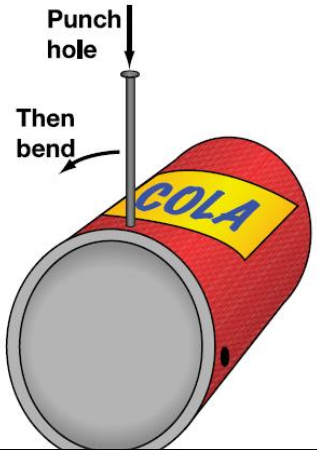
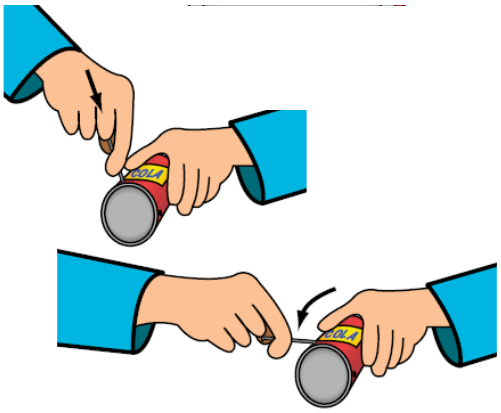
Wizards of Wright

Lesson: Hero's Engine - Testing Newton's 3rd (Testing Thrust with a Water-Propelled Can)

Use WOW! Lesson Intro to begin.

Background Info for Wizards:	The goal of this activity is for students to investigate Newton's third law of motion using thrust produced by falling water. Small groups will use soda cans to make water propelled engines. Then they will test ways to increase the action-reaction thrust produced by water shooting out of holes punched in the can sides. *Hero's invention was not self-contained and therefore, not a true rocket device. Heat to generate the steam had to be applied externally. Rockets are completely self-contained.*
Materials:	- 4 empty aluminum soft drink cans per team, with pull tabs intact - carpenter's nails of different sizes - string (about 50 cm) - water tubs (large plastic storage tub, small kiddy pool, sink, etc.) - water - paper towels - rulers - stickers or marker
Lesson Time: 50 minutes	Introduction: 5 minutes Guided Lesson: 5 minutes Wizard Demonstration: 5 minutes Student Activity 1 and 2: 30 minutes Conclusion: 5 minutes
Learning Targets:	Students will be introduced to Hero of Alexandria and his invention. Students will build and test their own Hero's Engine. Students can continue testing by changing their variables.
Introduction for Students: 5 minutes	**Ask students what they already know about Sir Isaac Newton and his Laws of Motion.** **Ask students to explain Newton's 3rd Law of Motion.**
Guided Lesson: 5 minutes	Hero of Alexandria was an ancient Greek mathematician and engineer. (c.10–70 CE) He is famous for his many contraptions and experiments. One of his most famous inventions was an Aeolipile, also known as Hero's engine. It was a spinning copper sphere that was propelled by a thrust produced by a jet of steam. It was an early demonstration of the action-reaction principle stated by Sir Isaac Newton 1,700 years later.

	Your activity today will simulate the operation of the classic engine he invented more than 2,000 years ago.
Prepping the Room:	Divide your students into small groups. Set up water tubs around the classroom and fill the tubs with about 20 cm of water. - Have no more than one or two teams test their engines at one time. - Discuss the importance of keeping the water in the tubs. - When engines are filled, they should not be raised any higher than the rim of the tub. This will keep water coming out of the holes from spilling on to the floor. - Be sure to recycle the cans at the conclusion of the activity.
Wizard Demonstration: 5 minutes	Have students sit in their teacher created groups. Demonstrate the procedure for punching holes in the cans. - The idea is to punch the hole without crushing the can sides. - Place the nail point near the bottom rim of the can. - Apply pressure with the nail, turning it, if necessary, to make the hole. - When the hole is punched, push the nail head to the right or to the left. - This will angle the hole so that water will stream out on a tangent to produce thrust. - Rotate the can 1/4 turn and punch a second hole. - Again angle the hole (in the same direction as before). 



