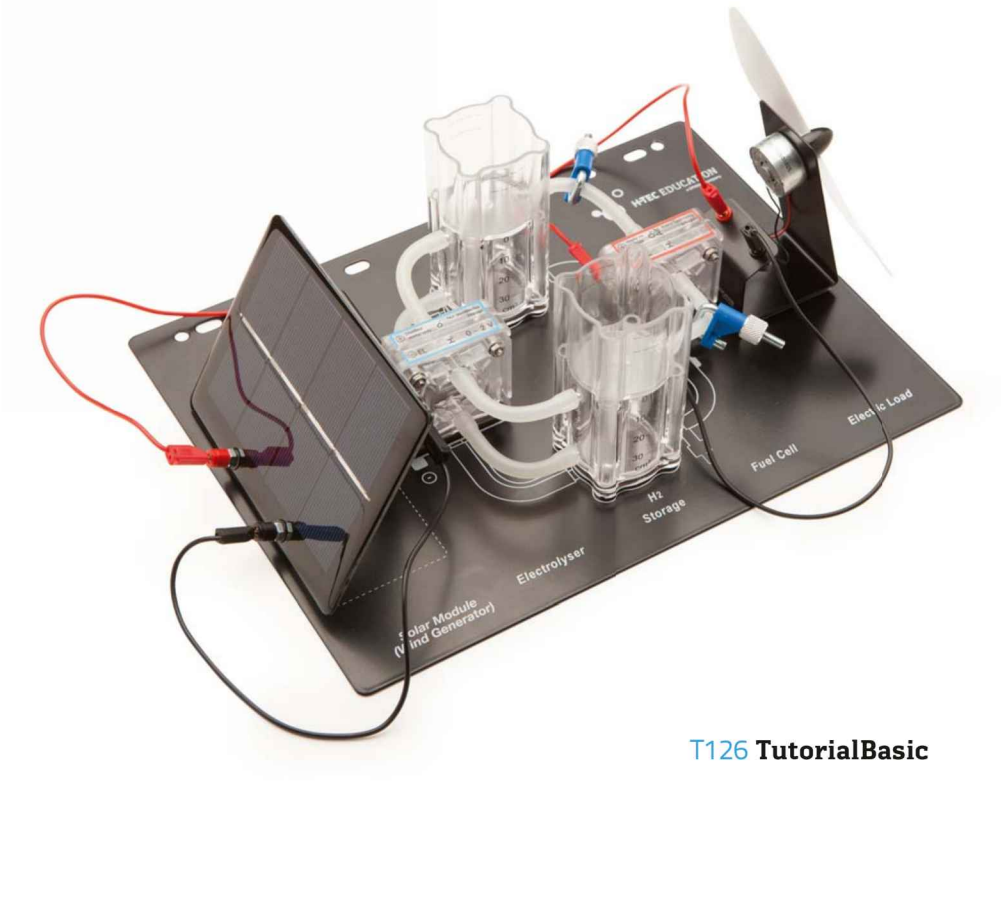
H-TEC EDUCATION
a GPJOULE company

Operating Instructions



T126 **TutorialBasic**

Contents

Your Duties as a Supervisor

These Operating Instructions are intended for the responsible supervisor.

- Read the Operating Instructions before using the equipment. Observe the instructions and keep them on hand.
- Pay particular attention to the General Safety Precautions (page 5).
- This product may be set up and operated only under the supervision of the person responsible.

Objective / Introduction

The predicted climate change combined with the worldwide increase in energy requirements and the declining resources of coal, oil and gas make the development of new energy sources one of the main tasks of the 21st century. Hydrogen technology is particularly important in this regard. With the help of fuel cells, electricity can be produced directly from hydrogen and oxygen. The only waste product is water.

With the help of electricity, which is obtained from renewable energy like solar cells or wind power, the required hydrogen can in turn be produced directly from water by splitting into hydrogen and oxygen. The principle on which this is based is called electrolysis. Together, the two processes form the solar hydrogen cycle.

