# UWindsor Engineering OUTREACH

University of Windsor
Faculty of Engineering

## Design a Pop Bottle Water Wheel: Grades 6 to 8

### YOUR MISSION

In this activity, you will be making a water wheel out of household materials to lift a weight up off the ground by using the power of water. This experiment will demonstrate how to create and transfer different types of power and work that helps power the modern world of today and how weight can affect the rotational rate.

Many of these principles are used in mechanical, environmental and civil engineering, where engineers have to calculate how much power can be generated by wind turbines and hydro electric dams (such as Niagara Falls) or how much power is required to move an object such as cars, elevators, and many more engineered objects.

To get started, here is an introductory video that helps explain Hydro Electric Power Generation

### WHAT'S GOING ON

Civil engineers design the many different components of the civilization we live in and use every day including roads, bridges, buildings, power plants, and more. The pop-bottle power wheel uses the same principles that a civil engineer would use in their projects and designs, like how water can be used to generate power, or move objects from one place to another.

Mechanical engineers design and engineer many of the systems we use in our lives including cars, robotic mechanisms, roller coasters and construction machinery. Mechanical engineers are required to calculate the forces and torques necessary to move objects, as well as the power generated by spinning objects. For example, they need to calculate the amount of energy that's required to lift an elevator of people from one floor to another.

Environmental engineers work to combine the environment around us and mechanical/civil engineering objects without disrupting the environment around the object. For example, they may calculate how much adding a power plant in an area will change the eco system around it. Will a wind turbine impact the migration pattern of birds, or will a hydro plant impact fish and waterways?

Before you start the activity, we can explain some key terms that will help you understand everything before we begin!

## KEY TERMS

- **Force:** The measurement of a push or pull on an object.
- **Moment/Torque:** The measurement of rotational force on an object
- **Work:** The amount of energy required to move an object. Expressed as force per distance or torque per rotational distance.
- **Energy:** The capability for something to do work (Example: the water has the energy to lift an object off the ground)
- **Power:** The amount of work performed over a certain amount of time. Usually expressed as Work/Time
- **Mechanical Energy:** The energy in a moving object (Example: Water falling, or an object spinning)
- **Potential Energy:** The energy that can be taken from something and converted to another type of energy (example: Water that can fall)
- **Rotational Rate:** The number of turns that takes place during a period of time. An Example is RPM (Revolutions Per Minute), which is how fast something turns in a minute.

How does your water wheel demonstrate these concepts? There are forces from the water pushing down on the flaps of the pop-bottle. As the pop-bottle spins it wraps the string around the neck of the bottle lifting the weight up from the ground. While the water is lifted up from the bottle, there is **potential energy** being held in the water. As the water falls down the **energy** is converted into **mechanical energy**. Once the water hits the flaps of the pop-bottle power wheel it exerts a **force** on the flaps which pushes the bottle around the axle. Since the water is exerting a force on a rotating object it converts the mechanical energy of the water into a **torque** on the bottle. The large size of the bottle gives us a higher torque which will help the bottle lift the weight.

Think of a how pushing a door open from the outside is easier than pushing it open from the middle of the door. When we push the door from the outside it's easier for us as we can create more torque with the same amount of force from our arm. Back to the pop-bottle water wheel, the speed at which the weight is lifted is directly connected to how quickly the bottle is rotating.

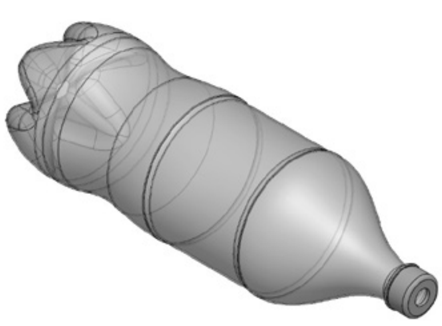
## MATERIALS NEEDED

- 1 empty 2-litre pop-bottle
- 1 roll of tape
- 12+ index cards (or more to experiment with other designs)
- 1 roll of plastic wrap (or another material to waterproof the index cards)
- 1 wooden dowel longer than the pop bottle, around ¼" in diameter
- 1.2 meters of string
- 100-200-gram weight (or an object that is similar in weight)
- 1 pair of scissors
- 1 pen or marker
- 1 piece of paper
- Stopwatch (can also use the app on your smartphone)
- Scale
- Water
- Funnel
- Pouring container (another pop-bottle or pitcher)
- Sink (or perform experiment outside if possible)

## WHAT YOU NEED TO DO

- Collect all the tools and building parts required for the project and lay them out on a table.