Student Activity #1:
(Activity 1 and 2: 30 minutes)

Remind students: It is very important to work carefully.
The idea is to punch the hole without crushing the can sides.

<u>Teams should only punch holes in their first can right now!</u>

DO this as a class, so they can follow your directions.

1. Using the nail point, punch holes in the can.
   - Place the nail point near the bottom rim of the can.
   - Apply pressure with the nail, turning it, if necessary, to make the hole.

2. When the hole is punched, push the nail head to the right or to the left. This will angle the hole so that water will stream out on a tangent to produce thrust.

3. Rotate the can 1/4 turn and punch a second hole. Again angle the hole (in the same direction as before).

4. Repeat the procedure two more times to make four holes in total.

5. Tie a string to the pop tab.

6. Place a sticker or a dot with a permanent marker near the top of the can. (There is a mark on the edge of the tub too, this will help students count the rotations.)

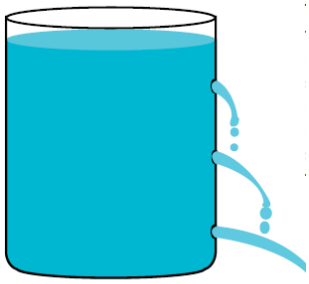
7. Immerse the can in the tub of water.

	8. When the can is full of water, lift it out by the string and observe the rotational motion. 9. Count the number of rotations and record results on Data Sheet. 
Student Activity #2: (Activity 1 and 2: 30 minutes)	Use the Data Recording Sheet to continue with your experimentation. (Provide each team with a Data Sheet.) 1. Review the instructions on the page and discuss the objective. ("Design an experiment to find a way to increase the number of rotations the Pop Can Hero Engine makes.") 2. Discuss student ideas for variables to test (hole size, number of holes, etc.). **Discuss the importance of changing only one thing at a time.** - The first Hero engine they created will serve as the baseline experiment. - The second and third engines will vary just one thing. (For example, Can 1 - medium size holes, Can 2 - smaller holes, Can 3 - larger holes) 3. Discuss ideas for keeping track of the number of rotations the cans make. (Place a large bright mark on one side, etc.) 4. Give teams time to pick their experiment, devise their hypothesis, and write the procedures they will follow on their experiment page.
Conclusion: 5 minutes	Have students clean up all materials, then discuss and review: What provides the force that causes the cans to rotate? - Actually, there are a combination of factors that contribute to the force that causes the cans to rotate. The most important is the force of gravity. It attracts

	the water in the can and causes it to stream out the holes. The shape of the hole directs the water streams. The diameter of the hole determines how fast the water streams out, etc. Which of Newton's laws of motion explains why the can rotates in the opposite direction from the direction of the water streams? - Newton's third law of motion Based on the results of the individual team experiments, what could you do to maximize the number of rotations of the Pop Can Hero Engines? - Individual answers: combine best hole size with the right number of holes, best placement, etc.

Potential Variables:

- Hole size, hole angle, number of holes, and the placement of the hole above the base of the can all affect the thrust produced.
- The most significant of these variables is the hole placement.
    - The greatest thrust occurs when the holes are punched just above the bottom of the can.
    - The strength of the water stream (thrust) is based on the pressure.
    - Water pressure in a container is the greatest at the bottom.
    - The pressure at the top of the water in the container is zero.
    - The water stream gets stronger the closer the hole is to the container bottom.
    - Thrust stops when water drains out to the level of the holes.
    - Holes at the bottom of the container produce thrust for a longer time.



The effects of the other variables are many.

- More holes means more water streams out of the can, but the water drains from the can more quickly.
- Large holes drain water more quickly than small holes. Ask students if this will affect the pressure.
- Holes angled in different directions counteract each other.
- Holes that are not angled produce water streams that leave the can perpendicular and no rotation occurs.

(The object is to have students discover the effects of the different variables themselves.)

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