The lesson plan: NOTE UNIT DATE 2018- is the date the curriculum was MADE not used, this is a feature of our lesson plan program. The December dates are 2019.

Honors Principles of Engineering

POE 1.3 Energy Applications 2018, Solar Hydrogen Boat Build and Test

Scheduled to be taught on 12/02 12/04 12/05

Created by Brownhill, James

Objectives

Test and apply the relationship between voltage, current, and resistance relating to a photovoltaic cell and a hydrogen fuel cell.
Experiment with a solar hydrogen system to produce mechanical power.
Thisproject provides a practical application for fuel cell technology. Students will build airboats. Wood blocks or other suitable parts should be made to emulate the weight and size of the fuel cells. This is important for two reasons. First, it will allow students to test their boats to be sure that the fuel cells will not fall overboard. Also, this allows more boats to be created than the number of fuel cells available.

Students can use several different methods to build the boats. Foam board works well, and cardboard will work if the boats are not left in the water for extended periods. Such materials can be made more waterproof if they are painted or covered with almost any kind of finish. Foam insulation works well, especially if you have access to a foam cutter. A band saw also cuts foam well. After the boat has been sanded, this insulation is likely to provide more versatility for creating curves than most other materials. Foam blanks and cutters are available from a variety of education suppliers. You may also wish to have students make the boats primarily from materials that they provide.

Teams may wish to test their boats before they insert fuel cells. Encourage students to attach a string to the front of the boat and simply pull the boat through the water by the string. If the testing apparatus is higher than the ground, students can attach a weight to one end of the string. They can drop the weight over the edge of the testing apparatus to pull the boat through the water.

Students will be evaluated on the speed of their boats. You can evaluate the speed of the boats in a number of ways. All of the boats in a course can race at the same time in a large testing apparatus. Boats can compete against one another in a tournament competition. If you have a small testing apparatus, you may wish to time the boats. You may wish to conduct additional contests, such as requiring boats to drive over a specific target.

Learning Activities, Instructional Strategies

Day 1: Students will research boat and propeller shapes and designs. Students will utilize research to design their boat and complete a decision matrix to arrive at final design.
Day 2: Students will work on Solar Hydrogen Boat Build - build and test boat
Day 3: Present Solar Hydrogen Boat

Differentiation

Various activities are presented to introduce and develop skills so that students of many learning styles are reached.
Students who need to be placed near the front of the room have been placed there and all 504 and IEP modifications are followed.

Resources Utilized

google classroom
eno board
VEX kits
Solar Panels
Hydrogen Fuel Cells

Standards

1. 1.HS-152 Grade 12 CPI CC-1
Engineers continuously modify these systems to increase benefits while decreasing costs and risks.
2. 1.HS-152 Grade 12 CPI DCI-1
All forms of energy production and other resource extraction have associated economic, social, environmental, and geopolitical costs and risks as well as benefits. New technologies and social regulations can change the balance of these factors.
3. 1.HS-152 Grade 12 CPI SEP-1
Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations)
4. 1.HS-161 Grade 12 CPI SEP-1
Analyze complex real-world problems by specifying criteria and constraints for successful solutions.
5. 1.HS-162 Grade 12 CPI DCI-1
Criteria may need to be broken down into simpler ones that can be approached systematically , and decisions about the priority of certain criteria over others (trade-offs) may be needed.
6. 1.HS-162 Grade 12 CPI SEP-1
Design a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations.
7. 1.HS-163 Grade 12 CPI DCI-1
When ev aluating solutions, it is important to take into account a range of constraints, including cost, safety , reliability , and aesthetics, and to consider social, cultural, and env ironmental impacts.
8. 1.HS-41 Grade 12 CPI CC-1
Models can be used to predict the behavior of a system, but these predictions have limited precision and reliability due to the assumptions and approximations inherent in models.

Lesson Documents

No documents have been uploaded to this lesson

INTRODUCTION

Airboats were originally designed to navigate the swamps in Florida and Louisiana. They are still in use today; in fact, the airboat rides in the Florida Everglades attract many tourists every year. Airboats are increasing in popularity, especially among rescue personnel. During Hurricane Katrina, thousands of flood victims and pets were rescued by airboats. Airboats also played an important role in the 2007 Minneapolis bridge collapse rescue efforts.

EQUIPMENT

Hydrogen fuel cell vehicle with a solar module
Distilled water
Small DC hobby motor
Propeller that will attach to the DC motor
Material and tools for creating a boat that will safely transport the fuel cell
Block of wood with the same general dimensions as the fuel cell
Water apparatus for testing boats

Procedure

In this activity your **team of two or three** will design and create an airboat that will be powered by a fuel cell/solar module.

Problem Statement

A company that gives swamp tours has decided that exhaust and loud engine noise in their current airboats is less than appealing to tourists. More importantly, the engines are affecting the proximity of wildlife to the boat and damaging the natural resources they rely on. They believe that if their engines did not emit fumes and were less noisy, their swamp tour would easily beat the competition.

