Fuel Cell

Physics 3600 - Advanced Physics Lab - Summer 2019
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I. INTRODUCTION

The objective of this experiment is to study the properties of a solar cell, electrolyzer and fuel cell. 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, Model SE-8573
Optical Power Meter, Thorlabs, Model PM100D-121C
2 DVMs; decade resistor (1Ω - 10 kΩ)
Strong light source (flood light); 2.0 V/2 A power supply

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.
   (Cracks in the plastic may not affect the performance.)

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.

   □ Measure the light power (p) over each of the 8 PV cells.
   □ Compute the average light Intensity (p/area) using the area of the detector.
   □ 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.

   □ Using the lamp, measure the voltage (V) and current (I) as you vary the resistance from R=0 to \( \infty \).
   □ Plot I versus V, I(V), as you vary R.
   □ Plot the output electrical power (\( P_E = I \times V \)) versus resistance, P(R).
   □ Compute the power (energy) conversion efficiency for the PV, \( \eta_{PV} = P_E / P_L \).

   YOU WILL NOT NEED THE PV AND LAMP FOR THE REST OF THE EXPERIMENTS.
B. **Set up Electrolyzer and Fuel Cell with Water**

1. Follow the instructions in the Appendix to set up the apparatus with water. Note that it may already have enough water in the two containers. You may need to squeeze the tube to fill the Electrolyzer with water.

2. The Fuel Cell must be clear of water. Make sure that the Fuel Cell and upper tube are free of water, by removing the bottom black plug to drain the water, then replace the plug.

C. **Efficiency of Electrolyzer**

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

2. Open the tube connecting the left-hand water container to the Electrolyzer with the clamp. Make sure the tube connecting the hydrogen reservoir to the Fuel Cell is closed off with the clamp.

3. Slowly raise the voltage to 2.0 V. **DO NOT EXCEED 2.0 volts or 0.5 amps.**

   □ Where does the oxygen go that is produced?

   □ Measure the time it takes to collect 5 cm$^3$ of gas in the right-hand container while measuring I and V. Turn down the voltage on the power supply.

   □ 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, $P_E$.

   \[ \eta_E = \frac{E_{\text{Hydrogen}}}{E_{\text{Elect}}} = \frac{(V_H \times HHV)}{(P_E \times t_E)}, \]

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

D. **Efficiency of Hydrogen Fuel Cell**

1. Remember that the Fuel Cell must be clear of water.

2. Turn on the power supply and slowly raise the voltage to 2.0 V. Collect ~30 cm$^3$ of hydrogen in the right-hand container. **DO NOT EXCEED 2.0 volts or 0.5 amps.**


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

5. Open the tube connecting the hydrogen container to the Fuel Cell with the clamp.
Measure the I and V as you vary the resistance from R=0 to ∞.
Plot I(V) as you vary R.
Plot the output electrical power versus resistance, P(R), using a log axis for R.

6. Select a resistance that gives the highest power output.
   - Measure the time \( t_{\text{FC}} \) it takes to use up 5 or 10 cm³ of gas.
   - Compute the energy conversion efficiency for the Fuel Cell, using the time \( t_{\text{FC}} \) it takes to consume a volume of hydrogen \( V_H \) and the output electrical power \( P_{\text{FC}} \).
     \[
     \eta_{\text{FC}} = \frac{E_{\text{FC}}}{E_{\text{Hydrogen}}} = \frac{(P_{\text{FC}} \cdot t_{\text{FC}})}{(V_H \cdot \text{LHV})},
     \]
     where LHV is the Lower Heat Value of hydrogen (also called Lower Calorific Value).

7. Repeat the last section at different resistances.
   - 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.
   - Plot the efficiency as a function of output power, \( \eta_{\text{FC}} (P) \).

IV. SUMMARY

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

In your Introduction:
- Describe how the Proton Exchange Membrane (PEM) Electrolyzer works.
- Describe how a Fuel Cell works.