

# User Manual



## Bio-Energy Kit

Recommended for ages 12+

Powered by  
**Horizon**

Made in China

[www.horizonfuelcell.com](http://www.horizonfuelcell.com)



Model No.: FCJJ-22

### Warning

To avoid the risk of property damage, serious injury or death:

This kit should only be used by persons 12 years old and up, and only under the supervision of adults who have familiarized themselves with the safety measures described in the kit. Keep small children and animals away, as it contains small parts that could be swallowed. Read the instructions before use and have them ready for reference.

## User Manual

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## I. About Bio-Energy

### What are biofuels?

Bio energy is energy that is derived from biomass. Bio mass is generally defined as materials that are derived from recently living organisms or their metabolic byproducts. Biofuels can be broadly defined as a combustible fuel produced from biomass including solid, liquid, or gas forms of fuel derived from recently dead biological material, most commonly plants. This differentiates biofuel from fossil fuel, which is derived from long dead biological material. Biofuels are generally in the form of alcohols, esters, ethers, and other chemicals produced from biomass. The Bio-energy discovery kit shows a new way to create electricity using tiny quantities of biofuel mixed with water, and without combustion - using a new energy conversion device called a direct ethanol fuel cell (DEFC). In the immediate term, this new ethanol fuel cell technology creates a non-toxic, easy to use, and long lasting power source alternative for small electronics.

### Types and source of biofuels

The two main types of biofuels are bioethanol and biodiesel. Bioethanol fuel is mainly produced by the sugar fermentation process. These main sources of sugars most commonly come from food crops such as corn, maize and wheat crops, waste straw, willow and poplar trees, sawdust, grasses, jerusalem artichoke, miscanthus and sorghum plants. Biodiesel can be produced from straight vegetable oil, animal oil/fats, tallow and waste cooking oil. The process used to convert these oils to Biodiesel is called transesterification. The largest possible source of suitable oil comes from oil crops such as rapeseed, palm or soybean.

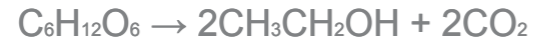
### What is Ethanol?

In common usage, Ethanol is often referred to simply as alcohol. It is a straight-chain alcohol and its molecular formula is variously represented as EtOH, CH<sub>3</sub>CH<sub>2</sub>OH, C<sub>2</sub>H<sub>5</sub>OH or as its empirical formula C<sub>2</sub>H<sub>6</sub>O.

After the use of fire, fermentation of sugar into ethanol is perhaps the earliest organic reaction known to humanity. In modern times ethanol intended for industrial use has also been produced from byproducts of petroleum refining. Ethanol is produced both as a petrochemical, through the hydration of ethylene, and biologically, by fermenting sugars with yeast. Advanced research today is looking at ways to obtain ethanol efficiently, economically, and in an environmentally friendly way from waste plant matter, and genetic engineering.

Ethanol has widespread use as a solvent for substances intended for human contact or consumption, including scents, flavorings, colorings, and medicines. In chemistry it is both an essential solvent and a feedstock for the synthesis of other products. The new technology in this kit eliminates the need for combustion of ethanol and finds a new uses for tiny quantities of the biofuel to power small electronics, not automobiles.

Ethanol for use in alcoholic beverages, and the vast majority of ethanol for use as fuel, is produced by fermentation. When certain species of yeast, most importantly, *Saccharomyces cerevisiae*, metabolize sugar in the absence of oxygen, they produce ethanol and carbon dioxide. The chemical equation below summarizes the conversion:



### **The Promise of Cellulosic Ethanol**

The “skeleton” of all plants—generally speaking, the “xylem” — is composed of cellulose, which cannot be easily decomposed. Most of the solar energy “captured” by plants is stored in the cellulose. In this process, some special enzymes are used to decompose the cellulose into simple sugars called saccharides, and then the saccharides can be transformed into energy for human to use. Cellulose is abundant in nature, the alcohol produced from it is clean, and both the energy consumed and the greenhouse gas emitted during this producing process are minute. If we can transform cellulose, which is naturally abundant but not edible, into alcohol, then it would become feasible to produce a renewable, clean biofuel for industrial and consumer use.

