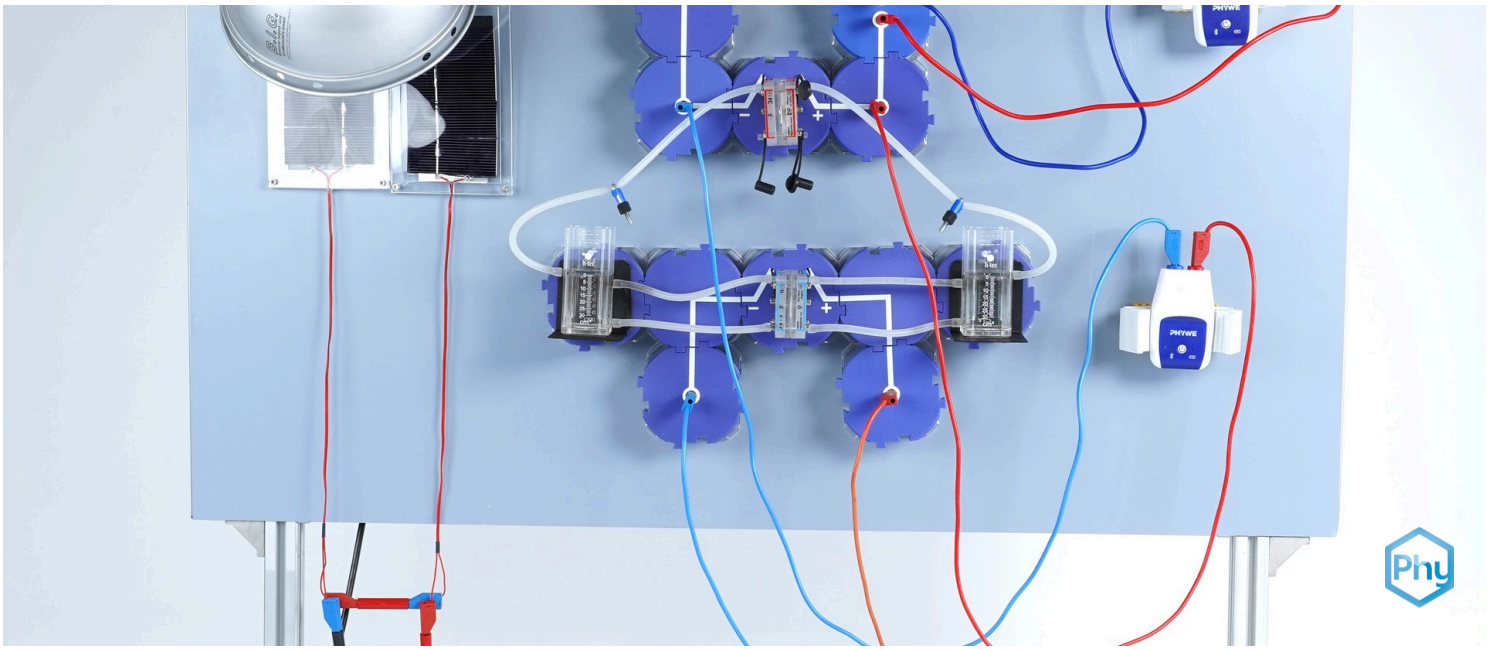
Solar hydrogen system with Cobra SMARTsense



Solar-Wasserstoff Anlage

Physics	Energy	Renewable energies: Water
Physics	Energy	Renewable energies: Sun

Difficulty level	Group size	Preparation time	Execution time
hard	-	10 minutes	30 minutes

This content can also be found online at:

https://www.curriculab.de/c/67aa720f6af1420002daec6f

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Teacher information

Application

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Generating Electrical Energy with a Fuel Cell and Solar-Hydrogen System

Since solar energy is not available continuously, storing it is essential. In the future, hydrogen could serve as an effective storage medium.

Hydrogen can be produced using an electrolyzer and stored in gas containers. When fed into a fuel cell, it generates electrical energy, which can then be used by a consumer.

In this experiment, students will explore this process through a solar-hydrogen system.

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Other teacher information (1/3)

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Prior knowledge

To carry out the experiment, basic knowledge of electrical engineering (parallel and series circuits) is required. Additionally, proper handling of the equipment is expected.

