Grades 9-12

TURN ON THE LIGHT WITH HYDROPOWER
BE AN ENERGY SYSTEMS ENGINEER
Instruction Sheet

Energy system engineers use math to optimize the transfer of energy to meet our clean energy demands.

Hydropower is energy generated from moving water. It is a clean energy source that can help fill energy requirements when other sources of energy, like solar and wind energy, aren't generated (like when it is cloudy or not windy). This is because hydropower fills the gaps by storing energy as water in a reservoir and releasing it when there isn't enough sun or wind to meet the energy demands. For this reason, it has the nickname "water battery".

Hydropower works by transferring energy from potential energy to kinetic energy (energy in motion). Head and flow are an important part of this. Head is the change in water levels from the place where the water comes into the place where water comes out. It is a vertical height. The bigger this height is, the bigger the head is. With a bigger head, there is more water pressure, which means more power is generated. The flow of water is also important, and it measures the volume of water passing through the hydropower site. The higher the flow, the more energy is generated.

To achieve clean energy goals, optimization is key! In this activity, students will calculate, design, build, and optimize a model hydropower system that can power an LED light.

MATERIALS

- ❑ A small cup
- ❑ A clear straw or dropper pipette
- ❑ Water & pitcher/cup
- ❑ Food coloring (optional)
- ❑ Ruler/measuring tape
- ❑ A paper
- ❑ A marker
- ❑ Adhesives (hot glue, duck tape, etc.)
- ❑ String
- ❑ Basin/bucket, sink, or tub
- ❑ Cardboard
- ❑ A pair of scissors or an exacto knife
- ❑ A wooden dowel
- ❑ Low voltage LED light
- ❑ Small DC Motor or generator
- ❑ Alligator wires

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ACTIVITY HIGHLIGHTS

- ❑ **NGSS HS-PS3-3**
  Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

GUIDING QUESTIONS

- ❑ **How does energy transfer?**
- ❑ **How can we generate electricity from water?**
- ❑ **How can we optimize our design?**

U.S. DEPARTMENT OF ENERGY
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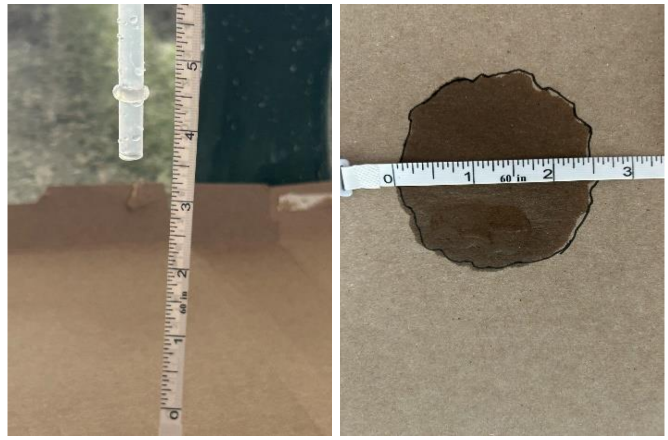
PROCESS / PROCEDURE STEPS

Part 1

In Part 1, you will explore potential and kinetic energy. This is adapted from the activity [“Falling Water”] (Zamora-Thompson et al., *Falling water - activity* 2022)

1. Fill a cup with water, and if you want, add in a few drops of food coloring.
2. Mark a line a few centimeters from the end of your straw or use a dropper pipette.
3. Fill your dropper pipette or fill your straw to the line with water by dipping it up to the line into the water and using your finger to plug the top hole.
4. Measure 25cm above your paper and position the bottom of your straw at that height above the paper.
5. Unplug the hole and let the water splash.
6. Draw a circle tightly around the splash area and measure how wide the circle is.
7. Refill your straw to the same amount, but this time, drop the water from 50cm. How does the height affect the size of the splash?



Part 2

Your challenge is to turn on a LED light using a model hydropower system you designed and built. To do this, follow the engineering design process just like Argonne researchers do:

1. **Identify:** What is the problem or thing that needs to be improved?
2. **Determine:** What requirements does the solution need to meet? What are the limitations?
3. **Explore:** Look at what others have done. Gather materials. Play!
4. **Design:** Come up with a design.
5. **Create:** Build your idea using our plan.
6. **Test:** Try it out! Did it work? Did it meet the requirements?
7. **Improve (Optimize):** What worked? What didn’t? How can you make it better?

Energy system engineers use mathematical formulas to help develop models, designs, and predictions. Below a formula that you may find useful in designing your model.

