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| **Fellow Name: Jacob Holden** | **Contact Info: (513) 257 - 6605** | **Date: January 26, 2015** |
| **Teacher Name: Amy Gunderman** | **School Name: Finneytown HS** | **Grade and Class: 12th grade Honors Physics** |

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| **Activity Title:** | **Water Turbine Challenge** |
| **Estimated Activity Duration:** | **4 class periods** |

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| **Setting:** | **Classroom** |

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| **Activity Objectives:** |

The student will be able to:

1. Identify the need in society for renewable energy
2. Construct the kinematics diagram of the water turbine (with rotational velocity, rotational acceleration, linear acceleration, etc.)
3. Describe the effect of turbine blade design on power output
4. Explain the benefit of water over air (a higher density means smaller turbine)

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| **Activity Guiding Questions:** |

1. Why are fossil-fuels insufficient?
2. What are the components of a water turbine and how is each part involved in the rotational motion?
3. How do different blade shapes change the power output of a water turbine?
4. What are the benefits of hydro-power?

| **Next Generation Science Standards (NGSS)**  |
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| **Science and Engineering Practices (Check all that apply)**  | **Crosscutting Concepts (Check all that apply)** |
| ☐ Asking questions (for science) and defining problems (for engineering) | ☐ Patterns |
| ☐ Developing and using models | ☐ Cause and effect |
| ☐ Planning and carrying out investigations | ☐ Scale, proportion, and quantity |
| ☐ Analyzing and interpreting data | ☐ Systems and system models |
| ☐ Using mathematics and computational thinking | ☐ Energy and matter: Flows, cycles, and conservation |
| ☐ Constructing explanations (for science) and designing solutions (for engineering) | ☐ Structure and function.  |
| ☐ Engaging in argument from evidence | ☐ Stability and change.  |
| ☐ Obtaining, evaluating, and communicating information  |  |

| **Ohio’s New Learning Standards for Science (ONLS)** |
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| **Expectations for Learning - Cognitive Demands (Check all that apply)** |
| ☐ Designing Technological/Engineering Solutions Using Science concepts **(T)** |
| ☐ Demonstrating Science Knowledge **(D)** |
| ☐ Interpreting and Communicating Science Concepts **(C)** |
| ☐ Recalling Accurate Science **(R)** |

| **Common Core State Standards -- Mathematics (CCSS)** |
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| **Standards for Mathematical Practice (Check all that apply)** |
| ☐ Make sense of problems and persevere in solving them | ☐ Useappropriate tools strategically |
| ☐ Reason abstractly and quantitatively | ☐ Attendto precision |
| ☐ Construct viable arguments and critique the reasoning of others | ☐ Look for and make use of structure |
| ☐ Model with mathematics | ☐ Look for and express regularity in repeated reasoning |

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| **Unit Academic Standards (NGSS, ONLS and/or CCSS):** |

According to the New Ohio's New Learning Standards in Science, circular motion is taught in the Physics Course under the content topics of Forces, Momentum and Motion.

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| **Materials**: (Link Handouts, Power Points, Resources, Websites, Supplies) |

* For Honors Physics Class, 6 teams of 4 students
* Total supplies needed:
	+ 6 - yogurt containers (Same diameter if possible)
	+ 6 – 24”x ½” wooden dowels
	+ 6 – 4 ft. long sections of string/twine
	+ 6 – 2”x ¾” wooden or cardboard collars (hubs for axels)
	+ 6 – Hanging masses (already in classroom!)
	+ 6 – Razor blades or X-acto knives
* Class supplies
	+ Sink
	+ **Serrated hose nozzle for lab sinks**
	+ Scissors
	+ Duct Tape

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| **Teacher Advance Preparation:** |

Sink must be equipped with a serrated (hose fit) nozzle. If it is not possible to install one, another method must be devised to power the water turbine. Bins of each team’s materials can also be prepared beforehand to simplify distribution.