The common raw materials used to produce alcohol from cellulose are stalk, bark, and fibrous tissues from plants whose cellulose cannot be eaten by humans. The production of ethanol from food sources such as maize is not an efficient method of ethanol production and could potentially decrease amount of land available for food production and influence the cost of grain products.

More efficient methods have been developed for ethanol production using plants that can grow in marginal areas, not only producing greater amounts of ethanol per area of land, but also allowing

arable land most suited for food crops to be reserved for food production. Most research currently revolves around the use of grass species such as switch grass, elephant grass, buffalo grass, that grow very quickly, contain high amounts of cellulose, can be grown in marginal areas that will not negatively affect food production. As a matter of fact, research indicates that in the fermentation of switch grass to produce ethanol, the yield of energy in ratio to the amount of energy exhausted to produce the fuel is as high as 540%, while for corn the same ratio is as low as 24%.

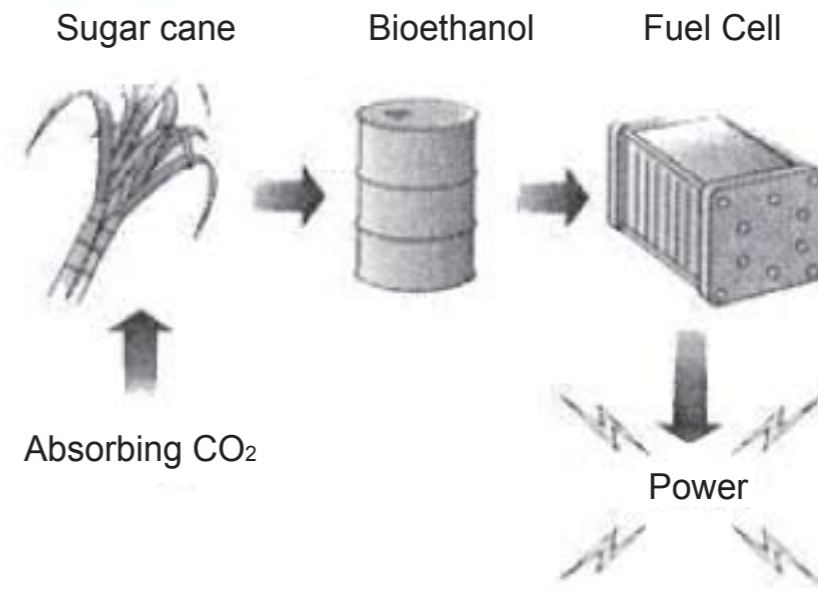
### **Could ethanol replace batteries in consumer devices?**

Demand for storable power is accelerating as more and more features being added to our portable electronic devices. It is expected that next generation energy storage devices such as fuel cells could provide longer lasting power than batteries. Fuel cells convert fuel to electricity, and so far most international research into fuel cells that would use liquid fuels for consumer electronics has been focused on methanol. Such fuel cells are called Direct Methanol Fuel Cells, or DMFC. In the last 10 years, DMFCs have received a lot of attention by many companies and research organizations globally, who are investigating the possibilities of creating a number of applications with DMFC technology, most of which are as a new power source for consumer electronics.

Today a cleaner and more economical solution could emerge from research in using ethanol instead of methanol as a fuel for fuel cells. The Bio-Energy Discovery Kit demonstrates the technology of a newly developed Direct Ethanol Fuel Cell, or DEFC, which unlike DMFC, does not use any corrosive fuel. Unlike other applications where biofuels are burned for energy, DEFCs do not burn ethanol, but create electricity by slowly converting ethanol to regular vinegar.

