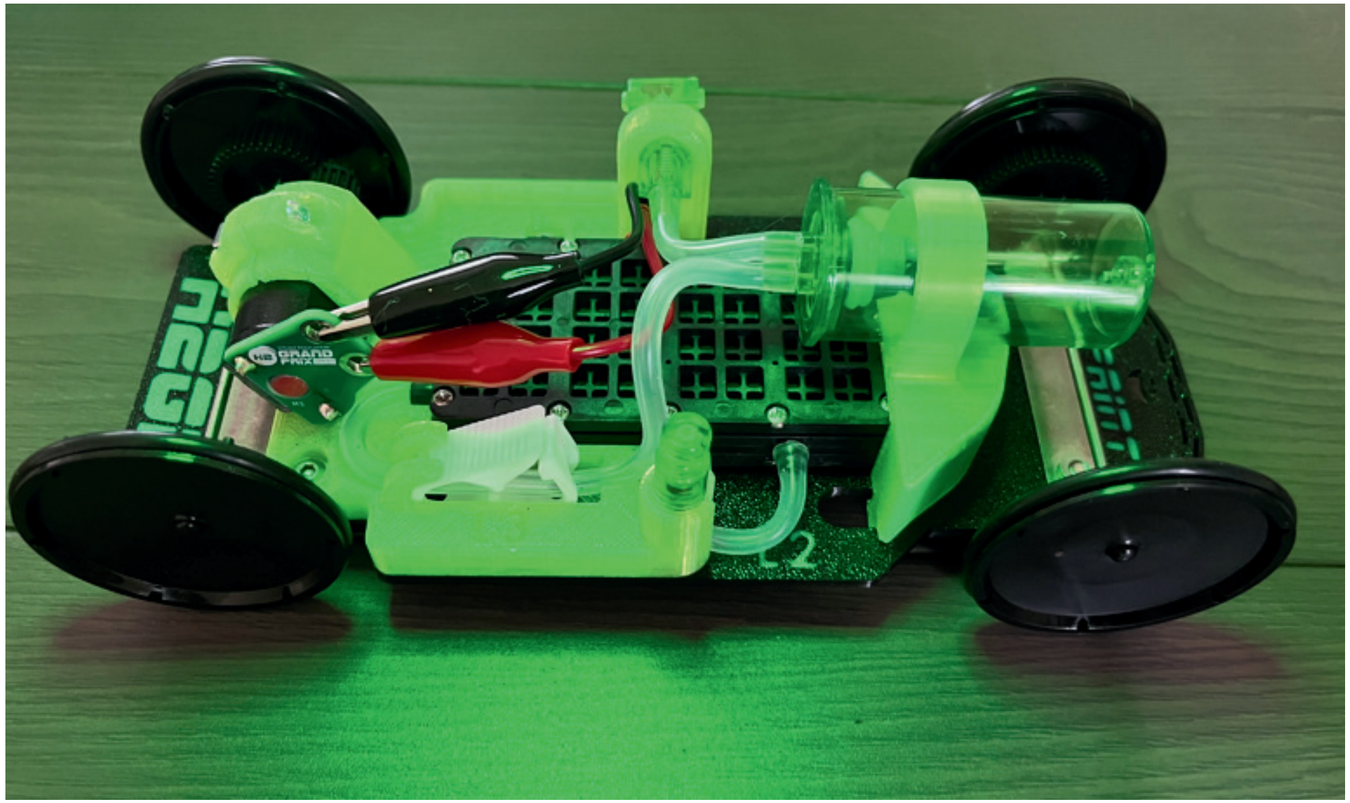
Hydrogen Fuel Cells

H2 Grand Prix Sprint

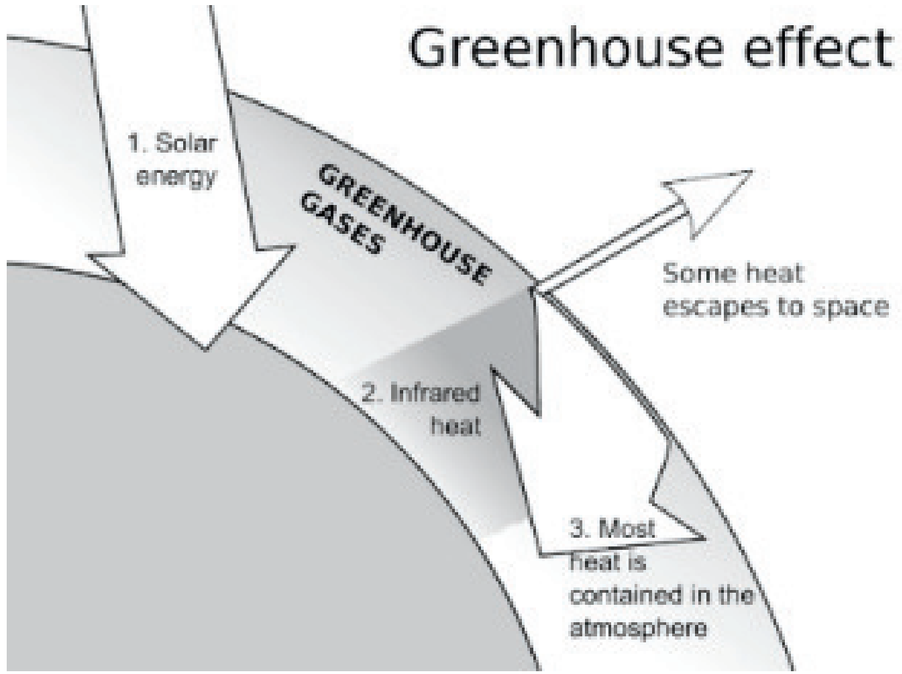
Let’s dive into the science behind hydrogen fuel cells and build and race your very own H2 Grand Prix car along the way!



Climate Change

The use of **hydrogen** to generate electricity has the potential to help **mitigate climate change.** Climate change is a long-term shift in global temperatures and weather patterns that many experts believe is mostly by human activities like burning fossil fuels, cutting down forests, and running factories.

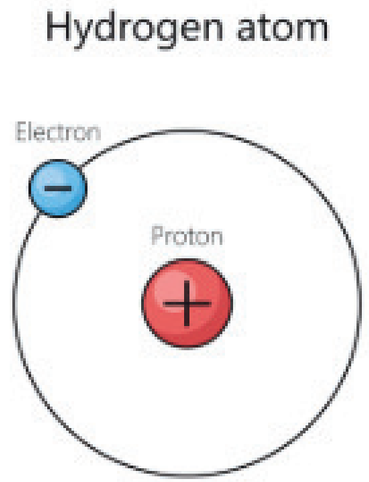
These activities release **greenhouse gases, such as carbon dioxide and methane**, into the atmosphere. These gases trap heat, causing the Earth to get warmer.



Think, Pair, Share! What are some of the symptoms of climate change?

Why Hydrogen?

Hydrogen is the lightest and simplest element, made up of only one proton and one electron. It is the most abundant element in the universe, accounting for about 75% of its normal matter.



On Earth, hydrogen is found in compounds like water and natural gas and must be extracted from these compounds to be obtained in its pure form. Pure hydrogen is essential for energy generation.

An advantage of hydrogen is that it can be **used to generate electricity** in fuel cells. In this process, hydrogen combines with oxygen to produce electricity, with water and heat as the only by-products. Since it doesn't release harmful emissions, hydrogen is a **clean fuel** that can help reduce pollution.

Hydrogen as Renewable Energy Storage

Hydrogen is a great way to **store energy** because it can hold large amounts of energy for a long time. When extra energy is made, like from wind turbines or solar panels, that energy can be used to split water into hydrogen and oxygen through a process called electrolysis.

The hydrogen is then stored in tanks or other containers until it’s needed. Later, the stored hydrogen can be used to make electricity, power machines, or run other devices. This makes hydrogen useful for storing renewable energy when the sun isn’t shining or the wind isn’t blowing.

