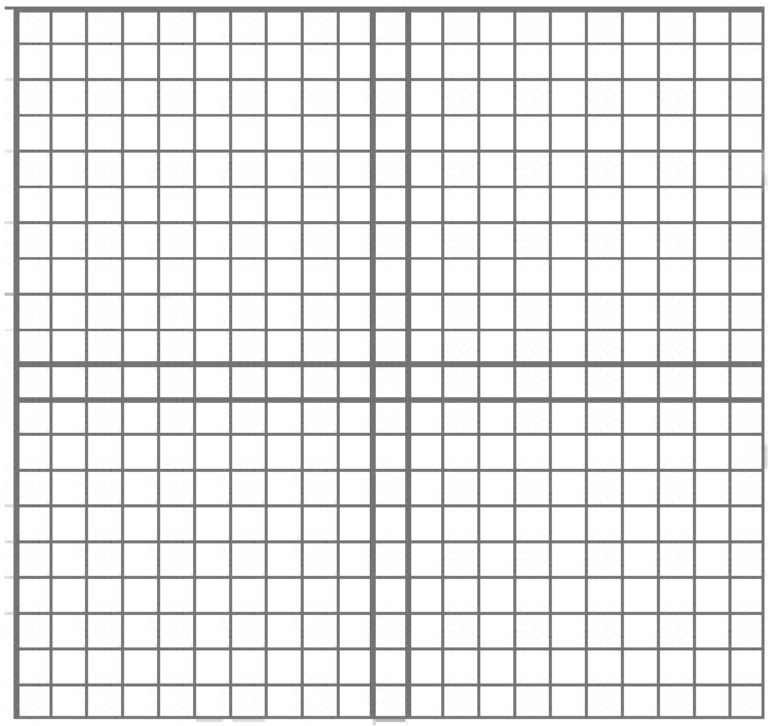
Power Output

Attach a motor/propeller unit to the fuel cell using a set of wires with alligator clips. Add a multimeter *into* the circuit in series (making a big circular circuit) and set it to read current (amperage). *Hint: Put the multimeter into the negative (returning) side of the circuit. If it doesn't work at first, you may have the connections backwards going into and out of the multimeter*. The second multimeter will be used to measure voltage by touching the leads *across* the circuit–in parallel–between the two terminals of the fuel cell. Set this multimeter to read voltage.

Open the bottom clamps so that hydrogen and oxygen flow into the fuel cell. The motor/propeller should begin to turn and you should have a reading on the current multimeter. If not, check and correct your circuit.

Touch the voltage multimeter across the terminals. Record both amperage and voltage. Continue taking readings every minute until the motor stops.

1. Graph the results below. Remember to label your axis.



Current and voltage output of our fuel cell over time

2. Describe what your graph tells you about the power output of your fuel cell.

3. Using this information, what size (voltage, amperage) motor should you use for a short race?

4. Would your choice of motor change if it was an endurance race--distance traveled rather than speed? Explain.

Hydrogen storage
How you will store the hydrogen and oxygen on your vehicle is a major design consideration. Obviously, the large water displacement tanks you have been using are not suitable for transportation, and when weight is a consideration as it will be in your Sprint vehicle, carrying extra water or using heavy materials is not desirable.

5. With your group, brainstorm several ways to store the gases on your vehicle. Write or sketch your ideas below.

Wiring
Wire size and length can add resistance to your electric circuit, cutting down the amount of usable power reaches the motor With the voltage and amperage results you obtained from your fuel cell, determine using the internet or an electronics handbook what size wiring you should be using for your Sprint car.

6. Optimal size of wiring ______________________________

Discussion and Design

With your group, discuss how you might use the findings from your investigations to help you design your Sprint vehicle. Your goal from this investigation is to figure out how to maximize the power your fuel cell is producing and determine what size of motor you need to pair with your fuel cell.

- In addition to wire size, connections such as alligator clamps can add resistance to your electrical circuit; however, you need some way to close your circuit to start the motor that is easy and quick to use, but adds little resistance to the open circuit.
- The added weight of a motor is unavoidable–but, how could you decrease this weight? And how could you use the motor weight to your advantage in your vehicle design? (This will also be discussed in the traction section of the *Wheels, Axles and Bearings* activity)
- Would pressurizing your gases increase the power output of your fuel cell? How would you investigate this question? How would you implement a pressurized system on your vehicle?
- Does the fuel cell assembly loose hydrogen slowly as it sits idle? If so, this could influence how you time your hydrogen production before the race. How would you test for this?