Scientific principle

To utilize the gases produced during electrolysis, a fuel cell is required. When the two gases are supplied to the fuel cell, it generates voltage, and the gases combine to form water again.

Other teacher information (2/3)

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Learning objective

The students will gain knowledge about the separation of water into hydrogen and oxygen using an electrolyzer. They will also learn how a fuel cell generates energy from this process and can power a consumer.

Task

In the first part of the experiment, a qualitative investigation will be conducted to examine how a motor can be powered using the solar-hydrogen system and whether the gases present in the air are sufficient for this purpose. The second part of the experiment will focus on a quantitative analysis of the system.

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Other teacher information (3/3)

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Instructions for Setup and Procedure:

- Only distilled water should be used for the gas container.
- The maximum voltage of the electrolyzer is 4 V, and the maximum current is 2 A.
- Before starting the experiment, the electrolyzer should run idle for about 2 minutes.

The dual PEM electrolyzer has a current of at least 0.6 A (nominal value) at 4.0 V. If the current of the electrolyzer is lower, it generally increases gradually with prolonged operation. If this does not happen, the two connections of the electrolyzer should be short-circuited for one minute or longer.

Safety instructions

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For this experiment, the general guidelines for safe experimentation in science classes apply.

For H- and P-statements, please refer to the safety data sheet of the respective chemical.

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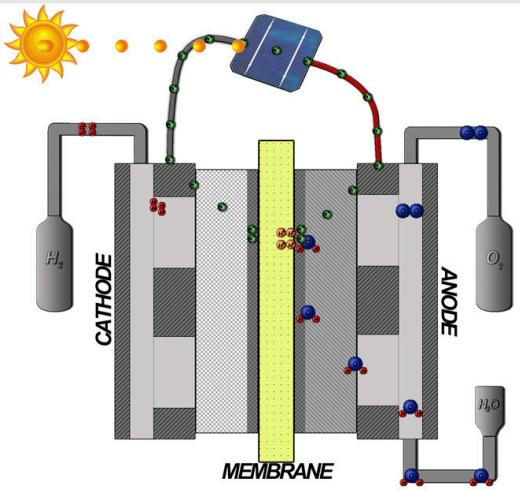
Theory



wikipedia - Example of water electrolysis

The energy is converted into electrical energy by the solar cell. This energy starts the electrolyzer, which performs water electrolysis, splitting water into hydrogen and oxygen.

The chemical equation is:

$$2H_2O \rightarrow 4H^+ + 4e^- + O_2$$

$$4H^+ + 4e^- \rightarrow 2H_2$$

When energy is needed, the hydrogen can be converted back into electrical energy using a fuel cell.

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Material

Position	Material	Item No.	Quantity
1	Cobra SMARTsense Voltage - Sensor for measuring electrical voltage ± 30 V (Bluetooth + USB)	12901-01	1
2	Cobra SMARTsense Current - Sensor for measuring electrical current ± 1 A (Bluetooth + USB)	12902-01	1
3	PHYWE Demo Physics board with stand	02150-00	1
4	Connector, straight, module DB	09401-01	2
5	Connector, angled, module DB	09401-02	4
6	Junction, module DB	09401-10	2
7	Motor with indicating disc, 5 V, module DB	09469-00	1
8	Solar battery, with cable, connectorsand magnet pads	06752-23	2
9	Clamp on holder	02164-00	1
10	Double PEM electrolyser, DB	09488-00	1
11	Double PEM fuel cell for hydrogen/ oxygen operation and hydrogen/ air operation, DB	09486-00	1
12	Gas storage tank (30 cm3) H2/O2	06723-01	2
13	Building Block with magnetic pad, DB	09490-00	2
14	Metal angle for building block with magnetic pad	09491-00	2
15	Connector, angled with socket, module DB	09401-12	2
16	Double sockets,1 pair,red a.black	07264-00	1
17	Support rod, stainless steel, 750 mm	02033-00	1
18	Ceramic lamp socket E27, with reflector, switch and security plug	06751-01	1
19	Filament lamp, 220V/120W, with reflector	06759-93	1
20	Pinchcock, width 10 mm	43631-10	2
21	Silicone tubing, inner diameter 3 mm	39292-00	2
22	measureAPP - the free measurement software for all devices and operating systems	14581-61	1

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Setup and Procedure

Setup (1/6)