Methods of Hydrogen Storage

HYDROGEN STORAGE

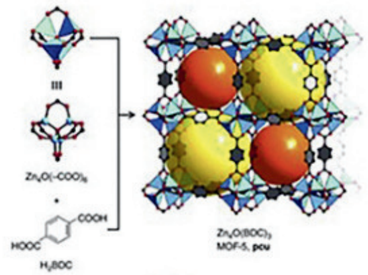
PHYSICAL

CHEMICAL

Compressed H_2 Tank

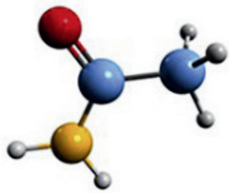
Cryo-Compressed Tank

Liquid H_2 Tank



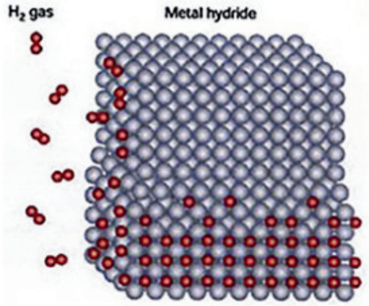
Sorbents

Example:-MOF-5, Carbon based material



Chemical Hydrides

Example:- Borohydrides



Metal Hydrides

Example:- Simple and Complex

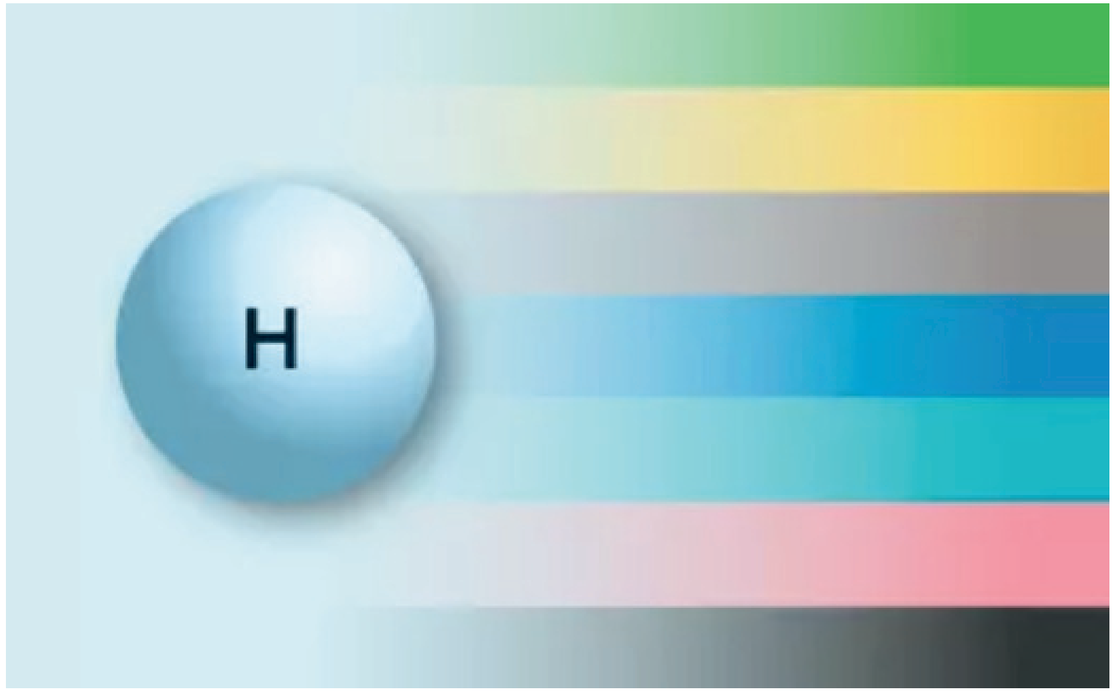
Hydrogen Production

Since pure hydrogen occurs rarely, it must be produced from compounds like water or natural gas to be used as an energy source. Currently only about 1% of hydrogen is produced utilizing renewable energy sources. The vast majority of hydrogen is still produced from fossil fuels.