Design Statement

Your team has been asked to design, create, and test a prototype that uses a fuel cell/solar module as its power source. The prototype will have high speed capabilities. Other teams also hope to design the boat that the company will ultimately decide to purchase. They will choose the boat that provides a combination of high quality and speed.

Constraints

- The airboat must be made from materials and processes as outlined by the instructor.
- The airboat must not tip and spill the fuel cell. A wood block should be used to test the airboat before the fuel cell is used.
- The airboat must be able to easily change between different fuel cells, to allow for charging and other groups using the fuel cell.
- The airboat must be able to carry a fuel cell and solar panel, both of which must be easily removable.

Deliverables

- Documentation of research into boat hull shapes and propeller designs.
- Three brainstorming sketches that include labels, descriptions, signatures, and dates.
- A final pictorial sketch that includes labels, descriptions, signatures, and dates.

- Your airboat can be powered by, a fuel cell, a solar panel, both fuel cell and solar panel in both series or parallel. You must submit testing protocols to determine which configuration you will use to power your boat. Your testing protocols must include wiring diagrams and how you will measure voltage and current.

- A testing summary that documents all tests performed prior to the final evaluation and the results of those tests. The summary will include descriptions and sketches of any changes that were made based on the tests.

- A reflection stating what was learned, what could be done differently to improve design of your boat going forward.

CONCLUSION QUESTIONS - to be incorporated into your reflection.
Compare the characteristics of high- and low-performing boats among the teams in your class.
How would you modify your design given more time?
Think of an application that does not involve transportation. Describe how fuel cells might be a better alternative than the fuel that is currently in use.

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Project 1.3.2 Fuel Cell Technology Rubric

Design

Elements	Weight	5 Points	4 Points	3 Points	2 Points	1–0 Points	Total
Brainstorm Sketches		The product includes at least five viable sketch ideas, which are neat and include labels, descriptions, signatures, and dates.	The product includes at least four viable sketch ideas, which are mostly neat and include labels, descriptions, signatures, and dates.	The product includes at least three viable sketch ideas. The sketches are not particularly neat but do include labels, descriptions, signatures, and dates.	The product includes at least three viable sketch ideas. The sketches are not particularly neat and may be missing some labels, descriptions, signatures, and dates.	The product provides little or no evidence that sketches have been created.	
Final Isometric Sketch		The product includes accurate isometric sketches that meet the required design concepts and include labels, descriptions, signatures, and dates.	The product includes accurate isometric sketches that meet most required design concepts and include labels, descriptions, signatures, and dates.	The product includes mostly accurate isometric sketches that meet some of the required design concepts and include labels, descriptions, signatures, and dates.	The product includes isometric sketches that are not completely accurate. The product may be missing some labels, descriptions, signatures, and dates.	The produce does not include isometric sketches.	
Prototype Testing Summary		The product specifically recounts testing procedures and results. The product includes a detailed description of the design modifications that were made based upon the results of prototype testing.	The product recounts testing procedures and results. The product includes a description of the design modifications that were made based upon the results of prototype testing.	The product includes a cursory summary of testing procedures and results. The product includes a less than adequate description of the design modifications that were made based upon the results of prototype testing.	The product does not recount testing procedures and results. The product includes a less than adequate description of the design modifications that were made based upon the results of prototype testing.	Little to no evidence exists to indicate that prototype tests were conducted.	

Design Requirements		The prototype fully meets all constraints and adequately supports the design function.	The prototype meets most constraints and adequately supports the design function.	The prototype meets some constraints and minimally supports the design function.	The prototype does not meet many constraints. The prototype does not adequately support the design function.	There is no evidence that the design requirements have been addressed.	

Prototype

Elements	Weight	5 Points	4 Points	3 Points	2 Points	1–0 Points	Total
Design Requirements		The prototype fully meets all constraints and adequately supports the design function.	The prototype meets most constraints and adequately supports the design function.	The prototype meets some constraints and minimally supports the design function.	The prototype does not meet many constraints. The prototype does not adequately support the design function.	There is no evidence that the design requirements have been addressed.	
Prototype Quality and Functionality		The prototype design functions consistently, and the chosen parts are appropriate.	The prototype design functions most of the time, and the chosen parts are appropriate.	The prototype design occasionally functions properly, and not all chosen parts are appropriate.	The prototype design rarely functions properly, and most chosen parts are not appropriate.	Little to no evidence exists to indicate that the prototype functions.	

Airboat Design and Research:

Insert weblinks and what you learned about boat hull and propeller design.

<table>
<tr><th>Link to Website</th><th>What was learned at that website</th></tr>
<tr><td>https://www.boaterexam.com/boating-resources/boat-hull-types-designs.aspx</td><td>

- Sailing boats, slow-moving boats, and large boats like cruise ships have displacement hulls. The combination of their weight and power means they move lower in the water, pushing or displacing water, rather than riding on top of it.
- Smaller, faster boats, like powerboats or personal watercraft, typically have planing hulls. Planing hulls are designed to rise up and ride on top of the water at higher speeds.