Ethanol is the easier fuel to work with for widespread use by consumers, especially as more research continues into the use of fuel cells in consumer electronics applications. Ethanol is a hydrogen-rich liquid and it has a higher energy density (8.0 kWh/kg) compared to methanol (6.1 kWh/kg). Most importantly, a non-toxic long-lasting battery-like energy storage device can now emerge as a clean alternative to alkaline batteries that contain mercury and cadmium substances, a major source of groundwater pollution.

A substantial amount of research is currently being devoted to ethanol since it can be an environmentally friendly fuel source which is based on renewable resources.



## Looking forward to consumer electronics and beyond

Mirroring the current uses being researched for use in DMFC (Direct Methanol Fuel Cells), the Direct Ethanol Fuel Cell (DEFC) could be used in small sized applications, independently of available electrical source/power supplies, in applications ranging from communications equipment to mobile phones, cameras, laptop computers, power supplies for LED lighting, toys, low voltage sensors and remote control devices for home appliances.

With more technological progress expected to take place in this field, the DEFC could be scaled up to address slightly larger electric applications in the future.

## 2. How the fuel cell works:

The Direct Ethanol Fuel Cell produces electricity while ethanol reacts at the anode side of the fuel cell. Hydrogen protons permeate from the ethanol solution through the DEFC's membrane, liberating electrons that are captured in an external circuit.

On the cathode side, the catalytic reaction of hydrogen with oxygen from the ambient air forms water as a result.

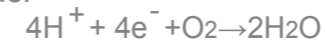
Direct-ethanol fuel cells or DEFCs are a subcategory of Proton Exchange Membrane (PEM) fuel cells where, the ethanol fuel is not first reformed into pure hydrogen, but fed directly to the fuel cell's membrane.

The mechanism is as follows:

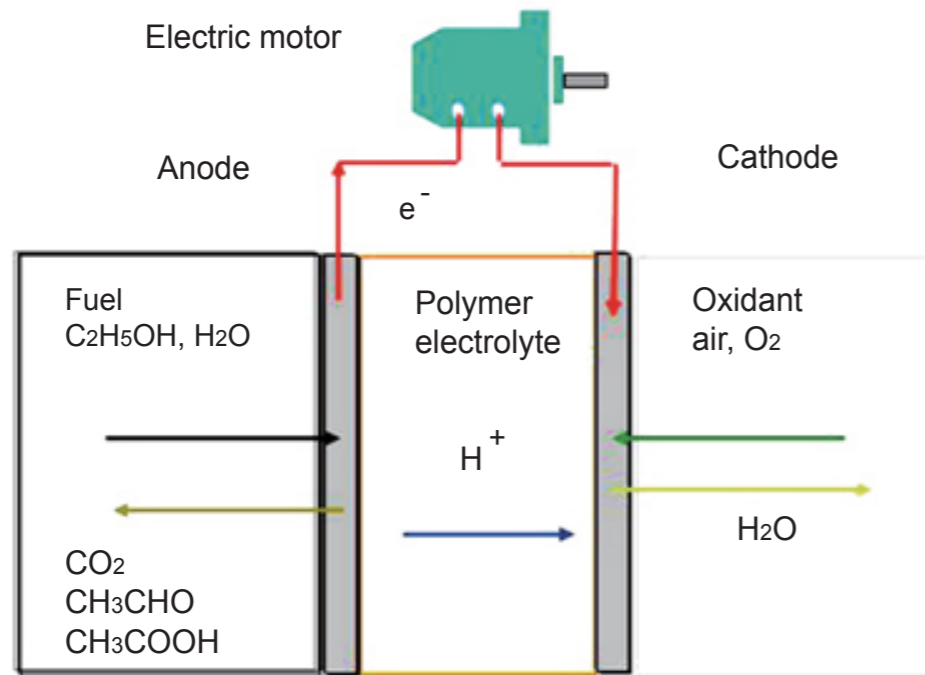
Anode:



Cathode:



During the reaction, some of the ethanol is oxidated completely and turns into CO<sub>2</sub> (as in the reaction #3, while some of the ethanol is oxidated incompletely and turned into acetaldehyde and acetic acid (as in the reactions #1 and #2 ).