- Put a hole in the cap of the bottle and the bottom of the bottle. If you are having difficulties, you can ask a parent or teacher to help by having them drill a hole in the cap of the bottle and the bottom of the bottle, as close to the center as possible.



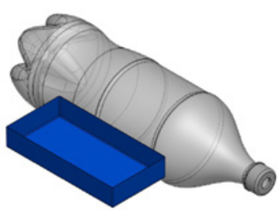
- Grab your pen/marker and paper and sketch out the design of your pop-bottle power wheel. Follow the basic design as shown in image below and only use the parts listed in the "Pop-Bottle Power Wheel Building Parts" list. Custom design the index card and wings design, the number of wings and the placement of them to try and maximize the effectiveness of the pop-bottle power wheel. The plastic wrap is meant to wrap around the index card wings to keep them dry.

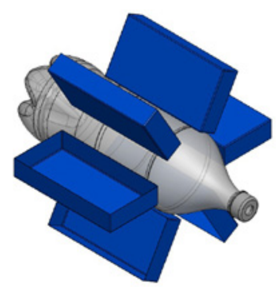
- Build your pop-bottle power wheel using only the supplies listed in the "Pop-Bottle Power Wheel Building Parts" list.

  a. You can use the pen and marker again to mark out where you want to mount your index card wings on your bottle.

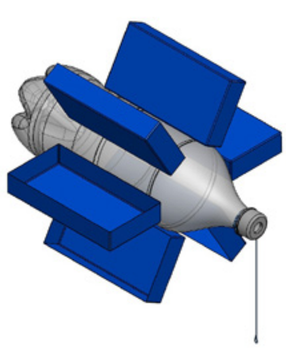
  b. Fold the index cards as you designed them and wrap them in plastic wrap (add tape to the back side to hold the plastic wrap in place)

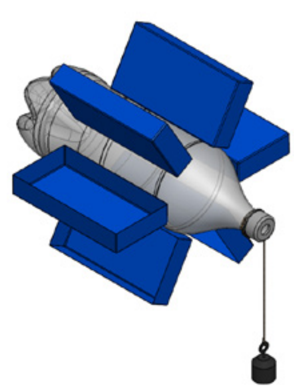
  c. Tape the wings onto your bottle in the places you marked out before



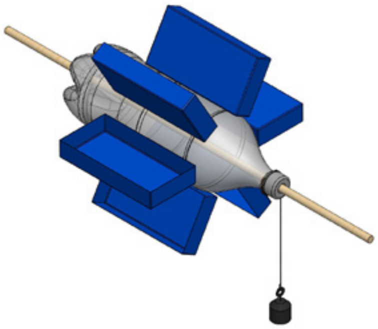


  d. Wrap the string around the neck of the bottle and tape it in place to prevent it from slipping. Tie the other end to the weight.





- e. Place the dowel through both holes in the bottle so it is free to spin around the dowel



- Think of ways to make it easier to count the amount of rotations of the bottle. You can add something to the pop-bottle power wheel if needed.

- Test your Pop-bottle water wheel! Go over to a sink, tub, or outside and fill your container with water to pour over the wheel. Pour the water into the funnel from about 20 cm above the wheel over the wings so the wheel turns and lifts the weight up.

- Using your stopwatch or clock, time how long it takes to make the weight lift up all the way. Also, count how many rotations the bottle makes during your test (you may need a partner to help count). Record your results in the results table below.

| Test # | Rotations | Time to lift weight (seconds) | On a calculator divide your rotations by the total time and record below. This is the rotations per second |
|---|---|---|---|
| 1 | | | |
| 2 | | | |
| 3 | | | |
| 4 | | | |

- Complete the 4th column of the table using a calculator.