All stages of the solar hydrogen cycle can be clearly explained with simple experiments using this working model. A simple principle, which works on both a small and a large scale, and in doing so conserves resources and unburdens the environment. It is therefore no wonder that all experts in fuel cell technology forecast excellent prospects for the future.

The design, set-up and operation of the TutorialBasic are explained in this manual. You will also find suggestions for using the equipment in tutorials. The team wishes you exciting experiments and an interesting insight into the future of energy supply

H-TEC EDUCATION GmbH

Intended Use

The equipment described in this manual allows the principles of PEM fuel cells (PEM = proton exchange membrane), PEM electrolysers and solar modules to be demonstrated, and appropriate measurements to be taken. The equipment has been developed for teaching and demonstration purposes only.

Any other use is prohibited.

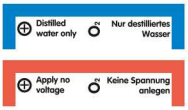
WARNING!

Distilled water is required to operate the TutorialBasic. The electrolyser splits this water into hydrogen and oxygen. In the fuel cell, hydrogen (H_2) and oxygen (O_2) react again. These gases can be dangerous if handled improperly. In order to avoid any risks you must follow the recommended safety precautions when using the equipment.

H-TEC fuel cells and electrolysers are clearly color-coded according to their function.

blue: electrolyser

red: fuel cell



Those descriptions show also the electric polarity and their gas connection (O_2 or H_2).

General Safety Precautions

The **General Safety Precautions** attached separately to the product must be read before using the product and must be observed!

Additional note

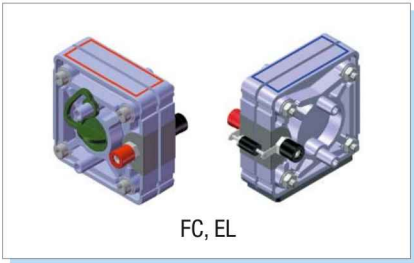
- Make sure that the polarity is always correct (red = "+", black = "-")!

Overview of TutorialBasic (T126)

The TutorialBasic is a working model of the solar hydrogen cycle and it features modular components for flexibility. The solar module generates electricity, which is used to break down the distilled water in the electrolyser into oxygen and hydrogen gas. The gases are collected in separate gas storage tanks. Then, in the fuel cell, the two gases react with one another to form water again. This reaction generates electricity, which can be used to operate an electric load.

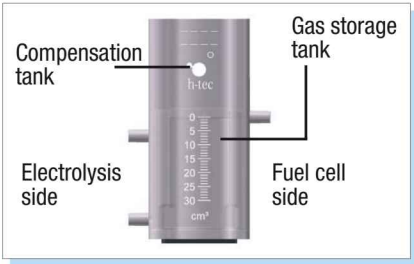
The TutorialBasic allows experiments across the whole range of hydrogen applications.

Contents of the case


FC, EL

1x Fuel Cell; Fuel Cell H_2/O_2/Air

1x Electrolyser; Electrolyser Cell5



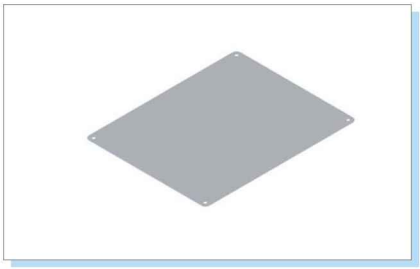
2x Gas storage tank; Storage 30

The tanks are provided with a measurement scale on the gas storage tank itself and two fill level marks on the compensation tank.

Note: When filling the tanks do this in strict accordance with the assembly instructions of each experiment.