Statista, Global Hydrogen Production Share by Type (2020)

Hydrogen Rainbow

The "hydrogen rainbow" refers to different ways hydrogen is produced, named by color to show how it’s made and its impact. These colors help explain the environmental effects of each method.



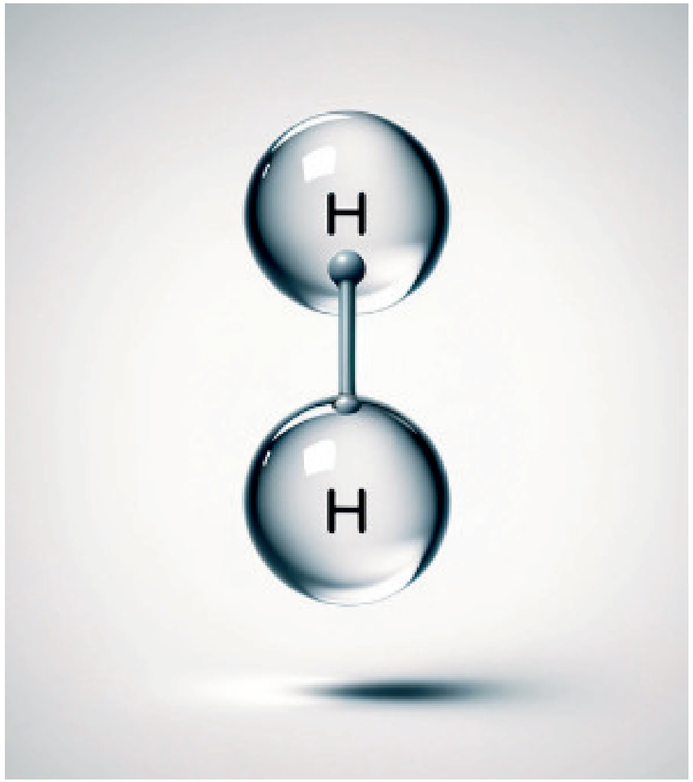
Statista, Global Hydrogen Production Share by Type (2020)

Hydrogen

Challenges and Potential

Using hydrogen as an energy source has some challenges. It has high production costs compared to fuels like gasoline and natural gas. Another issue is that hydrogen pipelines are only available in certain areas, so new ones would need to be built for wider use.

Despite these challenges, hydrogen has great potential to fight climate change because it’s a clean energy source. When made with renewable energy like wind or solar power, it doesn’t release greenhouse gases, making it an important part of a low-carbon future.