Flat-Bottomed Hulls → very stable; great for fishing and other things on calm, small bodies of water
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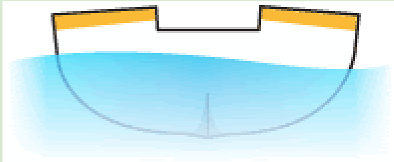
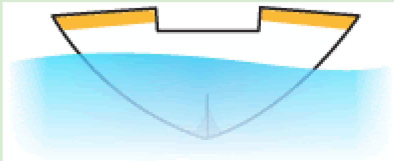
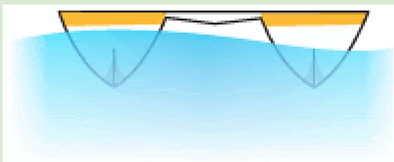
<tr><td></td><td>
Round-Bottomed Hulls → displacement hulls; designed to move through water with little effort; example is a canoe; drawback: less stablle in the water and capsizes more easily


V-Shaped Hulls → planing hulls; most common type of hull for power boats; designed to plane(glide) on top of the water at higher speeds; provide smoother rise through choppy water; boats with this shaped hull are usually equipped with a larger engine


Multi-Hulled → can have either rplaning or displacement hulls depending on the shape of hull and size of engine; some of the most stable hulls on water; require more room to steer and turn; examples are catamarans and pontoon boats</td></tr>
<tr><td>https://www.topnotchmarine.com/boat-hull-types/</td><td>
Cathedral → planes quick and easy; slams in waves; very stable; good deck area

Tri-hulls and Tunnel hulls → also called cathedral hulls; popular for fishing; one problem with them is that the increases surface area on the water makes them rougher than the round-hulled or V-hulled boats</td></tr>
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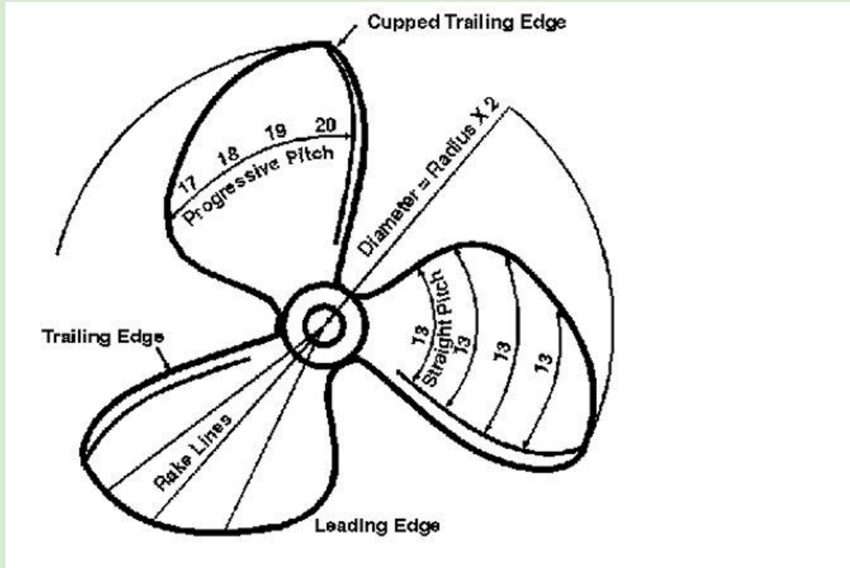
https://www.deepblueyachtsupply.com/boat-propeller-theory



Boat Propellers:

- includes blades (can have 3,4, or 5 blades) that turn on a shaft, which is powered by a motor
- Normally, the more blades, the more propulsion that can be achieved
- Motor provides power, and propeller blades displace the water or air to create the forces that move a boat forward
- Basic propeller shaft creates the torque/energy needed to turn the blades
- Propellers can turn in either direction and will work by the same principles
- Propeller works by turning torque into thrust, meaning it converts power from the engine into the action of turning the propellers to create force, by moving the flow of water/air downward and behind the blades. When this happens, it creates a temporary hole, which then fills with water/air, creating a low pressure system that lifts and pulls the blade forward (the momentum created by the low pressure is what moves the boat forward)
- Each blade has a slight curve and a particular shape
- Leading edge of blade is the part of the blade that hits the water first
- Trailing edge is the part where the water leaves the blade
- Curve of blade normally begins at the trailing edge and extends to the hub (curve also called the cup). It's what gives the blade its pitch, or angle.
- Boat propellers come in aluminium (least expensive; used when boat doesn' need to travel very quickly; easily dented), stainless steel (sturdier; can withstand hitting rocks, debris, and sand; but if the blade doesn't give, this may result in the propeller shaft being damaged; used in boats design for high performance and may consist of 5 or 6 blades for faster propulsion), and sometimes brass (reserved for heavy boating jobs)
- Propeller in motion creates a pitch, which is the forward movement of the propeller in one revolution