1x Solar module; Solar Module Tutorial

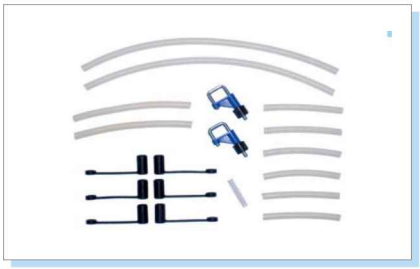
1x Ventilator; Fan Tutorial



1x Printed baseplate with assembly aid; Experimentation Plate

2x Connecting cable 2 mm; black

2x Connecting cable 2 mm; red



1x Tubes; TubeSet

Detailed view of: Cap for gas connector and stopper for sealing air inlet.

And 1x accompanying book "Fuel Cell Technology for Classroom Instruction" and 1x protective googles.

The following will also be required:

- Commercially available distilled water (conductivity <2 µS/cm)
- Sufficient sunlight or halogen lamp with focused light.
- Absorbent cloths

Experiments
Experiment 1: Solar energy

Summary

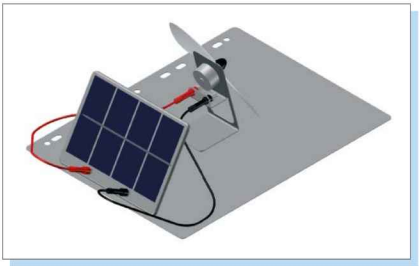
The object of the experiment is to convert light energy to electrical energy with the help of the solar module. An electrical load is used for illustration purposes.

Setup time: approx. 1 minute

Length of experiment: approx. 1 minute

Experiments from the accompanying book

- Current-voltage characteristics, power curve and efficiency of the solar module (2.2.)



Equipment and materials

For the experiment, you will require:

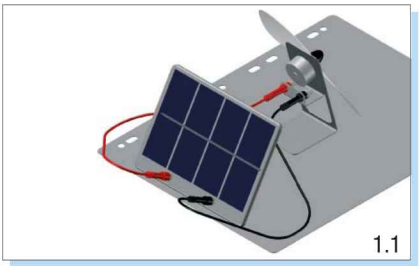
- 1x Solar module
- 1x Fan
- 1x Baseplate
- 2x Connecting cable 2 mm

The following will also be required:

- Sufficient sunlight or halogen lamp with focused light.

Setting up

1. Place the solar cell and the fan on the baseplate as shown in the sketch **(Fig. 1.1)**.
2. Connect the solar module to the appropriate connectors on the fan, using the connecting cables. When doing so, make sure that the polarity is correct (red = „+“, black = „-“).
3. When the illumination of the solar module is adequate, the fan will start to run.



1.1

Note

If the lighting is not sufficient, you can use a powerful halogen spotlight.

Experiment 2: Solar hydrogen production and storage (based on Experiment 1)

Summary

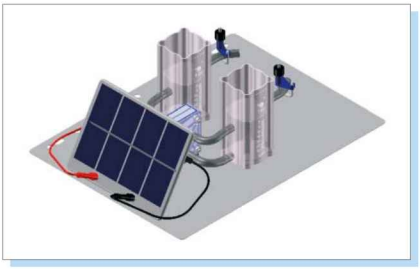
The object of the experiment is to use the electrical energy obtained from the solar module to power the electrolyser. The electrolyser breaks down water into hydrogen and oxygen gases, which are stored in their respective gas storage tanks.

Setup time: approx. 3 minutes

Length of experiment: approx. 5-15 minutes

Experiments from the accompanying book

- Decomposition of water with regard to the resulting volume of hydrogen and oxygen gas (2.1.)
- Current-voltage characteristics, power curve and efficiency of the solar module (2.2.)
- Current-voltage characteristics of the PEM electrolyser (2.3.)
- Energy efficiency and Faraday efficiency of the PEM electrolyser (2.4.)