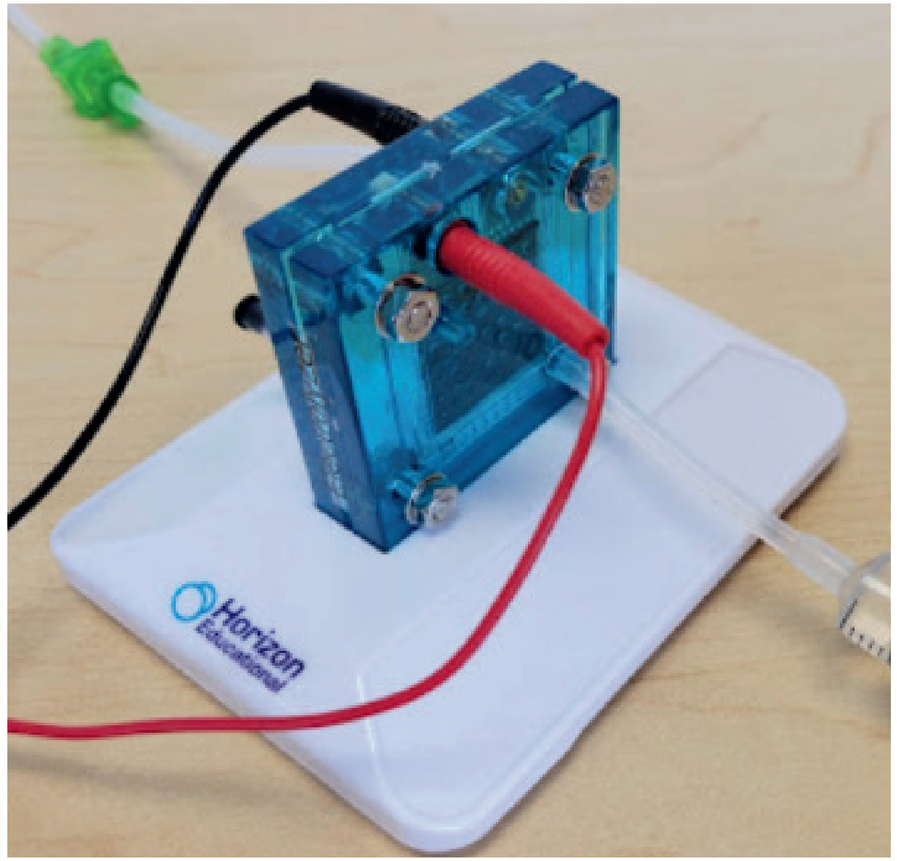


Using Electrolysis to Produce Hydrogen

Electrolysis uses electricity to split water (H_2O) into hydrogen (H_2) and oxygen (O_2) gases. In an electrolyzer, hydrogen forms at the cathode (negative electrode), and oxygen forms at the anode (positive electrode).

Electrolyzers, sometimes called regenerative fuel cells, perform the reverse process of fuel cells. While **electrolyzers split water** into hydrogen and oxygen using electricity, **fuel cells combine hydrogen and oxygen** to generate electricity.

Sprint Electrolyzer



Type of Electrolysis

PEM Electrolysis: Uses a solid polymer membrane to split **water into hydrogen** and oxygen ions. It operates efficiently at low temperatures and is well-suited for handling fluctuating energy supplies, making it ideal for use with renewable energy sources.

PEM Electrolysis is used to generate hydrogen for use in powering the Sprint Car!

Alkaline Electrolysis: Utilizes a liquid alkaline solution as the electrolyte. It has been used for decades and is known for its lower cost, but it operates at higher temperatures and is less compatible with variable power supplies, which limits its effectiveness with renewable energy.

How a PEM Electrolyzer Works

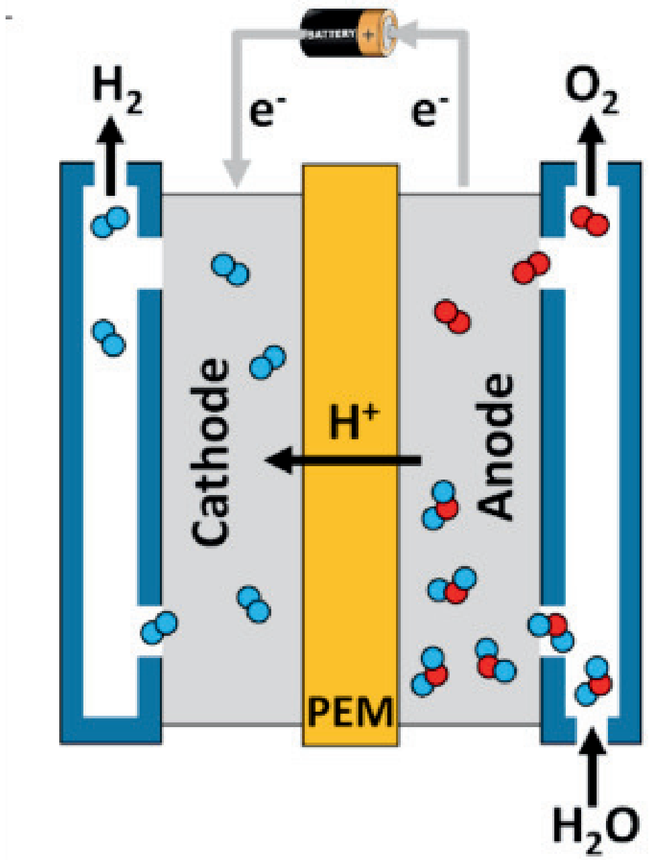
1. Water is introduced to the anode side of the electrolyzer where it is split into oxygen gas (O_2), protons (H^+), and electrons (e^-).