- Redesign your wings and try to lift as much weight as you can, start with a smaller weight and work your way up as you improve your wings. Record the amount of weight you were able to lift in the chart below. Compare your results from Table 1 and Table 2.

| Wing Design | Weight Lifted | Anything you can improve? |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |

## FURTHER REFLECTIONS

1. What do you think would happen if the weight was wrapped around the larger part of the bottle instead of the neck of the bottle?

2. What would happen if you dropped the water from higher up?

3. Is there somewhere on the wing that dropping the water on that helped the pop-bottle power wheel rotate faster, or have more torque?

4. Can you name the types of energy the weight has in it after it is lifted to the top of the bottle neck (before it falls back down)? Hint: Think of the water at the beginning.

5. What would happen if you poured more water over the pop-bottle power wheel?

## ENGINEERING DESIGN PROCESS

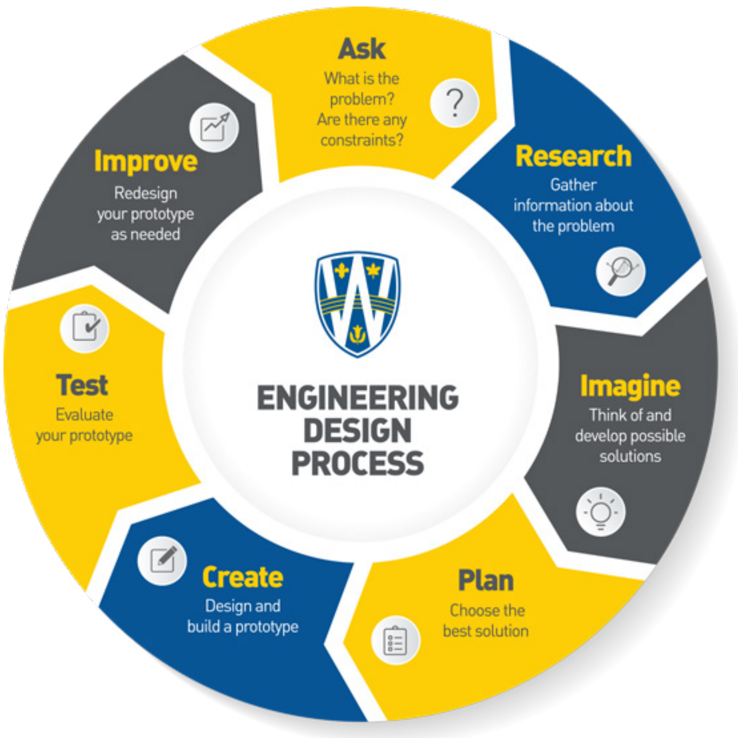
All engineers use the Engineering Design Process to plan, build, test and reflect on their designs and when coming up with solutions to a problem. The steps for the Engineering Design Process are listed below. Use the Engineering Design Process to test and improve your design.

First, think of the problem.

How can you fix it? Think of as many ideas as you can that you think will solve this problem.

It might be helpful to first sketch out your ideas on a piece of paper. Make as many different designs as you can!

Test and compare all of your solutions. Which one solves the problem and works the best?




## CURRICULUM UNIT CONNECTIONS

Grades 6 to 8 – Understanding Structures and Mechanisms – Form and Function; Understanding Structures and Mechanisms – Systems In Action; Understanding Matter and Energy – Fluids; Understanding Earth and Space Systems – Water Systems

## SHARE YOUR DESIGNS WITH US!

Tag us on our UWindsor Engineering Social Media Pages and show us your designs!

Twitter: @UWindsorENG
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Hashtag: #UWindsorENG

## REFERENCES

Teach Engineering.org STEM Curriculum For K-12. (2005). Waterwheel Work: Energy Transformations and Rotational Rates. https://www.teachengineering.org/activities/view/cub_energy2_lesson08_activity2

Teach Engineering (2018, September 25). Waterwheel Work: Energy Transformations and Rotational Rates. [Video]. https://www.youtube.com/watch?v=zruF812SouM

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