Equipment and materials

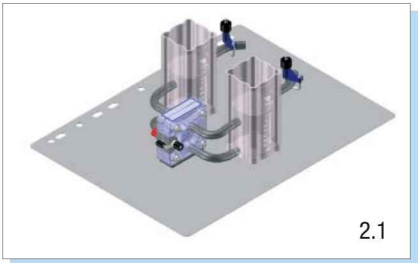
For the experiment, you will require:

- 1x Electrolyser
- 2x Gas storage tank
- 1x Solar module
- 1x Baseplate
- 1x Tube set (4x short, 2x long)
- 2x Hose clamp
- 1x Protective googles
- 2x Connecting cable 2 mm

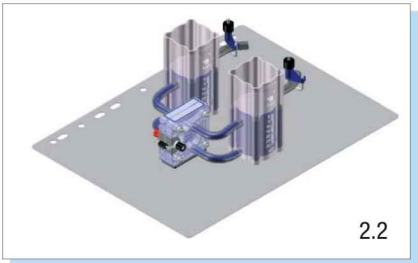
The following will also be required:

- 1x Water bottle with distilled water
- Sufficient sunlight or halogen lamp with focused light.

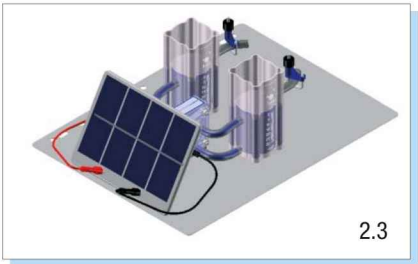
Setting up



2.1



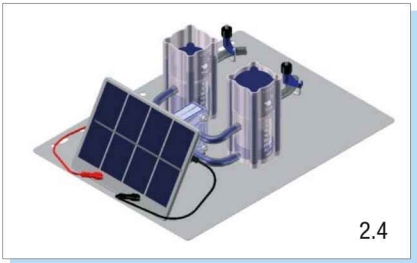
2.2



2.3

- Place the two gas storage tanks and the electrolyser on the baseplate as shown in the sketch **(Fig. 2.1)**.
- Connect the bottom and top connectors of the electrolyser to the corresponding connectors on the electrolyser side of the storage tanks using four short hoses.
- Fit long hoses to the connectors on the fuel cell side of the gas storage tanks and seal these with hose clamps **(Fig. 2.1)**.
- Fill both storage tanks with distilled water up to the top mark of the compensation tank.
- Open the hose clamps on the hoses on the fuel cell side of the gas storage tanks one after the other. Air will escape from the gas storage tanks and the electrolyser. The process is complete when the water level in the storage tanks stops falling **(Fig. 2.2)**. After this, reseal the hose clamps.
- Connect the solar module to the appropriate connectors on the electrolyser using the connecting cables **(Fig. 2.3)**. When doing so, make sure that the polarity is correct (red = „+“, black = „-“).

Gas production



2.4

1. When the illumination of the solar module is adequate, the electrolyser will begin to produce hydrogen and oxygen in a ratio of 2:1 **(Fig. 2.4)**.

Note

If the lighting is not sufficient, you can use a powerful halogen spotlight.

2. When the gas storage tanks are full, excess gas will escape in the form of bubbles.

Emptying the storage tanks

1. To empty the storage tanks disconnect the electrolyser from the solar module.
2. Take the storage tanks together with the electrolyser from the baseplate and pour the water into a collecting tray.

Experiment 3: Solar hydrogen system - H_2/O_2
(based on Experiment 2)

Summary

The object of the experiment is to use the stored gases to produce electrical energy. The gases are fed to the fuel cell, which converts the chemical energy into electricity and heat. An electrical load is used for illustration purposes.

Setup time: approx. 5 minutes

Length of experiment: approx. 10 minutes

Experiments from the accompanying book

- Decomposition of water with regard to the resulting volume of hydrogen and oxygen gas (2.1.)
- Current-voltage characteristics, power curve and efficiency of the solar module (2.2.)
- Current-voltage characteristics of the PEM electrolyser (2.3.)
- Energy efficiency and Faraday efficiency of the PEM electrolyser (2.4.)
- Current-voltage characteristics and power curve of the PEM fuel cell (2.5.)