### 3. General Safety Instructions

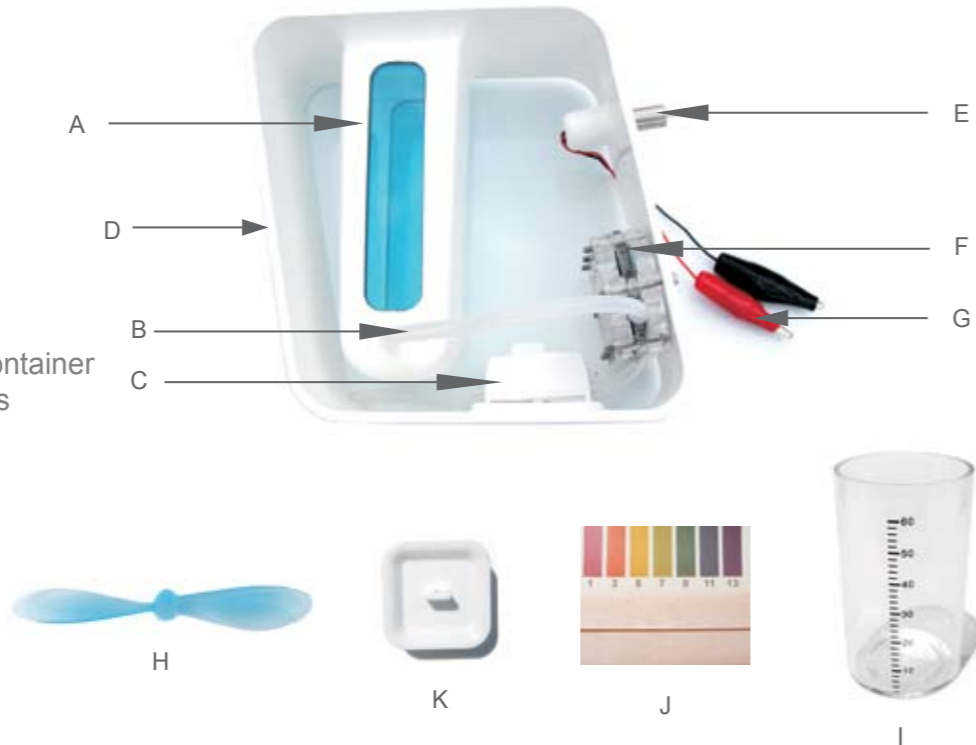
To avoid the risk of property damage, serious injury or death:

1. Read carefully and fully understand the instructions before starting assembly of this kit.
2. This kit is intended only for use by persons 12 years old and up, and only under the supervision of adults who have read and understood the instructions in this user manual.
3. When assembling this kit, tools may be used. Extra care should be taken to avoid personal injury.
4. Some parts are small and fragile: please be careful when handling and connecting parts to avoid breakage. Handle all parts and components with care.
5. Do not attempt to use any part, item, or component provided in this kit for any other purpose than what is instructed in this manual. Do not attempt to disassemble any part, item or component in this kit.
6. Do not attempt to ingest or drink new or used liquids needed for the purpose of this experiment kit.
7. Keep ethanol away from the fire or flame source while you are mixing the solution. Igniting the ethanol and the ethanol solution is strongly forbidden.
8. It is recommended that this kit be operated under the temperature between 5°C and 40°C.