2. Protons pass through the proton exchange membrane to the cathode.

3. Electrons travel through an external circuit, powered by electricity.

4. At the cathode, protons and electrons recombine to form hydrogen gas (H_2).

5. Oxygen is released at the anode, and hydrogen is collected at the cathode.



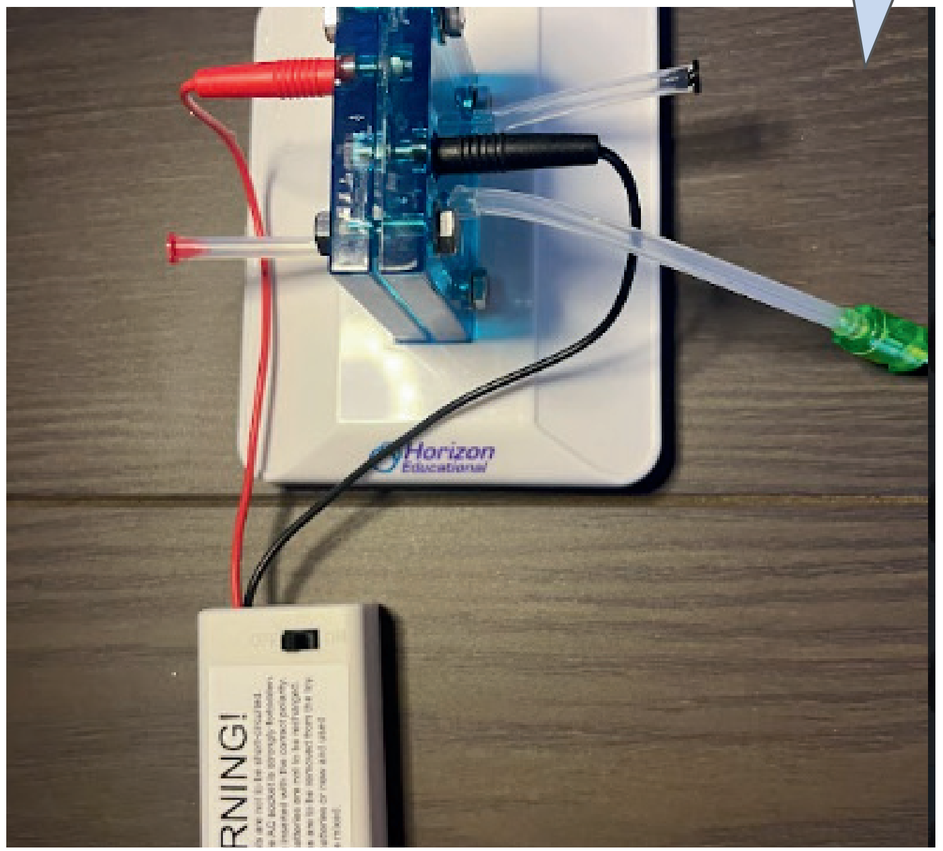
$$H_2O \longrightarrow H_2 + \tfrac{1}{2}O_2 \quad \textit{Total Reaction}$$

Assembling the Sprint Electrolyzer*

Let's Try it!