- Energy efficiency and Faraday efficiency of the PEM fuel cell (2.6.)

Equipment and materials

For the experiment, you will require:

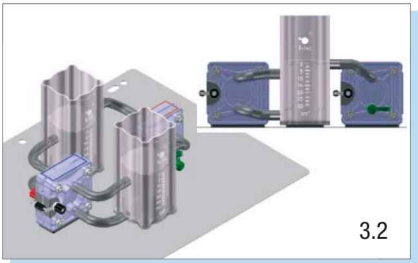
- 1x Electrolyser
- 1x Fuel cell
- 2x Gas storage tank
- 1x Solar module
- 1x Fan
- 1x Baseplate
- 1x Tube set (6x short)
- 1x Stopper
- 2x Cap
- 1x Protective googles
- 4x Connecting cable 2 mm

The following will also be required:

- 1x Water bottle with distilled water
- Sufficient sunlight or halogen lamp with focused light.

Setting up

3.1



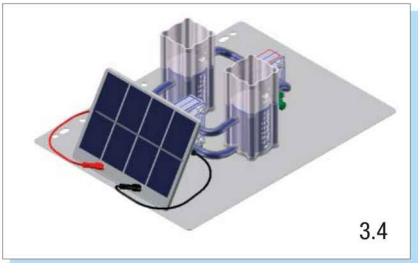
3.2

3.3

1. Place the two gas storage tanks and the electrolyser on the baseplate as shown in (**Fig. 3.1**).
2. Connect the bottom and top connectors of the electrolyser to the corresponding connectors on the electrolyser side of the storage tanks using four short hoses **(Fig. 3.1)**.
3. Place the fuel cell on the baseplate and connect the connectors on the fuel cell side of the gas storage tanks to the top connectors on the fuel cell using two short hoses. Make sure that the hydrogen side is connected with the hydrogen storage tank and the oxygen side is connected with the oxygen storage tank. Check that the stopper is fitted.
4. Fit caps to the bottom connectors of the fuel cell **(Fig. 3.2)**.
5. Fill both storage tanks with distilled water up to the lower mark on the compensation tank.
6. Open the caps on both sides of the fuel cell one after the other. Air will escape from the gas storage tanks, electrolyser and fuel cell. The process is complete when the water level in the storage tanks stops falling **(Fig. 3.3)**. After this, re-seal the bottom connectors of the fuel cell.

Note

Make sure that no water runs into the fuel cell.



3.4

7. Place the solar module on the baseplate and connect it to the appropriate connectors on the electrolyser using the connecting cables **(Fig. 3.4)**. When doing so, make sure that the polarity is correct (red = „+“, black = „-“).
8. Place the fan on the baseplate and connect it to the appropriate connectors on the fuel cell using the connecting cables. When doing so, make sure that the polarity is correct (red = „+“, black = „-“).

Gas production

3.5

1. When the illumination of the solar module is adequate, the electrolyser will begin to produce hydrogen and oxygen in a ratio of 2:1 **(Fig. 3.5)**.

Note

If the lighting is not sufficient, you can use a powerful halogen spotlight.

2. When the gas storage tanks are full, excess gas will escape in the form of bubbles.

Operating the fuel cell

1. Open the caps on both sides of the fuel cell so that approx. 10 cm^3 of the stored gases can flow through the fuel cell. Residual air remaining in the hoses and in the fuel cell will escape. After this, replace the caps.
2. The cell will use the stored gas to generate electricity, along with water and a small amount of heat. The fan will start to run.

Note

If gas production is stopped by removing the voltage source, the fuel cell will continue to produce current until there is no more gas left in the gas storage tanks. However, if gas production continues, then the fuel cell will also produce current continuously.

Emptying the storage tanks

1. To empty the storage tanks disconnect the electrolyser from the solar module and the fuel cell from the storage tanks.
2. Take together the storage tanks and the elctrolyser from the baseplate and pour the water into a collecting tray.