Hydropower formula:

$$P = Q * \rho * g * H * \eta$$

P = the electric power produced in kVA
Q = flow rate (m3/s)
ρ = 1000 kg/m3 = density of water
g = 9.81 m/s^2 = acceleration of gravity
H = waterfall height (m)
η = O.5* = global efficiency ratio for a micro-turbine

* Micro-turbines have an efficiency ratio of about 0.5; otherwise, the ratio is typically between 0.7-0.9.

Discussion Questions

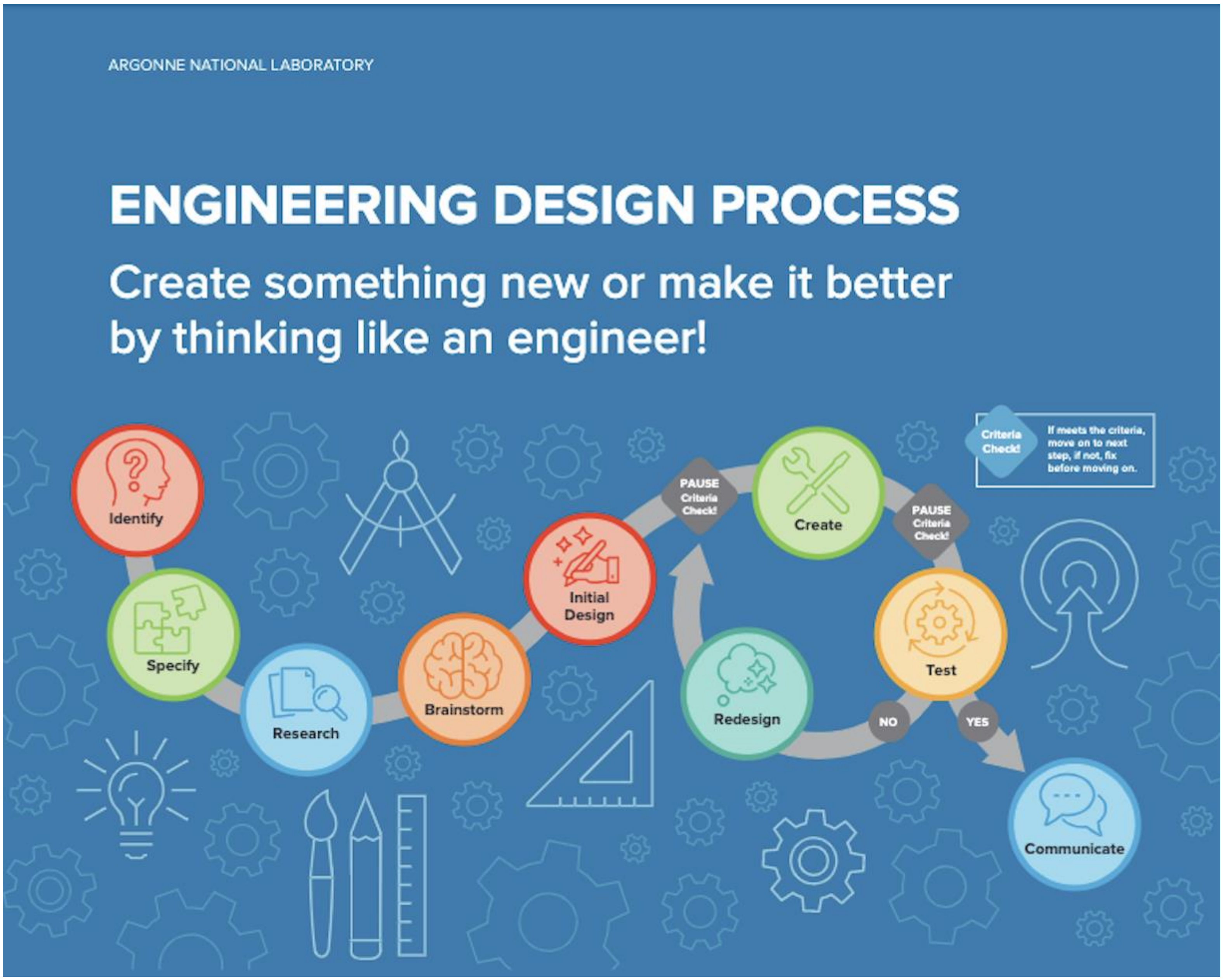
1. What did you notice about how the height and amount of water impact the flow of water?
2. What was the optimal height to turn on the LED?

How do you think scientists increase or decrease the flow of water?