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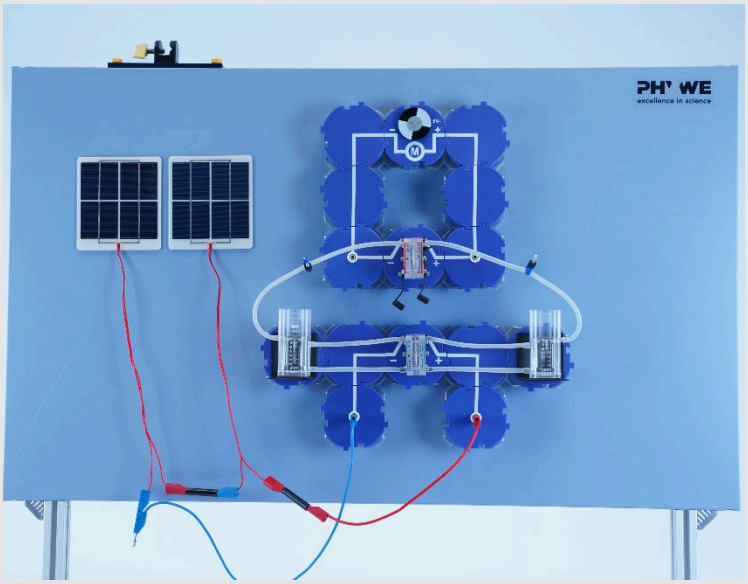

Part 1 of the Experiment: Qualitative Experiment

- Build the circuit for the electrolyzer and fuel cell according to the diagram.
- Pay attention to the polarity of the electrolyzer and the fuel cell.
- Connect the solar cells in series and attach them to the electrolyzer.
- Connect the red plug to the positive terminal and the blue plug to the negative terminal.

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Setup (2/6)

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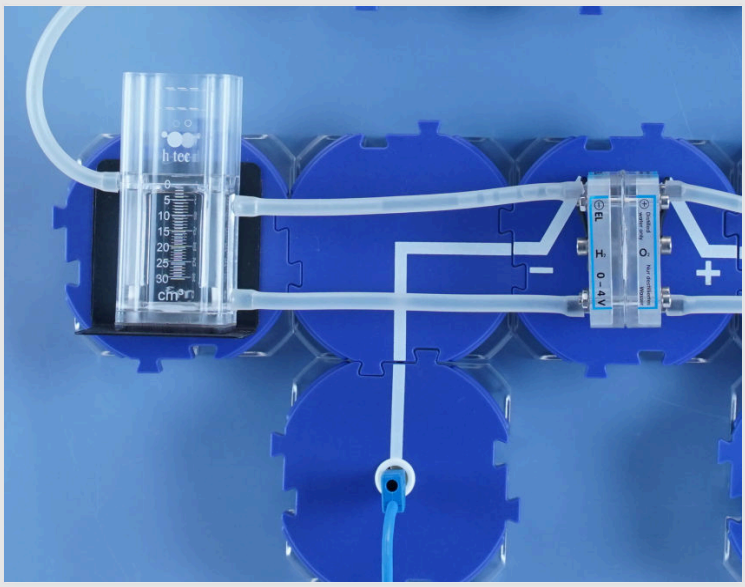

- Place the two gas containers to the right and left of the circuit and connect them to the electrolyzer using the silicone hoses.
- Attach another silicone hose to the free end of each gas container and seal it with a hose clamp.
- Fill the gas containers with distilled water up to the lower marking.

Setup (3/6)

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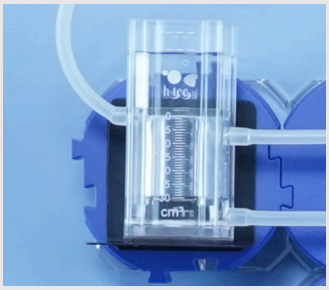

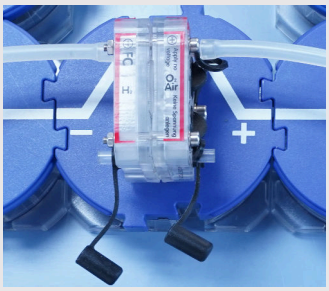

- Open the hose clamps while holding the hoses upright, so that the water flows into the lower part of the gas containers.
- Close the hose clamps and connect the hoses to the input nozzles of the fuel cell.
- Ensure that the gas container connected to the negative terminal of the electrolyzer is linked to the H_2 side of the fuel cell, and the gas container at the positive side is connected to O_2.
- Open the output nozzles of the fuel cell and close the air option (see diagram).

