Investigation 6:
Hydrogen Power in Motion

In Investigation 5 you saw Hydrogen powering the car's wheels as they turned free in air. In this investigation you will see if there is a difference between how long the wheels will turn when suspended in air and when the car is actually running on a surface. What do you think will happen? Will the wheels turn for a longer time, shorter time, or much the same?

You may already have some idea of what you will see in this investigation. You may have ideas about what would cause any change in the time the wheels turn, but think some more and come up with some reasons to support your thinking. This thinking about an investigation is called a hypothesis by scientists and is usually a written description of what you expect to happen and why. By writing down a hypothesis and then asking the appropriate questions in experiments, scientists get answers, adding to the information they already have. They might then revise the previous information, or form a new hypothesis and ask more questions.

It is important to run the car on a flat, smooth and clean surface such as your classroom, hall or gymnasium floor. You will usually need to turn the front wheels of the car so the radius of the circle traveled is small. If you have the opportunity to run the car on a swept gymnasium floor, you may be able to send it in a straight line from one corner of the room to the other.

Remember that your model car is actually running on Hydrogen Power that comes from a fuel cell using hydrogen produced by electrolysis of water. This is a completely pollution-free energy source. With an appropriate number of fuel cells connected to produce more power, experimental hydrogen powered cars and buses are now on the road, producing only water vapor in their exhaust.

When you have written your hypothesis, put on your goggles and let's find out what happens!

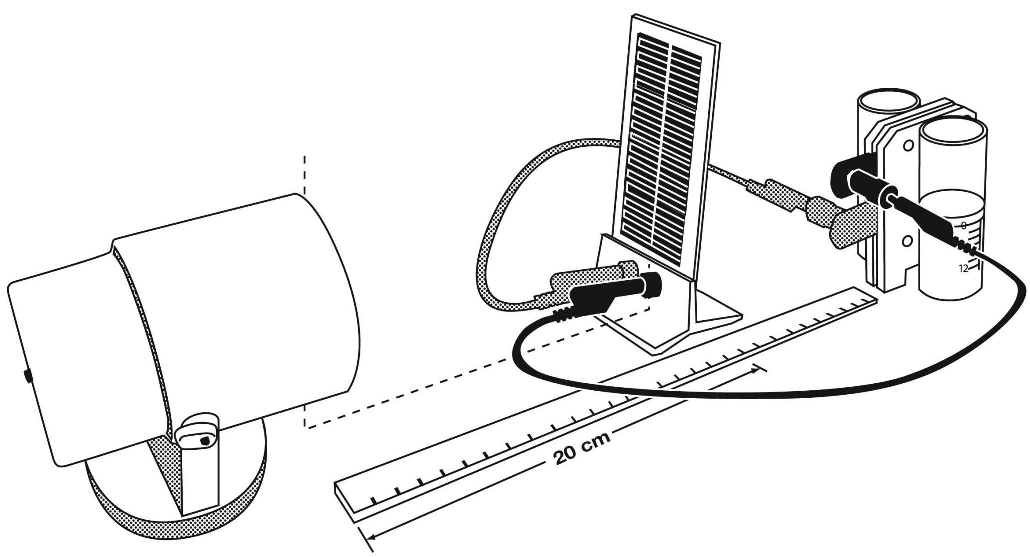
Will the wheels turn for the same period of time when used to power the car on a flat surface?

You will need:

- goggles or eye protection
- solar panel from the *Fuel Cell Model Car Kit*
- two patch cords
- reversible fuel cell and car base from the *Fuel Cell Model Car Kit*
- distilled water
- 75 watt PAR30 incandescent lamp, or equivalent light source.
- block of wood or other support for the car
- watch with second hand or stopwatch function

Procedure

1. Put on your goggles. Remember that they will only protect you if you wear them properly.
2. The bottom of the fuel cell storage cylinders should be completely filled with distilled water, with no air space or other gas in the cylinders. If you need to add distilled water to the fuel cell, refer to *Filling the electrolyzer* in the section *Using the Fuel Cell Model Car Kit* at the start of this handbook.



