

Efficiency of Energy Conversion

I. Introduction

In this experiment you will use a solar cell, an electrolyzer and a fuel cell to study the conversion of energy from one form to another.

The apparatus

- (1) uses a solar cell a photovoltaic (PV) to convert light energy to electrical energy;
- (2) then an electrolyzer converts the electrical energy to chemical energy by splitting water into hydrogen and oxygen;
- (3) finally, the fuel cell converts chemical to electrical energy.

In the introduction of your report you should explain what each of these things are. What is a solar cell? How does it work? What is an electrolyzer? How does it work? What is a proton exchange membrane (PEM) fuel cell? How does it work?

II. Apparatus

Hydrogen Fuel Cell Apparatus (Solar cell, eletrolyzer, fuel cell)

Optical Power Meter, ThorLabs Components Model PM100A with sensor S121C

2 DVMs; Decade Resistor (1Ω-10kΩ)

Strong light source (flood light)

III. Procedure

A. Measure Light Input to the Solar Cell

1. Your solar panel is made of ten small photovoltaic (PV) cells. Make sure the PV is disconnected from all wires.
2. Place the light source (flood lamp) no closer than ~40 cm from the PV cell and aim it so that it shines on the PV perpendicular to its surface. You will need to raise the level of the PV cell off of the table.
3. Set the wavelength of the power meter to $\lambda=785$ nm. Place the sensor of the power meter at the position of the PV.
4. Measure the light power over each PV cell, and find the average power.
5. The sensor measures the power that is incident on its area. The area of the solar cell is much larger than the area of the sensor, so the power incident on the solar cell is larger than the power incident on the sensor. To account for this, find the area of the sensor, A_{sensor} , and the area of the PV, A_{PV} . The diameter of the sensor is 1 cm.
6. Use equation (1) to compute the total average power on the PV, P_{Light} .

$$P_{\text{Light}} = \frac{P_{\text{avg}} \times A_{\text{PV}}}{A_{\text{sensor}}} \quad (1)$$

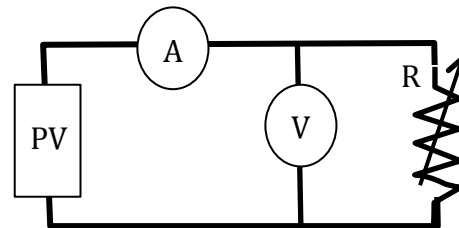


Figure 1 shows the circuit diagram for measuring the PV power.

B. Efficiency of the Solar Cell

Set up the circuit as shown in figure 1 to measure the PV power.

- With the lamp light on high, measure the voltage (V) and current (I) as you vary the resistance from $R=0$ to $10,000\Omega$. Be sure to put the ammeter on the mA scale.
- Plot I versus V, $I(V)$, as you vary R.
- Plot the output electrical power ($P=I \times V$) versus resistance. $P(R)$. What is the maximum power?
- Using the maximum power, compute the power (energy) conversion efficiency, η , for the PV,

$$\eta_{\text{PV}} = \frac{P_{\text{PV}}}{P_{\text{Light}}} = \frac{(I \times V)}{P_{\text{Light}}} \quad (2)$$

Efficiency of Energy Conversion

C. Generate Hydrogen

1. Figure 2 is an image of the electrolyzer. Using the squirt bottle provided, add distilled water to the reservoirs 2f and 2c until the water level in each cylinder is between the 0 and 1 ml mark. **Use only the distilled water provided!** Note that you may already have enough water in the two containers.
2. Connect the Hydrogen side of the Electrolyzer to the Fuel Cell (Figure 3) by attaching 2d to 3b with a tube and then close off this tube with the clamp.
3. Connect a tube to the hydrogen and oxygen gas outlets on the Fuel cell, 3c and 3e respectively, and close them off with a clamp or stopper.
4. Make sure that there is a bit of distilled water in the fuel cell. If it is dry, add some water to the oxygen input 3d.
5. Connect a tube from the oxygen gas on the electrolyzer to the fuel cell by connecting 2g and 3d.
6. Finally, connect the solar cell being careful to connect the red terminals together and the two black terminals together.
7. Turn on the lamp. Watch for bubbles in the electrolyzer, and watch it produce Hydrogen!
8. Collect about 1.0 cm³ of Hydrogen gas in the right-hand container.