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Setup (4/6)

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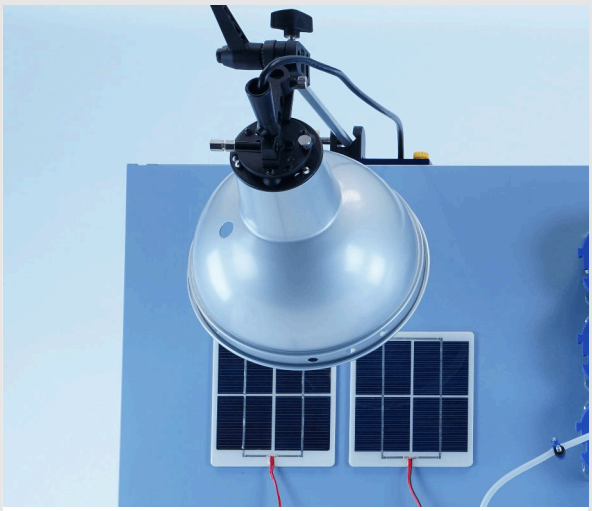

Lamp setup

- Position the sleeve at the upper edge of the board, above the solar cell, on the support and carefully screw it in place.
- Secure the rod with the lamp inside the sleeve and align it with the solar cell.
- The distance between the center of the solar cell and the front of the lamp should be approximately 35 cm.

Setup (5/6)

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Part 2 of the Experiment: Quantitative Experiment

To take measurements with the Cobra SMARTsense sensors, the PHYWE measureAPP is required. The app can be downloaded for free from the App Store – QR codes are provided below. Make sure Bluetooth is enabled on your device (tablet or smartphone).

measureAPP for Android operating systems.

measureAPP for iOS operating systems.

measureAPP for tablets / PCs with Windows 10.

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Setup (6/6)

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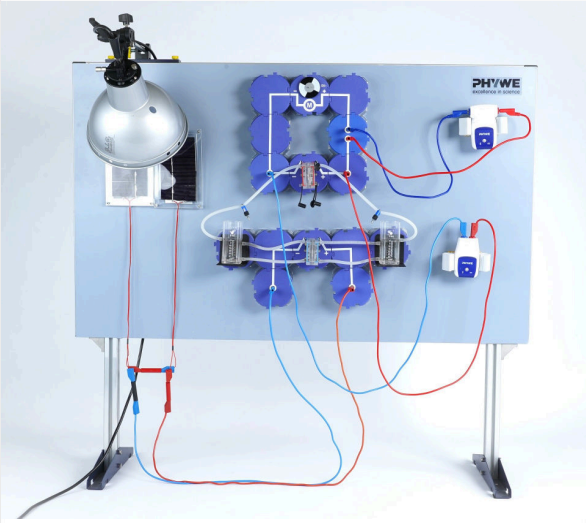

Experimental setup

- Replace one of the two straight conductor blocks with an interrupted one.
- Connect the Cobra SMARTsense Current sensors between the fuel cell and the motor.
- Connect the Cobra SMARTsense Voltage sensor left and right from the fuel cell.
- The current flowing to the motor and the voltage across the fuel cell should be measured.

Procedure (1/6)

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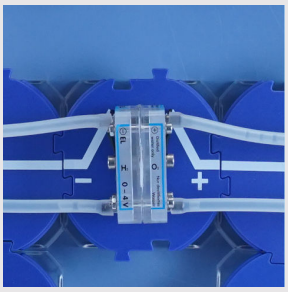
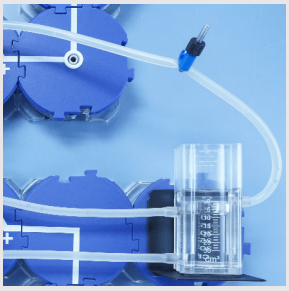
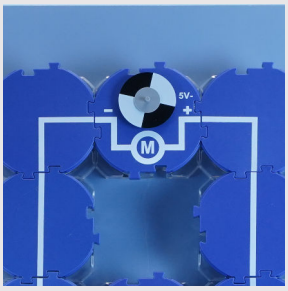
Part 1 - Qualitative Experiment

- Align the lamp so that the light beam strikes both solar cells equally and as vertically as possible.
- Turn on the lamp and observe the electrolyzer.
- Once both gas containers are filled with at least $10 cm^3$ of gas, first open the hose clamp on the oxygen side of the fuel cell.
- Observe the motor.