3. With the patch cords, connect the solar module to the reversible fuel cell, which we are using here as an electrolyzer. Red goes to red and black goes to black.

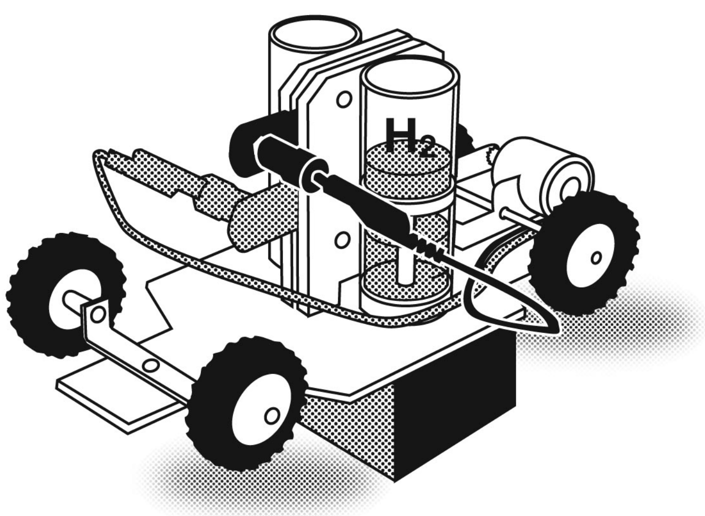
Position the solar panel so it directly faces the light source at the distance your teacher recommends and turn on the light.

4. When the hydrogen storage cylinder is filled to around 6 ml carefully remove the solar panel from the system by disconnecting the patch cords from the reversible fuel cell.

5. On the top side of the car base directly in front of the gears, you will notice a felt-covered upright piece of plastic. Also notice that the bottom of the fuel cell has a slot between the two cylinders. Turn the fuel cell so that the red and black contacts are towards the front of the car. Carefully slide the fuel cell over the black felt and push down gently until the fuel cell is fully seated on the car base. You may need to hold the connecting cables out of the way as you do this.

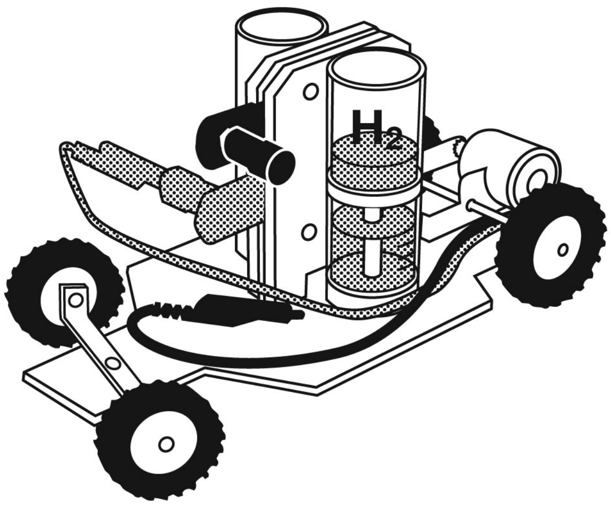
6a. **If you are running the car in a circle**

- Position the car on the floor and turn the front wheels so that the car will run in a fairly small circle without hitting anything. (Don't turn the wheels so much they catch on the frame of the car.)
- Connect the black and red wires from the motor to the fuel cell and let the car run in a circle. If necessary, adjust the front wheels and the car position until you are satisfied with the circle the car is making.
- Use chalk or a piece of tape to mark a point on the circle and another point exactly opposite. Mark where the centre of the car travels, not the outside or inside wheels. Measure this distance and make note of it as the diameter of your driving circle. You will need this measurement to calculate how far your car travels for each ml of hydrogen.
- Place the car on the block of wood so that the wheels are free to turn, and let the motor continue to run until the level of hydrogen is exactly 4ml. At this point disconnect the black wire so the motor stops (If already below 4ml reconnect the solar panel to produce more hydrogen)



6b. **If you are running the car in a straight line**

- place the block of wood under the car base, so that the wheels on your car are free to turn. Connect the black and red wires from the motor to the fuel cell and let the motor run until the level of hydrogen in the hydrogen storage cylinder is exactly 4ml. At this point disconnect the black wire so the motor stops.