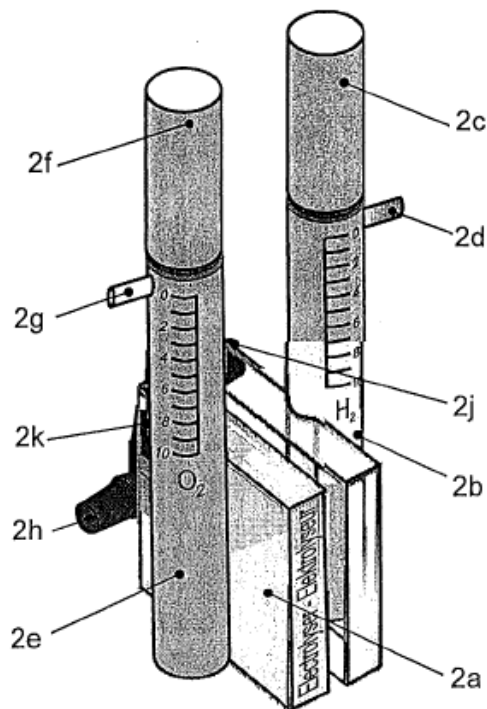


Figure 2 shows the electrolyzer

D. Efficiency of the Electrolyzer

1. Turn off the lamp
2. Connect the circuit in shown in figure 4. Connect an ammeter set to the DC mA scale in series with the PV and electrolyzer. Connect a voltmeter across the Electrolyzer to measure the voltage.
3. Turn on the lamp and measure the electrical power input to the Electrolyzer. After making these measurements you should disconnect this circuit.
4. Measure the time it takes to collect 5 cm³ of hydrogen gas. If you reach 20 minutes, and you don't have 5cm³ of gas, continue collecting only until the next easy to read gradation on the cylinder and measure the elapsed time and the volume of gas.
5. You should continue collecting hydrogen because it will be helpful for the next experiment. **Turn off the lamp** when you have 10ml of hydrogen.
6. Compute the energy conversion efficiency for the Electrolyzer, using the time, t_E , it takes to produce $V_H = 5\text{cm}^3$ of hydrogen and the input electrical power to the Electrolyzer, P_E ,

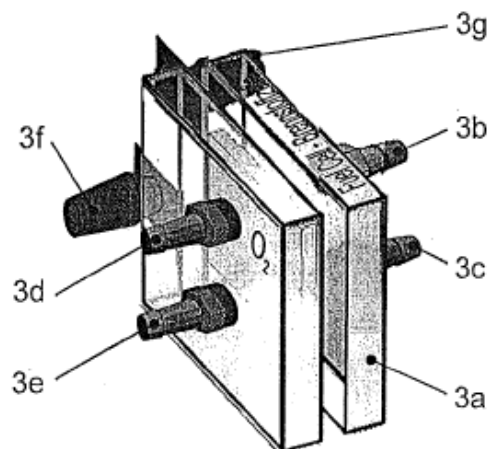


Figure 3 shows the Fuel Cell

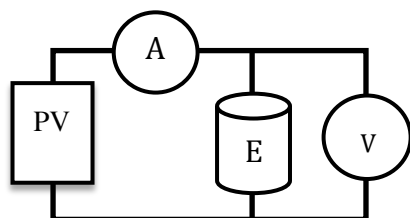


Figure 4 shows the circuit for measuring the input power to the electrolyzer

$$\eta_E = \frac{E_{\text{Hydrogen}}}{E_{\text{Electric}}} = \frac{(V_H \times LHV)}{(P_E \times t_E)} \quad (3)$$

Efficiency of Energy Conversion

where LHV is the Lower Heat Value of hydrogen (also called Lower Calorific Value). You will need to look up this value for hydrogen and you will also need to find the density of hydrogen to make the units work out correctly.

E. Efficiency of the Hydrogen Fuel Cell

1. Set up the circuit shown in figure 5 to measure the power output from the Fuel Cell.
2. Open the tube connecting the Electrolyzer to the Fuel Cell with the clamp.
 - Measure the voltage and current as you vary the resistance from $R=0$ to $10,000\Omega$.
 - Plot $I(V)$ as you vary R .
 - Plot the output electrical power versus resistance, $P(R)$.

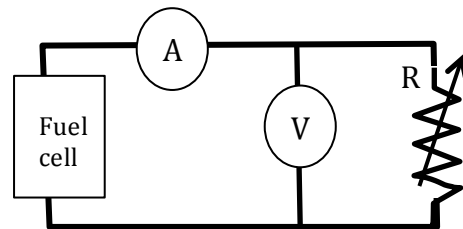


Figure 5 shows the circuit for making measurements on the fuel cell.

3. Select the resistance which gives the highest power output.
 - Measure the time (t_{FC}) it takes to use up 5 cm^3 of gas. . If you reach 20 minutes, and you haven't used 5 cm^3 of gas, continue using gas only until the next easy to read gradation on the cylinder and measure the elapsed time and the volume of gas you used.
 - Using equation (4) compute the energy conversion efficiency for the Fuel Cell, using the time (t_{FC}) it takes to consume this volume of hydrogen (V_H) and the output electrical power P_{FC}

$$\eta_{FC} = \frac{E_{FC}}{E_{Hydrogen}} = \frac{(P_{FC} \times t_{FC})}{(V_H \times LHV)} \quad (4)$$

4. Repeat the last section (E.3) using a resistance that provides only one-half the maximum power.
 - Measure the energy conversion efficiency for the Fuel Cell.
 - Compare the efficiencies for the two different resistances and discuss.

F. Summary

- List all the efficiencies (experimental and expected values) in a table with uncertainties.
- Discuss the efficiencies and compare to expected values.