Experiment 4: Solar hydrogen system - H_2/Air

(based on Experiment 2)

Summary

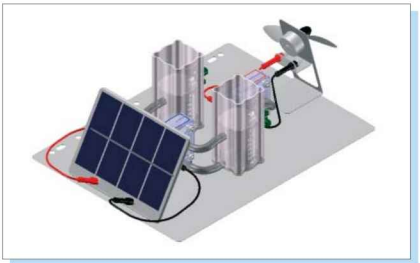
The object of the experiment is to produce electrical energy by using the stored hydrogen and the oxygen in the air. The hydrogen is fed to the fuel cell, which converts the chemical energy into electricity, water and heat. An electrical load is used for illustration purposes.

Setup time: approx. 5 minutes

Length of experiment: approx. 10 minutes

Experiments from the accompanying book

- Decomposition of water with regard to the resulting volume of hydrogen and oxygen gas (2.1.)
- Current-voltage characteristics, power curve and efficiency of the solar module (2.2.)
- Current-voltage characteristics of the PEM electrolyser (2.3.)
- Energy efficiency and Faraday efficiency of the PEM electrolyser (2.4.)
- Current-voltage characteristics and power curve of the PEM fuel cell (2.5. in air modus)



- Energy efficiency and Faraday efficiency of the PEM fuel cell (2.6. in air modus)

Equipment and materials

For the experiment, you will require:

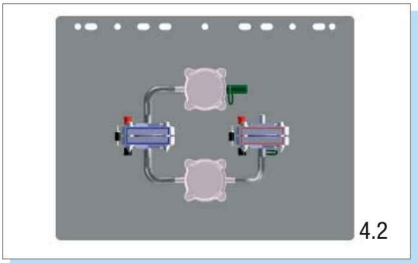
- 1x Electrolyser
- 1x Fuel cell
- 2x Gas storage tank
- 1x Solar module
- 1x Fan
- 1x Baseplate
- 1x Tube set (5x short)
- 2x Cap
- 1x Protective googles
- 4x Connecting cable 2 mm

The following will also be required:

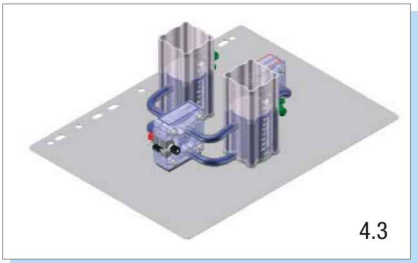
- 1x Water bottle with distilled water
- Sufficient sunlight or halogen lamp with focused light.

Setting up

4.1

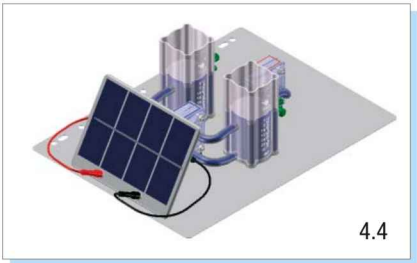


4.2



4.3

1. Place the two gas storage tanks and the electrolyser on the baseplate as shown in the sketch **(Fig. 4.1)**.
2. Connect the bottom and top connectors of the electrolyser to the corresponding connectors on the electrolyser side of the storage tanks using four short hoses **(Fig. 4.1)**.
3. Place the fuel cell on the baseplate and connect the connector on the fuel cell side of the hydrogen storage tank to the top connector on the hydrogen side of the fuel cell using a short hose **(Fig. 4.2)**.
4. Fit a cap to the bottom connector on the hydrogen side of the fuel cell and to the connector on the fuel cell side of the oxygen storage tank.
5. Fill both storage tanks with distilled water up to the lower mark on the compensation tank.
6. Open the cap on the bottom connector of the fuel cell and on the fuel cell side of the oxygen storage tank. Air will escape from the storage tanks, electrolyser and fuel cell. The process is complete when the water level in the storage tanks stops falling **(Fig. 4.3)**. After this, re-seal the bottom connector of the fuel cell and the connector on the oxygen storage tank.