	- Propeller doesn't always move the exact distance it is designed to move due to slippage - Good propeller will have 10%-30% slippage (depends on design of propeller and blades)
http://www.airboatprops.com/FAQ.htm	More "wing area" gives you more lifting surface. The more lifting surface available, the more "lift" (thrust) per revolution. - Ways to increase this: - Increase the diameter - Use wider blades - Add another blade More wing area is generally better if you have the horsepower. Lower RPM means less noise. The faster the tips of a propeller have to spin to generate thrust, the more noise will be generated. If the propeller doesn't have to "hit" the air as often to create lift/thrust, then there is less shock and the engine won't have to work as hard either. - More "wing area" also means more mass to spin up - Less blades require RPM for same lift
https://www.westmarine.com/WestAdvisor/Selecting-a-Propeller	- Engine rpms and pitch are inversely related. Increasing the pitch will decrease engine rpms and decreasing the pitch will increase engine rpms. - if your engine is under revving, consider a propeller with less pitch. If your engine is over revving, consider a propeller with more pitch. - <u>Propeller size</u> is expressed with two numbers, <u>diameter</u> and <u>pitch</u>. - <u>Diameter</u> is two times the distance from the center of the hub to the tip of any blade. Smaller prop diameters generally go with smaller engines, or with fast high performing boats. - <u>Pitch</u> is the theoretical forward distance, in inches, that a propeller travels during one revolution. There is always some "slip" between the propeller and the water (generally 10 to 15 %) so the actual distance traveled is somewhat less than the theoretical value. Think of pitch as speed. - <u>Rake</u> is the degree that the blades slant forward or backward in relation to the hub. Rake can affect how water flows through the propeller, which can make a difference regarding boat performance. - Aft rake helps to lift the boat's bow, decreasing the hull's wetted surface area and improving top end planing speed. - <u>Cupping</u> of the trailing edge of the propeller blade is common on many propellers.

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A downward curve of the lip of the blade (like a plane’s wing with the “flaps” down) allows a better hole shot, less slippage and ventilation, and helps the propeller get a better bite on the water.
A cupped propeller may allow the engine to be trimmed with the prop closer to the surface, and will also decrease rpm.

Three-blade designs give you all-around performance with an advantage on top end speed.
Four-blade designs work well with boats that are difficult to get on plane, underpowered or used in watersports where top-end speed is not critical. Four blades in many cases will drop your rpm with identical pitch.