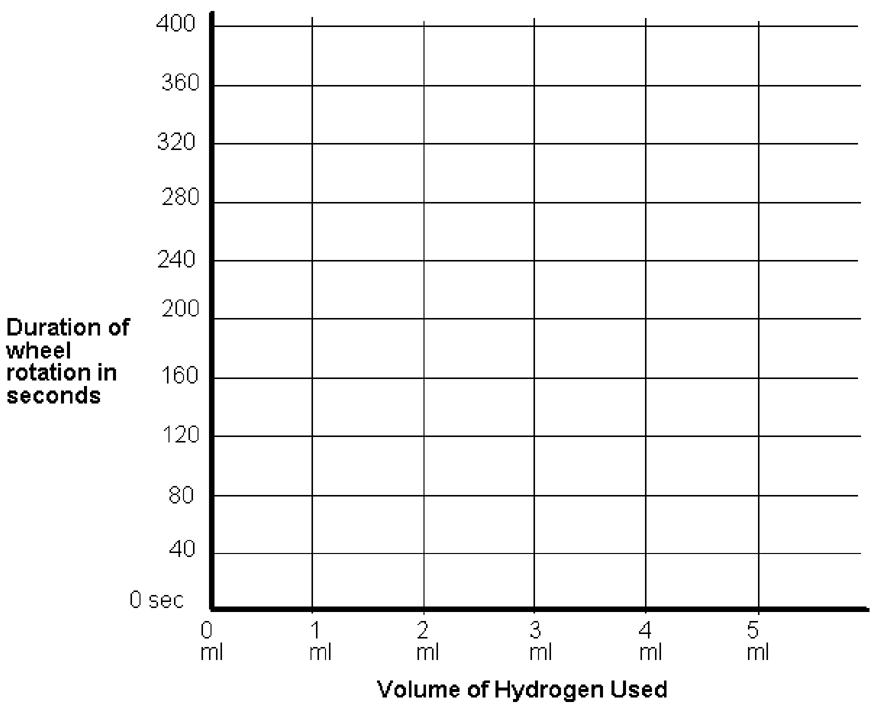


7. Be ready with a stopwatch or some means to record the time to the nearest second. Position the car on the floor and connect the black cable. If your car does not move immediately give it a slight push to overcome the starting friction in the gears. Start the stopwatch or note the time.
8. As the car travels, count the number of circles it makes, or keep track of the straight-line distance travelled, If the car runs into a wall quickly turn it around sending it back and repeat until the car finally stops. When the car finally stops, note the time on the stop watch (or the current time) and write it in the table. If you were not using a stopwatch, you will need to do some arithmetic to fill in the "elapsed seconds" column. Write the number of circles or the straight-line distance the car travelled.

Check the level of hydrogen gas in the storage cylinder; there should be no hydrogen gas left in the storage cylinder. If there is, see your teacher for further instructions.

	Trial 1		Trial 2		Trial 3		
	time	elapsed seconds	time	elapsed seconds	time	elapsed seconds	Elapsed seconds of car travel (average of trials)
Starting time							
Time when car stops, 4 ml H_2 used							

9. If there is enough time, repeat the procedure as many times as your teacher suggests, noting the duration your car was able to run for each filling.
10. Put your "elapsed seconds" data on the following graph, at the "4 ml" point. If you have data from Investigation 5—time of wheel rotation when the car was not moving—then add this data to your graph, and notice any difference.



Duration of Rotation per given volume of Hydrogen

11. If your teacher wants you to disassemble the equipment, do so, put it away, then take off your goggles and return them carefully.

Questions

1. Why must we start the car with the hydrogen at a known level?

2. What is a hypothesis and why do we write one before an investigation?

3. What did you find when you compared the times of rotation between this investigation and investigation 5?

4. If you found a difference, what do you think caused this?

5. Can you think of any other examples of this from your personal experience?

6. How do you think this would affect cars in the future if they drove on flat or hilly roads? Is this effect similar to what happens to the cars we drive now?

