Fuel Cell

Physics 3600 - Advanced Physics Lab - Summer 2021

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I. INTRODUCTION

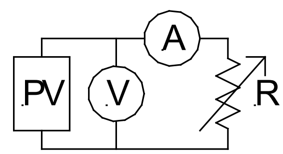
The objective of this experiment is to study the properties of a solar cell, electrolyzer (EL) and fuel cell (FC). You will (1) study the electrical properties of each component, and (2) measure the conversion efficiency of energy between light, chemical and electrical.

The apparatus is used to convert energy:
(1) from light to electrical energy using a photovoltaic (PV) solar cell;
(2) from electrical to chemical energy using an electrolyzer, by splitting water into hydrogen and oxygen;
(3) from chemical to electrical energy using a hydrogen fuel cell.

II. APPARATUS

Hydrogen fuel cell apparatus, H-Tec, Model T-126
Optical Power Meter, Thorlabs, Model PM100D-S121C
2 DVMs; decade resistor (1 Ω - 10 kΩ)
Strong light source (flood light)
2.0 V/2 A power supply, EasyPlot software

III. PROCEDURES



A. *Measure Light Input to the Solar Cell and Determine Efficiency*

1. Set up the circuit to measure the PV power.

2. Place the lamp 40 cm from the PV and aim it so that it shines centered on the PV.

3. Place the head of the ThorLabs power meter at the position of the PV. Set the wavelength to 532 nm. Active area is 9.5 mm diameter. Divide the meter power by 12.5 to get the true light power.

    a. Measure the light ***power*** (p) over each of the 8 PV cells.
    b. Compute the average light ***Intensity*** (p/area) using the area of the detector.
    c. Compute the **total average light Power** on the PV (P_L) using the measured area of the PV.

    DO NOT MOVE THE POSITIONS OF THE LAMP AND PV APPARATUS

4. Measure the output power of the PV.

    a. With the lamp on, measure the voltage (V) and current (I) as you vary the resistance from R=0 to ∞.
    b. Plot I versus V, I(V), as you vary R.
    c. Plot the output electrical power (P_E= I*V) versus resistance, P(R) on a log x-axis.
    d. Compute the power (energy) conversion efficiency for the PV, $\eta_{PV} = P_E / P_L$.

    YOU WILL **NOT** NEED THE PHOTOVOLTAIC AND LAMP FOR THE REST OF THE EXPERIMENTS.

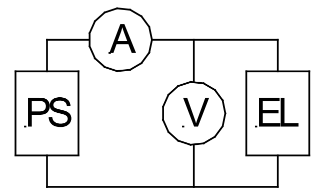
You must show the TA your plots at the end of each section before proceeding to the next section.

B. Set up Electrolyzer and Fuel Cell

1. See the Appendix if you need to set up the apparatus with water.
   Note that it may already have enough water in the two reservoirs.

2. The Electrolyzer must be filled with water, but the Fuel Cell must **NOT** have water in it.

C. Efficiency of Electrolyzer



1. Make sure the tubes connecting the hydrogen and oxygen reservoirs to the Fuel Cell are closed off with the hose clamps.

2. Connect a Power Supply (PS) to the Electrolyzer using an ammeter and voltmeter to measure I and V.

3. Slowly raise the voltage to 2.0 V. **DO NOT EXCEED 2.0 volts or 0.6 amps.**

   a. Where does the oxygen go that is produced?
   b. Measure the time it takes to collect 5 cm^3 of gas in the hydrogen reservoir, while measuring I and V. Turn down the voltage on the power supply.
   c. Compute the energy conversion efficiency for the Electrolyzer, using the time (t_E) it takes to produce V_H= 5 cm^3 of hydrogen and the input electrical power to the Electrolyzer, P_E.

$$\eta_E = E_{Hydrogen} / E_{Elect} = (V_H * HHV) / (P_E * t_E),$$

where HHV is the Higher Heat Value of hydrogen (also called Higher Calorific Value).