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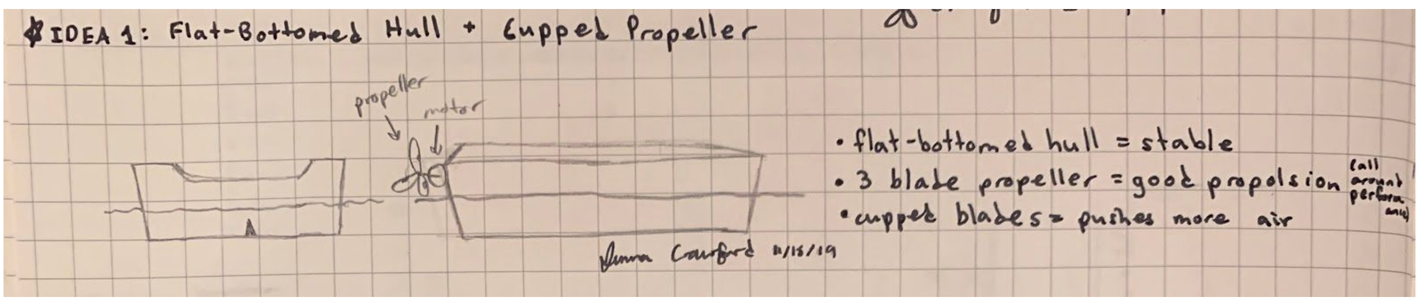
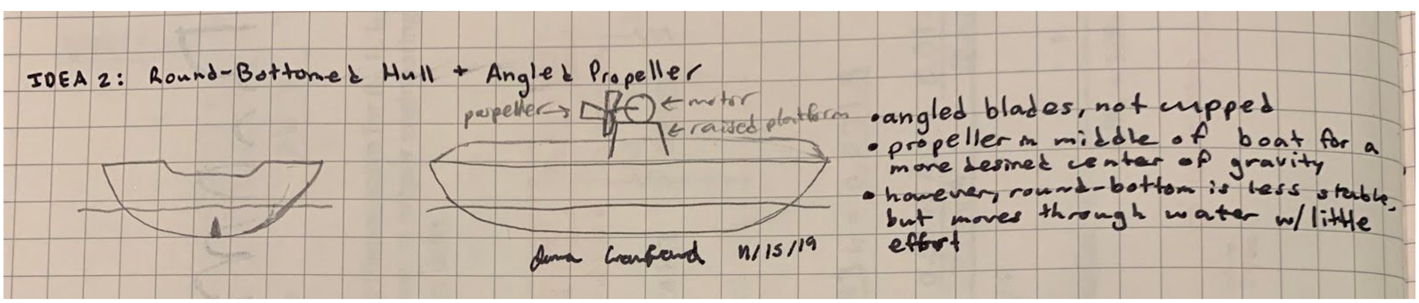
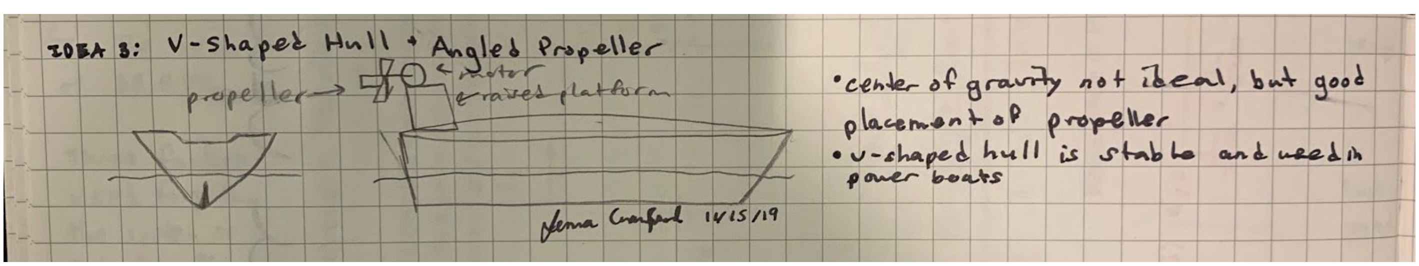
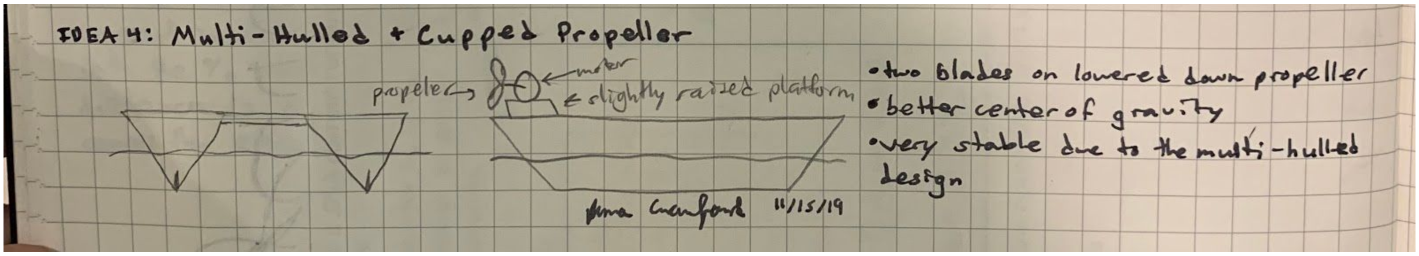
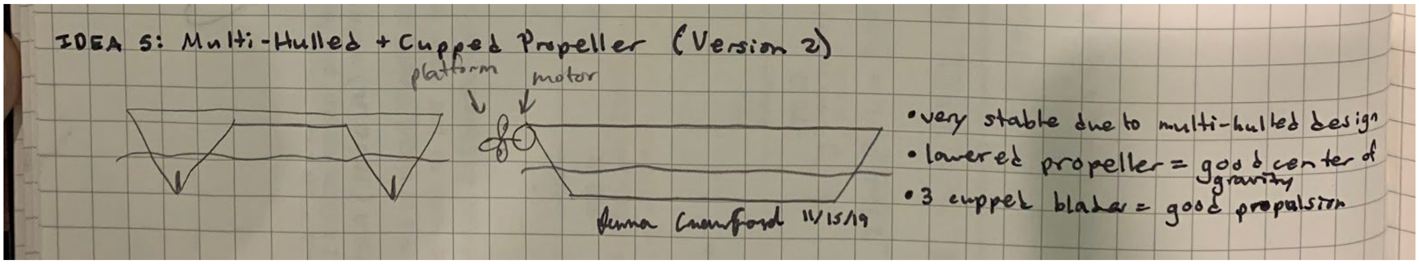
PART 1 Insert Images from your notebook of your brainstorming ideas











Decision Matrix:

Idea	Best Number of Blades for Propulsion	Stability	Easily Buildable	Total
IDEA 1: Flat-bottomed Hull and Cupped Preller	5	5	5	15
IDEA 2: Round-bottomed Hull and Angled Propeller	5	2	3	10
IDEA 3: V-shaped hull and Angled Propeller	5	3	4	12
IDEA 4: Multi-hulled and Cupped Propeller	3	5	4	12
IDEA 5: Multi-hulled and Cupped Propeller (Version2)	5	5	4	14

Based on the results from 1.3.1 Activity - How do you plan to power your boat and why have you chosen this method.