4.4

Note

Make sure that no water runs into the fuel cell.

7. Place the solar module on the baseplate and connect it to the appropriate connectors on the electrolyser using the connecting cables **(Fig. 4.4)**. When doing so, make sure that the polarity is correct (red = „+“, black = „-“).
8. Place the fan on the baseplate and connect it to the appropriate connectors on the fuel cell using the connecting cables. When doing so, make sure that the polarity is correct (red = „+“, black = „-“).

Gas production

4.5

1. When the illumination of the solar module is adequate, the electrolyser will begin to produce hydrogen and oxygen in a ratio of 2:1 **(Fig. 4.5)**.

Note

If the lighting is not sufficient, you can use a powerful halogen spotlight.

2. When the gas storage tanks are full, excess gas will escape in the form of bubbles.

Operating the fuel cell

1. Open the stopper on the oxygen side of the fuel cell.
2. Open the cap on the hydrogen side of the fuel cell so that approx. 10 cm^3 of the stored hydrogen can flow through the fuel cell. Residual air remaining in the hoses and in the fuel cell will escape.
3. Replace the cap.
4. The fuel cell will use the stored hydrogen and atmospheric oxygen to generate electricity, along with water and a small amount of heat. The fan will start to run.

Note

If gas production is stopped by removing the voltage source, the fuel cell will continue to produce current until there is no more gas in the gas storage tanks. However, if gas production continues, then the fuel cell will also produce current continuously.

Emptying the storage tanks

1. To empty the storage tanks, remove the electrolyser from the solar module and the fuel cell from the storage tanks.
2. Take the storage tanks together with the electrolyser from the baseplate and pour the water into a collecting tray.

Maintenance

The fuel cells we provide in our sets are maintenance-free. However, always remember:

- Use fresh, distilled water each time.
- Drain the water from the storage tanks after use.

Before putting the cell away:

- Continue operating the cell until the electric load (e.g. the fan) stops by itself. This will ensure that a little water remains in the fuel cell and keeps the membrane moist.
- Close the caps and the stopper so that the water in the fuel cell does not evaporate.
- Wipe the baseplate dry in order to prevent water marks.

Troubleshooting

The fuel cell only produces low power.

Cause:

- The fuel cell has been stored for a very long time or is too dry. A fuel cell with a dry membrane will lose power.

Solution:

- Continue operating the fuel cell. The fuel cell will moisten itself during operation and gradually return to full power.

The electric load connected to the fuel cell does not work, despite hydrogen being present.

Cause:

- Water has gotten into the fuel cell (e.g. via the storage tank). Drops of water in the fuel cell can block the gas feed and lead to a rapid loss of power.

Solution:

- Dry the fuel cell by opening the connectors and blowing through the fuel cell.

No hydrogen is produced by the electrolyser when the solar cell is connected.

Cause:

- The light intensity is insufficient.

Solution:

- Check the power specifications designed for the light source. You need sufficient sunlight or halogen lamps with focused light. Energy-saving lamps, fluorescent tubes, etc. are not suitable for the operation of solar modules.

The electrolyser does not work despite being set up correctly.

Cause:

- You have not used distilled water. The cell is permanently damaged.

Technical Data

TutorialBasic (T126)

Elektrolyser:	5 cm^3/min H_2 2.5 cm^3/min O_2 1.16 W
Max. permissible voltage	0-2 VDC
Max. permissible current	0-2 A
Fuel Cell:	H_2/O_2 mode: 500 mW H_2/Air mode: 150 mW
Gas storage tank:	30 cm^3 H_2 30 cm^3 O_2
Solar module:	2.0 VDC / 600 mA
Fan:	10 mW
Cable length (single):	250 mm
H x W x D:	140 x 450 x 380 mm
Weight:	1.25 kg

Notes