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| **Activity Procedures:** |

**For Teachers:**

1. Begin discussion about power and where our electrical power comes from. General overview of typical coal power plant: Burn coal, heat water, make steam, spin turbine, spin generator, create electricity, and transmit electricity. Brainstorm/discuss why fossil fuels aren’t ideal (limited quantity, unhealthy emissions, wars, climate change is understood and accepted). Can we take off coal parts of this process and still make electricity? Yes! We just need another source to spin our turbine!
2. What is a turbine? Start with a basic diagram and terminology. Describe the **hub**, the **blades**, and the **shaft** as the primary components. Everything is rotating and must be firmly connected.
3. Energy is conserved in all cases! The kinetic energy contained in the volume of a moving fluid is the amount of energy that can theoretically be converted into some other form (rotational energy is what we want!). Why are we using water instead of air? Water has a much higher density than air, therefore a much smaller volume contains the same amount of energy, meaning…a smaller turbine!
4. Begin a discussion on design. In order to convert as much of this energy as possible, we want the best blade design. What are our design variables? Number and size/shape of blades. The main considerations should be that a longer blade gives water more leverage (torque) on hub, but weakens material. Higher blade number gives more blades to do work, but too many and they will block each other or create more harm when not under the water. Try to bring these points about through discussion, or let groups come to it on their own.
5. Item 4 above can happen either as a class discussion before the activity has begun, or it can be facilitated once the activity has already started and students are working with their groups. Either way, begin the activity and ideally have some extra materials (particularly bottles or yogurt containers) for students to test parts of their designs before cutting into their final turbines.
6. In presenting the procedure for the actual activity, set checkpoints. They will require instructor approval or signage before moving on. Suggested checkpoints are (\*see the attached material for a student handout with instructions and checkpoints):
	1. **Preliminary Design**: Read all instructions and then each group member should have a simple sketch and description of their ideas.
	2. **Design Critique and Compilation**: After analyze each other’s design and discussing the pros and cons of each, the group reaches a composite design and finalizes it.
	3. **Prototype Model**: Before cutting into the groups’ final container, they must demonstrate on one of the test containers that their method of cutting the blades will work.
	4. **Test Ready Design**: At this point all teams designs will be tested and power output will be analyzed
7. Look to the formative assessment section for instruction on working with groups during the design and building process.

**For Students:**

We have found that the conventional methods we have for generating electrical power are harmful to humans and the environment, posing significant problems for the future. We will be using our knowledge of circular motion, energy, work, and power to assess one of the most important scientific and engineering questions, how can we generate renewable power? We will design and build water turbines and measure the power output by lifting a known mass in a certain amount of time.

1. **Blades:** The plastic container will serve as the *hub* of our turbine. We must cut blades out of it with the X-acto blades provided (carefully!). From the demonstration, it is up to you to discuss as a team and decide what the best *blade shape, and blade count* will be to generate the most power. Cut 3 sides of your blades and fold them out from the container. Make sure they are in a position where they are still firmly attached to the container.
2. **Axle:** Once you have cut your blades out, it is time to install the axle for the water turbine to rotate on. In base of your container, make an “x” pattern with two incisions in the center (~ ½ inch for each incision). If you are using a yogurt container, make the same incisions in the lid. Then run your wooden dowel trough the lid of the container, then through your cuts in the base. It is important that your dowel fit snugly in the container. To ensure that there is no slipping, tape the top of the container to the dowel.
3. **Installation:** Once your have attached the container to the dowel, your turbine is finished! All that remains is to install it in your water source (sink). To do this, tape the two collars to the countertop on either side of the sink and insert your axle into the collars. Be sure to position your turbine blades in the stream exactly where you want them.
4. **Mass:** Finally, join one end of the string to the part of the axle that is sticking out from the countertop over the floor and the other end to the mass on the floor. Now the set-up is ready to run!
5. **POWER:**  Now, when the team is ready, turn the sink on and time how long it takes for your water turbine to hoist the mass from the ground up to the axle height. Once you have finished, measure the exact height that you have moved the mass, in order to calculate you *power output.*

**Formative Assessments:** Link the items in the Activities that will be used as formative assessments.

The most important assessment will be in the blade design process. It is important that students are considering the blade geometry and the effects on power output. If groups are stuck or not discussing specific geometric features, the checkpoints are the perfect time to probe until a conversation develops. The first checkpoint, after an individual brainstorming process, will show if students are conceptualizing the problem correctly. Checkpoints continue later to be excellent assessments of the distribution of tasks (i.e. are more than one student actually helping with construction?).