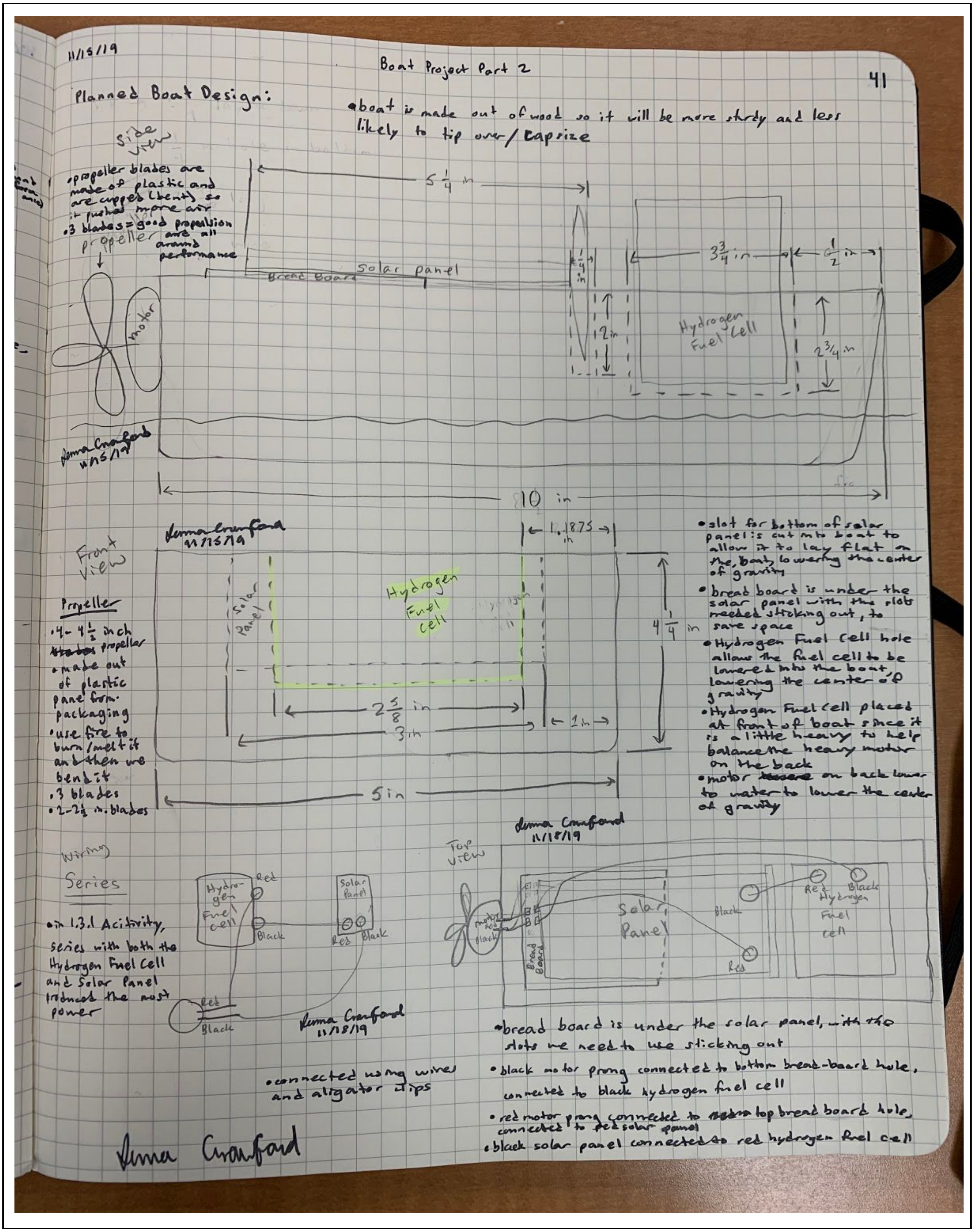
I plan to power my boat using the hydrogen fuel cell and solar panel in series. This is because, based on the results from the 1.3.1 Activity, when the hydrogen fuel cell and solar panel were in series, the most power

was produced. I need the most power possible in order to get the boat to be the fastest it can be.

List the Members of your group and their responsibilities.

Group Member	Responsibilities
Jenna Crawford	• Design boat • Wiring configurations • Painting and making boat look nice
Abby Winterbottom	• Design boat • Get wood material → cut and sand • Gets plastic propeller blades
Thomas Fisher	• Design boat • Wiring configurations • Bends propeller blades

PART 2 Insert image of planned boat design - include wiring to show how boat will be powered.



Build Day 1: Progress

- We built the basic boat out of wood over the weekend.
- We made sure all of the parts fit into the holes (solar panel and hydrogen fuel cell).
- Brainstormed more about the propeller.
- Tested boat in the water and decided to take out some of the excess wood that was adding extra weight to the boat.
- Determined where propeller will have to be based on water level on boat
- Planned an add on piece of wood to hold the motor for the propeller

Plan for day 2:

- Make propellers after deciding how to attach them to the motor
- Also decide if we should follow through with the original plan of making cupped blades, or just have straight blades turned diagonally.
- test boat to make sure it doesn't tip once it is all set up and also moves forward
- Make any additional changes to boat to help it float better

Build Day 2: Progress

- Put the motor holder onto the boat using screws
- Wired the boat and tested it
  - Boat is dragging on the bottom so we will take off more weight
  - Boat propeller spun so wiring is correct
- Made the propeller using plastic binder tabs
  - Glued straight blades to a bottle cap after diagonally slitting the cap to put the blades into it
- We don't need a breadboard after figuring out how to connect everything perfectly in series so that is less weight
- Figured out that we have to hold a light over the solar panel while the boat is driving