## 4. Included Parts

- A. Ethanol storage
- B. Tubing
- C. Purging valve
- D. Supporting base
- E. Electric motor
- F. Direct Ethanol Fuel Cell
- G. Wiring with crocodile clips
- H. Fan blade
- I. Ethanol solution mixing container
- J. PH paper measuring strips
- K. Storage lid

Not Included:  
Ethanol solution



*Note:*  
*Parts except H-K have already been assembled.*  
*Please see experiment 1 for how to assemble the fan blade or how to create the solution.*

## 5. Experimenting with the Bio-Energy Kit

Preparing the system

Step 1. Remove the fan blade (part H) from the box.

Step 2. Push the blade onto the axis of the motor slowly and carefully. (see A-C)



A

B

C



**Warning!**

*Do not allow pure ethanol to enter the fuel cell. The DEFC creates power using 5-15% alcohol only. A concentration higher than 15% could damage the fuel cell and cause it to stop working correctly. For best operation please use a mixture of 10% ethanol / 90% Water. Keep ethanol away from the fire or flame source while you are mixing the solution. Igniting the ethanol and the ethanol solution is strongly forbidden.*

The reason for this is that at higher concentrations, ethanol molecules are more likely to “cross-over” the membrane which would stop the chemical reaction needed to create electricity. In the case of methanol fuel cells, methanol molecules are even smaller than ethanol making the effects of cross-over more difficult to overcome.

**Preparing a 10% ethanol solution:**

Step 1. Fill the mixing container (part I) with 6ml of pure ethanol (fill container to the 6ml level) (see A)

Step 2. Fill the remainder of the container with water to the 60ml level. (see B)

Step 3. Stir the liquid in the container thoroughly.



A



B

**Experiment 1: Create electricity from ethanol and water**

Step 1. Open the purging valve by pushing the switch to the right side. (see 1A)

Step 2. Pour the solution into the Ethanol container. (see 1A)



1A



1B

*Make sure that the tubing connecting the container to the fuel cell is securely attached. Make sure the tubing connecting the tubing with purging valve is securely connected to the fuel cell and the switch on the purging valve is positioned at the right side close to the solution tank.*

Step 3. Put the lid back to the container. (see 1C)

Step 4. When the solution starts dripping out of the tube, close the purging valve by pushing the switch to the left side. (see 1D)



1C



1D

Then connect the two crocodile clips that are attached to the motor to the two separate terminal plates of the fuel cells current collector, which are both located on the upper part of the fuel cell (see 1E&1F). Do not connect any clips to the welded collector also located on the fuel cell.



1E



1F

If the system is connected properly the blade should begin to turn after about one minute. If the fan does not start by itself, give it a light push with your finger. Since the reaction is slow, the fan can run for several hours without purging. (see Experiment 3)

**Note:**

*Once the fan begins to run slower or stops running, complete the following three steps in order to make the fan run again.*

Step 1. Place the exhaust tube (connected to the purging valve) over a container or suitable receptacle.

Step 2. Open the purging valve by sliding the switch to the right side, purging out the used solution in the fuel cell chamber and allowing a new volume of ethanol solution to re-enter the fuel cell chamber, then close the valve (see the picture below).

Step 3. Wait a while and then tap the fan's blade to get it started and watch it go at constant speed. If the fan still stops running, disconnect the crocodile clips and then exchange them to re-connect the fuel cell. The fuel cell is able to start the reaction once more (and more hydrogen protons can permeate through the membrane).



## Experiment 2: Exploring polarity

Step 1. Connect the positive (red) crocodile clip to the positive side of the fuel cell (red "+" mark), then connect the negative (black) crocodile clip to the negative side of the fuel cell (black "-" mark). You will notice the fan will turn clockwise.

Step 2. Now repeat the process, this time however connect the positive (red) crocodile clip to the negative side of the fuel cell (black "-" mark) and connect the negative (black) crocodile clip to the positive side of the fuel cell (red "+" mark). You will notice the fan will turn counter-clockwise.