Part 3 (Optional)

In Part 3, redesign your model so that it is a part of a larger energy system with solar and/or wind. Design and create a model system that uses solar or wind energy to pump water up to the reservoir. Some suggested materials include:

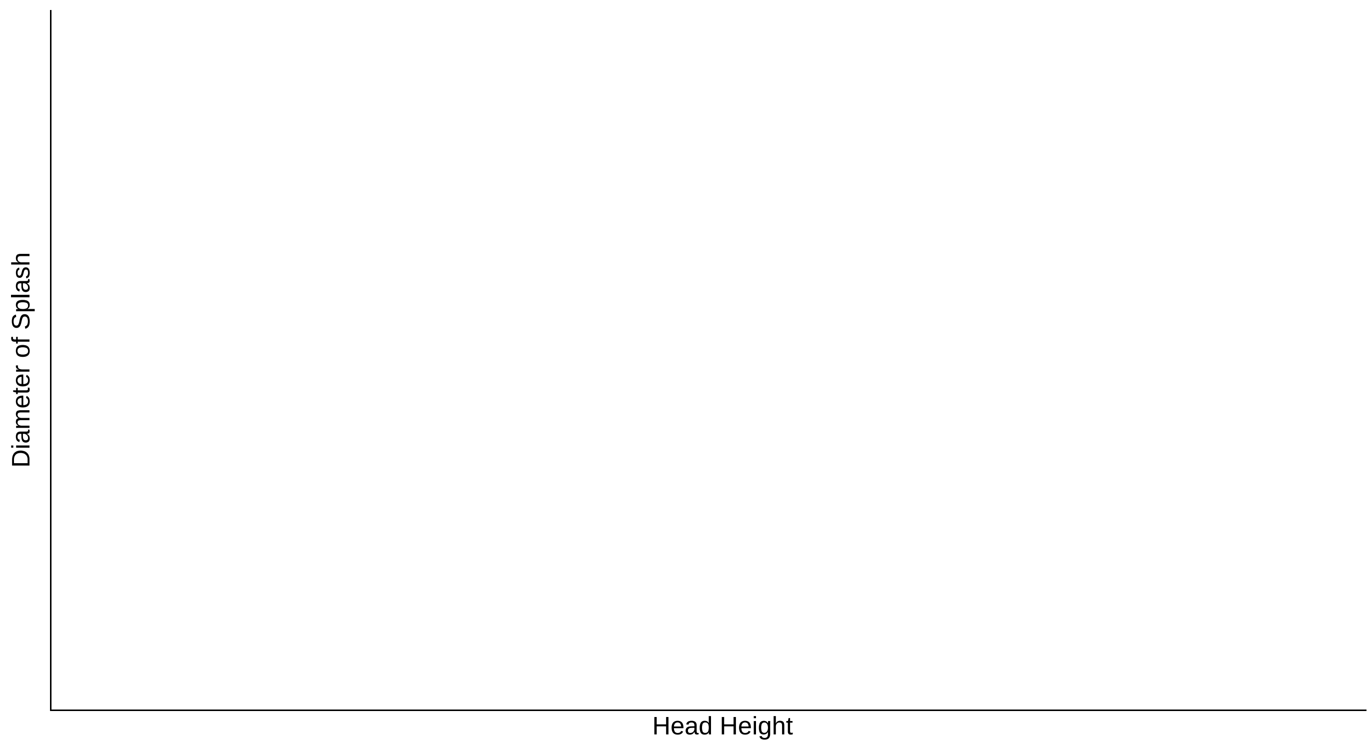
- Turbine (from water pressure to electricity): https://www.amazon.com/dp/B098LBZ7Q6
- USB-powered pump (the other way around): https://www.amazon.com/dp/B08BCCJ9GD
- USB multimeter: https://www.amazon.com/dp/B07X3HST7V
- LED light: https://www.amazon.com/Waterproof-Operated-Decoration-Christmas-Holiday/dp/B01837ULPU/



POTENTIAL ENERGY ACTIVITY TABLE

Complete the data table for Part 1. What conclusion can you make? How does head height affect the diameter of the splash? Does increasing the head height increase or decrease the potential to kinetic energy?

Head Height	**Diameter of "Splash"**			
	Trial 1	**Trial 2**	**Trial 3**	**Average Diameter**
25 cm				
50 cm				
75 cm				
100 cm				
Conclusion:				



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Data Sheet

Identify: What is the problem or thing that needs to be improved?	**Determine:** What requirements does the solution need to meet? What are the limitations?

Explore: Look at what others have done. Take notes from your research and tinkering.

Design, Create & Test: Pick one idea and make a drawing. Build your idea using your plan and test it out.

Improve (Optimize): What worked? What didn't? How can you make it better?

References

Zamora-Thompson, X., Duren, S., Mach, N., Zarske, M. S., & Carlson, D. W. (2022, June 17). *Falling water - activity*. TeachEngineering.org. Retrieved March 24, 2023, from https://www.teachengineering.org/activities/view/cub_energy2_lesson08_activity1