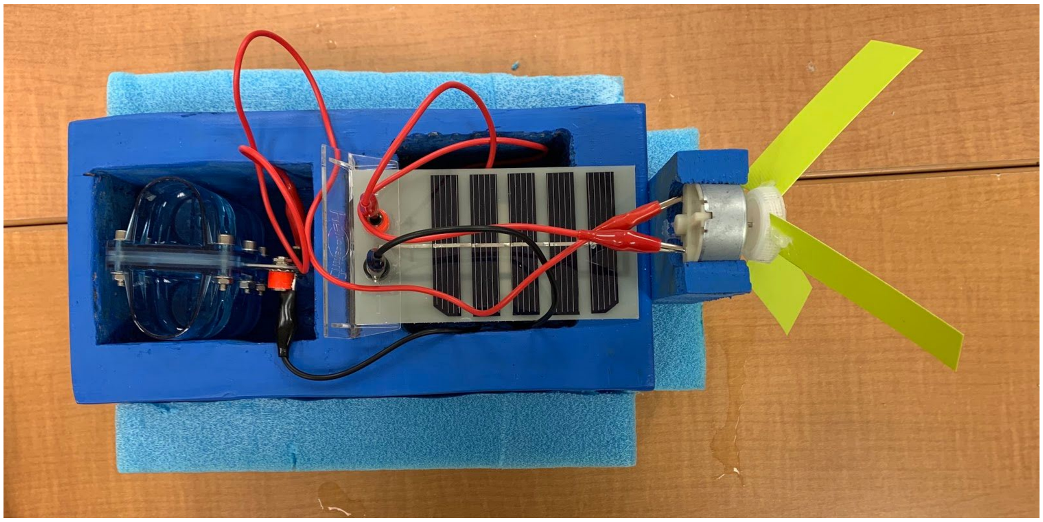
(we will make any additional changes we need over the weekend after performing multiple tests to see if the boat meets all the requirements and works properly)

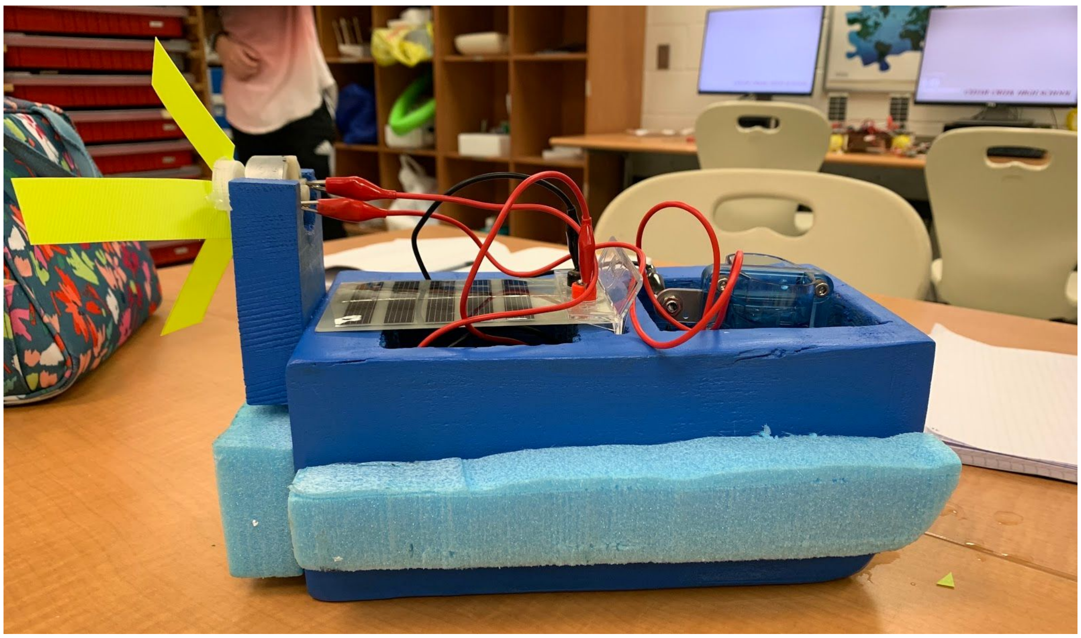
Plan for day 3:

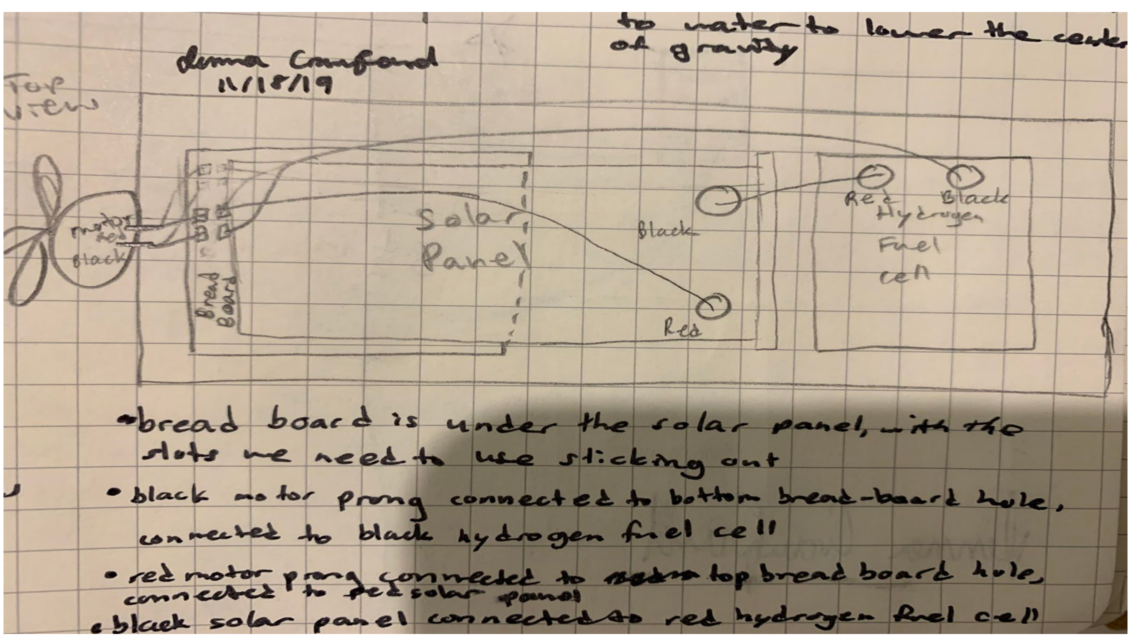
- Final test for boat to make sure everything works (wiring and that the boat floats without capsizing)
- Hot glue motor to the wood holder
- Completely set up the boat with the correct wiring and present the boat by having drive on the "lake"

Boats will be presented on Day 3 - this is not a "build" day.

Part 3 Insert Image of Boat as Built - include documentation on how boat is wired.







Description of how boat performed.

Our boat performed well. The propeller spun in order to move the boat across the lake. Our boat moved successfully across the lake at a medium-speed when powered by both the solar panel and the hydrogen fuel cell. When powered only by the hydrogen fuel cell, the boat moved a little slower, but still successfully made it across the lake. Our boat was successful!

A reflection stating what was learned, what could be done differently to improve design of your boat going forward. Answers to the following should be incorporated into your reflection.
- Compare the characteristics of high- and low-performing boats among the teams in your class.
- How would you modify your design given more time?
- Think of an application that does not involve transportation. Describe how fuel cells might be a better alternative than the fuel that is currently in use.

Our boat met the requirements and successfully made it across the lake. Compared to other high-performing boats, our boat was the second fastest. The one boat that was faster than ours was powered only by solar panels and was made out of foam. This boat was lighter than ours, which is one of the characteristics that went into making it move faster than ourboat. Also, this high-performing boat had a multi-hull. This was a very sturdy design. Our boat also had a sturdy design, but had a flat-bottom hull. Compared to the low-performing boats, our boat moved on its own without being pushed. Some of the other boats made by different groups had to be given a push before they started moving across the lake. Also, all of these low-performing boats were made out of plastic and foam, where our boat was made of wood. The majority of these low-performing boats had the characteristics of being powered by only solar panels, which may not have produced enough power to move the boat quickly.

I learned that our boat could be powered by both a hydrogen fuel cell and a solar panel together, and with just a hydrogen fuel cell. By doing this boat project, I learned that a bigger propeller is not always better. Although it would push more air, it is also heavier. For our boat, the smaller propeller worked better since the bigger propeller was too heavy to spin as fast as the smaller propeller. I also learned that you can switch the direction that the propeller spins. By testing both ways that the propeller spins, you can see which direction works the best and makes your boat go the fastest. When our boat was not moving very fast, we switched the direction that the propeller spun and the boat started moving at a faster speed.

Despite our boat working, it could still be improved. I would design our boat slightly differently. While still making the boat out of wood, since wood is very sturdy, I would not make the boat as high as we did. This extra height that was not needed and only added extra weight. This extra weight made the boat too heavy, causing it to touch the bottom of the lake. Therefore, we had to add foam to the sides to make it float better. By not making the boat as high, a lot of extra weight would be taken away, allowing the boat to float without having to add any foam. Another design change I would make is to create a cupped propeller. Our propeller had rectangular-shaped blades. Although these worked, based on research, cupped propellers would work better. We ran out of time before we could figure out how to make a cupped propeller blade, so we had to use the straight, rectangular blades. To improve our boat's design going forward if I were given more time, I would not make the boat as high to get rid of extra weight and I would create a cupped propeller.

Fuel cells might be a better alternative than the fuel that is currently used in heating a house with propane, which is an application that does not involve transportation. The fuel used in heating a house with propane is propane. In order to use propane to create heat, it is stored as a liquid and as it depressurizes, it turns to a gas, and then burns to create heat. Propane is pretty expensive to buy. Fuel cells might be a better alternative to use to create heat or used to power a heater of somesort in order to heat your house because it will cost less money in the long run than buying propane multiple times a year for the rest of your life. The cost of the fuel cell will ultimately be less than the amount of money you spend on propane. Also, it will most likely be more efficient and is less harmful to the environment. Since your have to burn propane to create heat, this contributes to the pollution going into the atmosphere. However, a fuel cell does not pollute the atmosphere. The fuel cell is also more efficient since it keeps recycling the water it uses so you will almost never have to put new water into it.