D. Efficiency of Hydrogen Fuel Cell

1. Collect 20 to 40 cm^3 of hydrogen in the right-hand container. **DO NOT EXCEED 2.0 volts or 0.6 amps.**
   Make sure that there is no water in FC by following the procedure on the final page.

2. Draw a circuit having an ammeter, variable resistor and Fuel Cell and connect them all in series.
   Add a voltmeter across the Fuel Cell.

3. Set up the circuit to measure the power output from the Fuel Cell.

4. Open the two tubes connecting the reservoirs to the Fuel Cell.
   a. Measure the I and V as you vary the resistance from R=0 to ∞.
   b. Plot I(V) as you vary R.
   c. Plot the output electrical power versus resistance, P(R), using a log x-axis.

5. Select a resistance that gives the highest power output.
   a. Measure the time (t_{FC}) it takes to use up 5 or 10 cm^3 of gas.
   b. Compute the energy conversion efficiency for the Fuel Cell, using the time (t_{FC}) it takes to consume a volume of hydrogen (V_H) and the output electrical power P_{FC}.

$$\eta_{FC} = E_{FC} / E_{Hydrogen} = (P_{FC} * t_{FC}) / (V_H * LHV),$$

where LHV is the Lower Heat Value of hydrogen (also called Lower Calorific Value).

6. Repeat the last section at different resistances.
   a. Measure the energy conversion efficiency for the Fuel Cell at different output powers.
      Important - collect data in one day, as data taken during different days may not match.
   b. Plot the efficiency as a function of output power, η_{FC} (P).

IV. SUMMARY

a. List all the efficiencies (experimental and expected values) in a table with uncertainties.
b. Discuss the efficiencies and compare to expected values.
c. Identify and discuss the major sources of error in computing each efficiency.

In your Introduction:

a. Describe how the Proton Exchange Membrane (PEM) Electrolyzer works.
b. Describe how a Fuel Cell works.

APPENDIX – Setup and Operation of Fuel Cell Apparatus

NOTE: you probably don't need to do any setup

H-TEC EDUCATION

Experiment 3: Solar hydrogen system - H_2/O_2

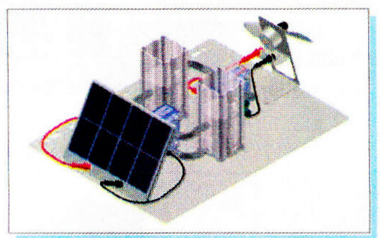
(based on Experiment 2)

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 effi ciency 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

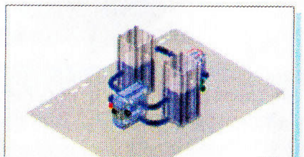
The following will also be required:

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

Setting up

3.1

3.2

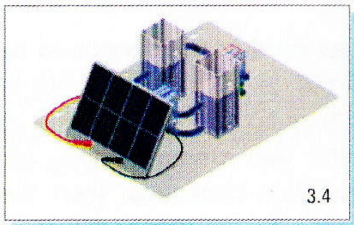


3.3

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.

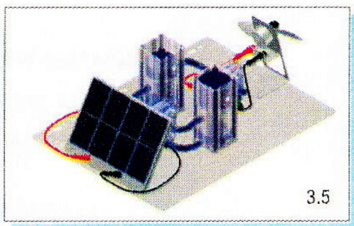
H-TEC EDUCATION


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.

H-TEC EDUCATION

Operating the fuel cell

See #1 at the bottom

1. Open the caps on both sides of the fuel cell so that approx. 10 cm^3 of the stored gases can fl ow 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.

1. Follow this procedure to remove any water from the FC before using it.
Make sure that you have more than 20 cc of hydrogen and oxygen.
Make sure that the blue clamps are closing off the tubes going to the FC.
Remove the two black caps on the lower part of the FC.
Slowly open then close one of the blue clamps to let out about 10 cc of gas.
Do the same for the other side of the FC.
Replace the two black caps on the FC.