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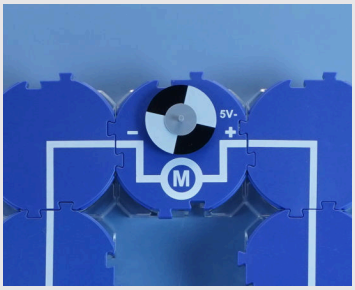
Procedure (2/6)





- Open the air option of the fuel cell and observe the motor.
- Open the hose clamp on the hydrogen side of the fuel cell and continue observing the motor.
- Turn off the lamp.
- Close the hose clamps.



Procedure (3/6)

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Cobra SMARTsense Voltage

Part 2: Quantitative Experiment

- Turn on your Cobra SMARTsense Voltage Sensor by pressing the button on the sensor for 3 seconds.
- Open the measureAPP on your tablet or smartphone and make sure the device can connect to Bluetooth devices.
- Select the "Cobra SMARTsense Voltage" sensor.

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Procedure (4/6)

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Cobra SMARTsense Current

- Now, turn on your Cobra SMARTsense Current Sensor and connect it to the measureAPP like the voltage sensor.

Procedure (5/6)

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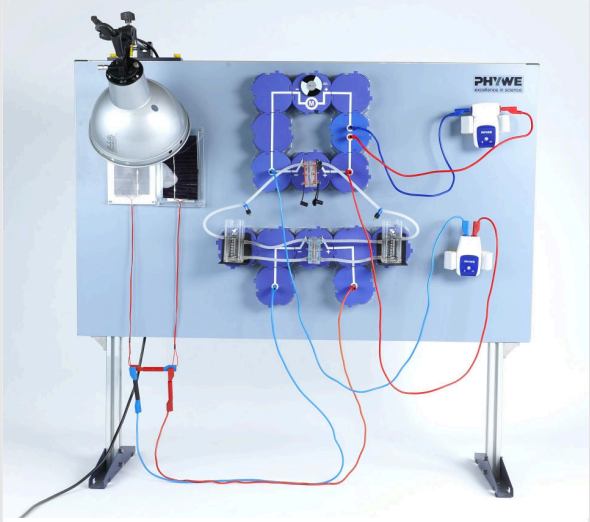

Experimental setup

- Start a measurement in the measureAPP.
- Turn on the lamp and wait until one of the gas containers contains at least $10 cm^3$ of gas.
- First, open the hose clamp on the oxygen side, then the one on the hydrogen side of the fuel cell.
- Observe the motor carefully and record the voltage and current.

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Procedure (6/6)



- Read the maximum voltage and current using the Cobra SMARTsense sensors via the MeasureAPP.
- Calculate the power from the values and enter it into the table.

Voltage U	Current I	Power P



Evaluation (1/3)

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Part 1

Qualitative Experiment



When the lamp is turned on, gas bubbles are generated in the electrolyzer, which travel through the hoses to the gas containers.

- This happens quickly and irregularly.
- This happens slowly and irregularly.
- This happens slowly but steadily.

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Evaluation (2/3)

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Drag the words into the correct blanks!

A fuel cell requires hydrogen and _____ to generate electrical energy. The _____ in the air is only 3%. The _____ in the air, however, is 21%. When the hose clamp for _____ is opened, pure hydrogen is supplied to the fuel cell, and the oxygen content from the air is enough to generate sufficient _____ for the motor to start rotating.

oxygen content
electrical energy
hydrogen content
oxygen
hydrogen

Check

Evaluation (3/3)

PHYWE

In the second part of the experiment, the motor does not run when the hose clamp on the oxygen side is opened. However, when the clamp on the hydrogen side is opened, the following can be observed: The voltage remains constant, but the current fluctuates.

At the beginning, a clear power peak should occur. The fluctuations in the values are caused by friction in the motor, and the peak at the start arises from the increased initial power the motor needs to overcome friction and start rotating.



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