**Conclusion:** *the current flows from positive to negative, creating a clockwise spin of the fan. By inverting the polarity connections, the current flow reverses and makes the fan spin in the opposite direction.*

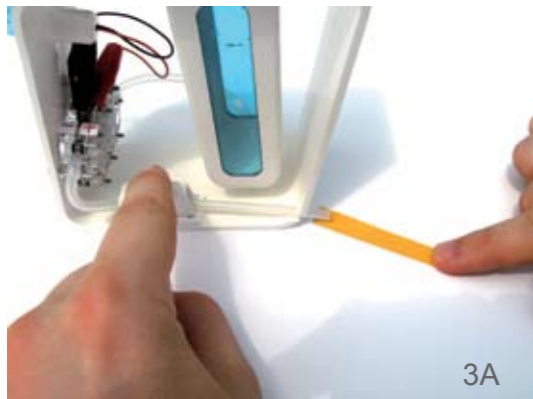
### Experiment 3: Ethanol fuel consumption

When the fan begins to run slower or stops running completely, this means the ethanol present in the fuel cell chamber is mostly consumed. In normal temperature conditions, the majority of the ethanol inside the fuel cell chamber turns into acetic acid, which is the main component of vinegar.

Let's investigate the consumed fuel (acetic acid) when the fan begins to run slowly.

Step 1. Place a piece of PH paper under the outlet of the purging tube. (see 3A)

Step 2. Open the valve slowly by sliding the switch towards right side, and release a drop of the solution onto the pH paper, and then close the valve. You can see the paper color changing to a reddish color quickly. (see 3B)



3A



3B

Step 3. Dip a new pH paper into the solution container. You will notice that the color of the PH paper changes very little. (see 3C-3E)



3C



3D



3E

The difference in pH paper coloring indicates the change of the acidity level. Ethanol turns into acetic acid during the reaction taking place at the anode side of the fuel cell, and the pH of the solution noticeably changes from pH level 6 to pH level 2 (see 3E) showing a red color. The chemical reactions taking place at the anode and summarized on page 8 show that acetic acid is formed as hydrogen protons depart from the ethanol molecule and the water molecule. These hydrogen protons cross the fuel cell membrane, and the liberated electrons form the electricity that is able to propel the fan.

**Conclusion:** *The Direct Ethanol Fuel Cell creates electricity by chemically converting the ethanol solution into an acid solution, which is close to common vinegar. In order for the fuel cell to function continuously, "spent" fuel must be replaced with new fuel regularly.*

#### Experiment 4: Exploring the effect of varying fuel concentrations

You can make the different concentrations of ethanol fuel in the initial mix. For a 15% solution, add 9 ml of pure ethanol and fill water to the level of 60 ml. You can use a multi-meter or Horizon's fuel cell software adaptor product ref. FCJJ-24 to measure the voltage difference produced by the fuel cell. Through experimentation, you will find that increasing or decreasing the concentration of the Ethanol does not noticeably make the fan run faster.

The reason for this is that the capability of the catalyst used on proton exchange membrane in the fuel cell is limited. Similarly to many people going through a narrow door, the speed of people going through the door is determined by the width of the door, but not by the amount of people.

*Warning: The safe experimentation range for the Bio-Energy kit is within ethanol concentrations ranging from 5-15%. Please note that the concentration cannot be higher than 15-20% otherwise it will permanently damage the fuel cell.*

*Tip: If the device will not be used for more than one day, first pour out the solution in the container and then purge out all the remaining solution in the fuel cell by pouring purified or distilled water in the container. Make sure the purging valve is switched to the right side. Make sure all of the purified or distilled water flows out of the container. Do not let the solution stay in the fuel cell otherwise it will damage the fuel cell.*

#### Experiment 5: Create electricity using different types of alcohol

Try using different types of alcohol such as wines made from grapes or rice instead of the ethanol/water solution as described earlier on page 13.

Follow up the steps in the [experiment 1: create electricity from ethanol and water](#) to create electricity.