Cut tubing and attach parts as shown

Assemble Electrolyzer



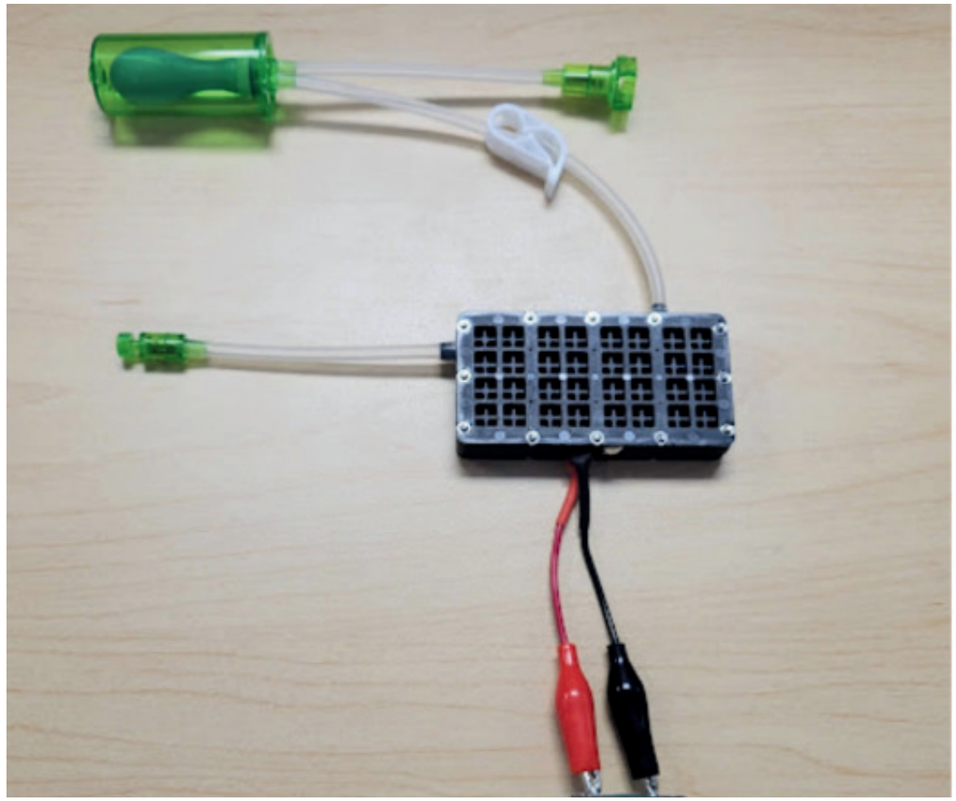
*Detailed assembly instructions can be found in "Producing Hydrogen with the Sprint Car Electrolyzer"

Using Fuel Cells to Generate Energy

Hydrogen can be used in fuel cells to generate electricity by reacting with oxygen, producing electricity, water, and heat.

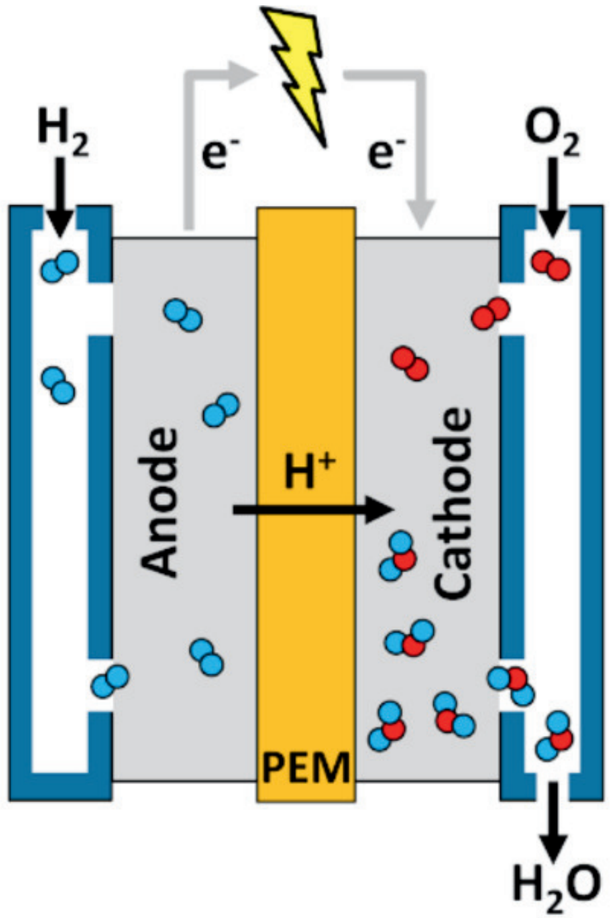
This process is clean and efficient, with no harmful emissions, making it an environmentally friendly way to provide power. Hydrogen fuel cells are versatile and are already being used in vehicles like cars and buses, as well as in buildings.