**Summative Assessments:** Prepare a Pre-Test and Post-Test with the input of the RET Teacher. This should be a simple 10-12 question assessment tool. These questions will cover the content related to the Standards. The Pre and Post Test will be identical. There may be several summative assessments at the end of this Activity. Besides the Pre and Post Tests, the students might create a product for which this is a rubric developed. The rubric is also a summative assessment tool. Link the assessment tools.

A Pre- and Post- test is given with the following questions. On the first implementation of this activity, average class performance on this test went from 49% (3.2 questions correct) on the pre-test to 86% (about 6 questions correct) on the post-test.

1. What are the key components of a hydro-turbine? (Answer: Hub, blades, shaft)
2. How are power and work related? (Answer: Power = (change in Work)/time)
3. How are work and energy related? (Answer: Work = (change in Energy)/time)
4. What unit measures the power output of a water turbine? (Answer: Watt)
5. What are the potential uses of the power from a water turbine (Answer: open ended)
6. What are the advantages of putting a turbine in water rather than air? (high density means smaller turbine)
7. What are the disadvantages of putting a turbine in water rather than air? (more difficult to maintain etc.)

A collective data and analysis sheet is documented separately. This includes spaces for each student to sketch all of the turbines created in the class and record the measured output from them. After answering a series of analysis questions, they are asked to sketch a final design using all of this new information to iterate once more. The analysis questions are the following:

1. Which team produced the best results?
2. Why do you think their design impacted power output?
3. What improvements could you make on your design to give it more power output?
4. Why is water a good power source for the turbine?
5. What would happen if you used moving air instead of water?

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| **Differentiation:** Describe how you modified parts of the Lesson to support the needs of different learners.Refer to Activity Template for details. |

 The different learning styles in the class will cause the students to work together in much different ways in this team-based challenge. One possible way to manage this is to first ask every team to choose a leader and a scribe. This immediately gives structure to the exercise, which will make the setting more comfortable for everyone to engage.

The role of the teachers in the room will also be crucial in differentiating. If certain students are not grasping concepts in the group discussion and problem solving setting, the group will leave them behind. If this is noticed by any teacher, it is important to go work with that group and that student specifically, bringing everyone back up to speed perhaps by talking through the design ideas in a different or more in depth manner.

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| **Reflection:** Reflect upon the successes and shortcomings of the Activity. This is done after the Activity is implemented. |

 The Activity was a huge success. The most glaring difference between the planned and actual outcome, however, is that rather than 2 class periods, it requires more like 4 class periods to be done well. I chose to use a checkpoint technique in the structuring of the activity, which may have added slightly to the overall time, but allowed for students to learn much more. Checkpoints made the overall goal much more manageable by breaking it down into progressive tasks. This also created an excellent formative assessment opportunity. I could have individual conversations with each team member, inquiring about their understanding and role in the decision-making process for that checkpoint.

 One shortcoming would be my method for securing the water turbine shafts before testing them. It is desirable to find a better and faster way of doing this. My method was to tape rings to either side of the sink that the shaft could rotate freely in but this required drying everything and re-taping in between groups. A more interchangeable method would be good. Disclaimer…No matter what modifications is made, THIS ACTIVITY WILL SPRAY WATER EVERYWHERE.

 Overall, this activity caused students to stay engaged with topic of circular motion with a secondary theme of renewable energy throughout the entire activity. Adding a competitive element also helped with student motivation (whichever turbine generates the most power “wins”). Prefacing this activity with two class periods of circular motion introduction and a discussion about energy really helped from the topic. It is important to following the discussion outlined in the teacher’s procedure section.