7. Using your data on the distance your car travelled, how far did your car travel on 4ml of hydrogen? How much hydrogen would you need to have your car travel exactly one kilometer? Show all your calculations. Circumference = $\pi \bullet$ diameter of circle

Teaching supplement for Investigation 6: *Hydrogen Power in Motion*

The major objective of this investigation is to have the students realize that putting a car in motion on the road will involve a greater load on the electric motor due to increased friction as the work done in having the entire car move is greater. The learning objectives may be written:

- Students will record that hydrogen is used up at a faster rate when the electrical motor does more work.
- Students will note that repeating an experiment will produce similar results.
- Students will use this data to produce a graph that will allow them to compare the duration of rotation for a given volume of hydrogen gas when the electric motor is doing more work.
- Students will demonstrate correct safety procedures for this investigation.
- Students will answer questions designed to elicit understandings and allow teachers to assess the efficacy of the investigation.

Teacher Notes

As in Investigation 5, this investigation requires that the electrolyzer is hydrated and able to produce bubbles of hydrogen fairly soon after the lesson begins. If several classes are to do this investigation in succession the electrolyzer should not be emptied between sessions and may be left filled overnight for use on the subsequent day.

Try out the system beforehand to see if there is enough time to have your students repeat this experiment to get more data. Two repetitions may take about forty minutes.

It is important that the floor surface be as smooth as possible. The car will not run on carpeting. Having a broom or dry mop available to sweep the area before the car begins its travel will help. Because of the car's turning radius, you will need an area at least 2.5m wide.

If it appears that the motor is not strong enough to drive the car, make sure that you filled the electrolyzer properly (see *Filling the electrolyzer* in the section *Using the Fuel Cell Model Car Kit* at the start of this handbook), and that you have made enough (5-6 ml) of hydrogen. In addition, it may be necessary to lubricate the gears in the car's drive mechanism.

Remind your students to measure the volumes very carefully to ensure reproducible results. Students must get at eye level with the electrolyzer to read the graduations on the hydrogen storage cylinder accurately when the car is placed on the support block and the motor connected to get the hydrogen storage cylinder level to exactly 4ml.

If the car stops before you think it should, refer to *Fuel cell stops working before it runs out of hydrogen?* in the section *Using the Fuel Cell Model Car Kit* at the start of this handbook.

Answers to the student questions

1. *Why must we start the car with the hydrogen at a known level?*

   We must start the car with the hydrogen at a known level if we are to compare our results with the results we obtained in Investigation 5.

2. *What is a hypothesis and why do we write one before an investigation?*

   A hypothesis is a statement made to try to explain something before we actually test it. We write one before we do an investigation because it helps us to think about what we might find and whether the investigation is asking the question we want to answer.

3. *What did you find when you compared the times of rotation between this investigation and investigation 5?*

   We found out that when the car was placed on a flat surface it did not run nearly as long as it did when the car was placed on a support with the wheels turning in the air.

4. *If you found a difference, what do you think caused this?*

   We did find a change and we think it was caused because the electric motor had not only to turn the wheels but it had to get the wheels to drive the car over the ground. This would need more work from the motor and it would use up the hydrogen faster.

5. *Can you think of any other examples of this from your personal experience?*

   There may be many answers here. Assess them all for reasonableness. For example; When I ride my bicycle on flat ground it is a lot easier than when I go up a hill. When I turn it upside down and just run the wheels in the air I can turn the pedals really easily with my hand and the wheel can go around really fast.

6. *How do you think this would affect cars in the future if they drove on flat or hilly roads? Is this effect similar to what happens to the cars we drive now?*

   I think that cars used on hilly roads would use up the hydrogen faster than cars running on flat surfaces. I think cars on hilly roads use up the gasoline faster than cars running on flat roads. The principle is the same - more work requires more fuel.

7. *Using your data on the distance your car travelled, how far did your car travel on 4ml of hydrogen? How much hydrogen would you need to have your car travel exactly one kilometer? Show all your calculations.*

   Answers will vary depending upon the experimental results. The students will need to know how to determine the circumference of a circle given the diameter.

   ($C = \pi D$ where C = circumference, D = diameter, $\pi = 3.14$)