Sprint Fuel Cell



How a Hydrogen Fuel Cell Works

1. Hydrogen gas (H_2) enters the anode, where a catalyst splits it into protons (H^+) and electrons (e^-).
2. Protons pass through the membrane to the cathode.
3. Electrons travel through an external circuit, creating an electric current.
4. Oxygen (O_2) enters the cathode, where it combines with protons and electrons to form water (H_2O).
5. The fuel cell outputs electricity, water, and heat, with no harmful emissions.

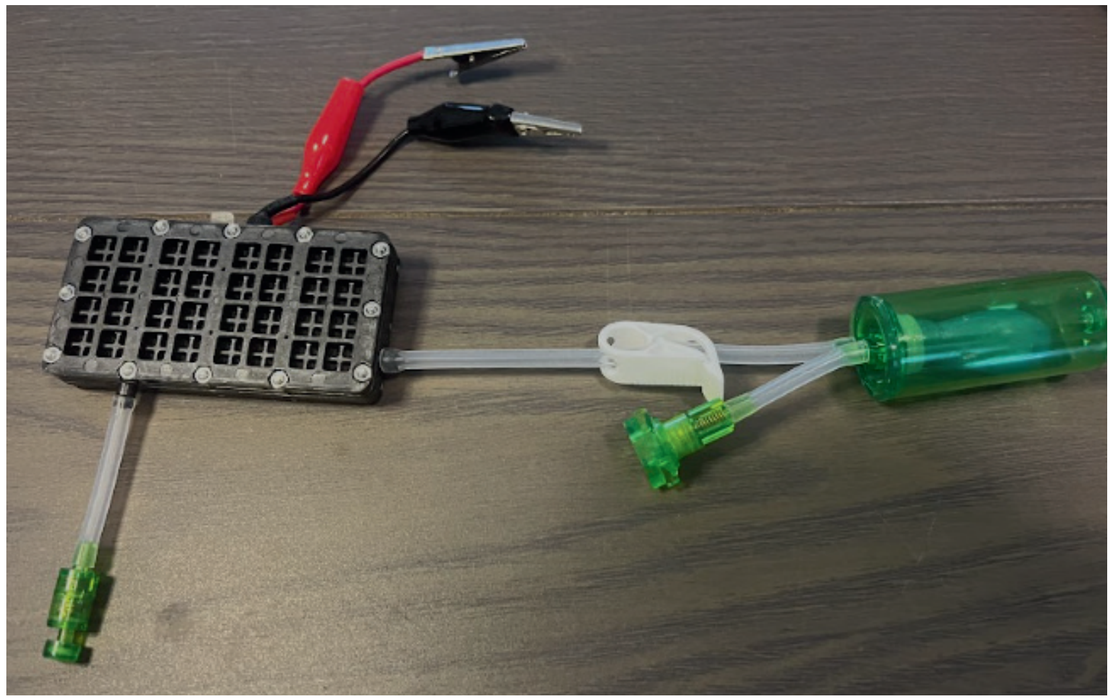


Total Reaction: $2H_2 + O_2 \rightarrow 2H_2O$

Assembling the Sprint Fuel Cell*

Let's Try it!

Attach tubes with clip and purge valve



Connect black and red clips to motor

*Detailed instructions can be found in "Powering the Sprint Car Motor Using a Fuel Cell"

Troubleshooting Tips

If the balloon isn’t filling with hydrogen:	If the motor isn’t working:
• Check for any kinks or pinches in the tubing that could obstruct gas flow. • Ensure tubing is securely attached and fully covers the nozzles to prevent leaks. • Verify that the male and female valves are properly connected and tightly closed with a twist to allow hydrogen to flow. • Make sure the AA batteries are fully charged and functioning properly.	• Ensure the clips are securely connected to the motor terminals. • Ensure the balloon contains enough hydrogen to supply the fuel cell. • Inspect wires and connections for any damage or loose components. • Test the motor separately to confirm it is functioning properly.