*Warning: 1. Alcohols used should stay within the range of 5-15% alcohol. If you are using an alcohol that has a higher concentration than 20% please mix the adequate amount of water into the alcohol to keep the required concentration range of 10-15%.*

*2. Using impure ethanol can damage the performance of the fuel cell. You may want to conduct experiments using impure ethanol once all other experiments using pure ethanol are completed.*

When you have finished the whole steps as in the experiment 1, you may notice the fan may run very slowly, or may not run. When using different alcohol types, this can affect performance. This has to do with the purity of the solution, since some alcohols such as wine contain elements that can clog the membrane on the fuel cell, limiting its permeability. Use a multi-meter or Horizon's fuel cell software adaptor ref. FCJJ-24 to measure the voltage or current produced by the fuel cell under various conditions and slowing the speed of the chemical reaction.

See experiment 6: You will be able to prove that at different temperature conditions, different voltages are produced, and you can plot these results into a chart to determine the optimal temperature conditions for the fuel cell to generate the best results.

## Experiment 6: Exploring the effects of temperature.

*Note: Before you blow warm air towards the fuel cell, try to blow your hand first to make sure the air is not too hot. ( below 60°C is preferred)*

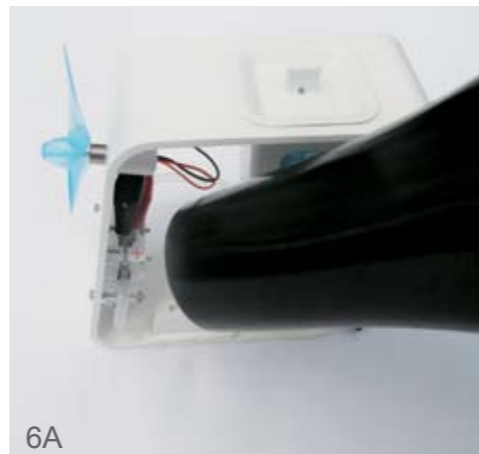
Step 1. Use a hair drier to blow hot air towards each side of the fuel cell or place a warmer ethanol/water solution into the ethanol storage tank. You will observe that the motor and fan will be operating at a faster speed. (see 6A)

Step 2. Use a multi-meter or Horizon's fuel cell software adaptor product ref. FCJJ-24 to measure the voltage produced by the fuel cell. You will be able to test that at different temperature conditions, different voltages are produced, and you can plot these results into a chart to determine the optimal temperature conditions for the fuel cell.

At higher temperatures, atoms tend to move faster and are more likely to interact with the catalysts located on the surface of the membrane. With more interactions, the reaction accelerates and more electricity can be produced, which means the fan starts to turn faster.

### Conclusions:

- (1) Higher temperature will make it more likely for ethanol molecules to interact with the catalysts located on the surface of the membrane, which accelerates the speed of the chemical reaction.*
- (2) High temperature can also make the membrane more active, so it will demonstrate an increased ability of proton exchange within the membrane and an increase the speed of the fan motor. Increasing the power capability of ethanol fuel cells can be done by increasing their operating temperature, or the temperature of their fuel.*



## 6. Troubleshooting

A. The fan begins to run slower or stops running completely.

Solution:

- Place the purge tube (exhaust tube) over a container and empty the contents of the acetic acid solution. Open the valve to let a few drops of acetic acid flow out, allowing the mixture of the fresh ethanol solution to re-enter the fuel cell. Tap the fan's blade to get it started and watch it go at constant speed.
- If the fan still stops running after purging, exchange the two clips.
- If the solution level is too below in the container, mix new solution and pour it into it to reach the proper level.

B. After all the wires and tubes have been connected, the fan still can not run.

Solution:

- Make sure that the red and black plugs are connected on the two separated terminals located on the upper part of the fuel cell.
- Make sure that the tube from the solution container is well connected to the nozzle of the fuel cell on the same side.