<u>Pop Can Hero</u> **Primary Audience: 3rd – 10th Grade**

Description: Demonstrate Newton's Third Law of Motion by using the force of falling water to cause a soda pop can to spin.

Keywords: Newton's Laws of Motion

Concepts:

- An object at rest will stay at rest and an object in motion will stay in motion, unless acted upon by a force. (Newton's First Law of Motion)
- Force equal mass times acceleration. (Newton's Second Law of Motion)
- For every action there is an equal and opposite reaction. (Newton's Third Law of Motion)

Materials:

- For Demonstration:
  - Skateboard
  - Hero Engine
  - Heat Source
- Per Participant:
  - Pop Can
  - Screwdriver
  - Fishing Line
  - Access to Water

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Instructions:
A roller coaster will move along at track only when it is pulled by gravity or pushed by an outside force such as linear induction (magnetic propulsion). The train pushes on the magnets, and the magnets in turn push on the train. The whole process is very similar to riding a skateboard.

Imagine that a skateboard and rider are in a state of rest (not moving). *(Reveal a skateboard and climb on board.)* What would happen if I were to jump off the skateboard? *(Take a few hypotheses and then forcibly leap from the skateboard.)* In Newton's Third Law of Motion, the jumping is called an action. The skateboard responds to that action by traveling some distance in the opposite direction. The skateboard's opposite motion is called a reaction.

To further demonstrate Newton's Third Law of Motion, let's examine the Hero Engine. The Hero Engine is similar to a water kettle…heat it up…steam comes out.

Demonstration of Hero Engine:

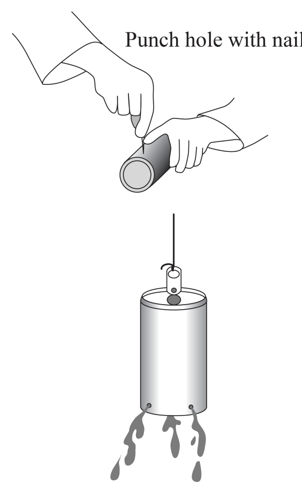
1. Place a small amount of water (about 10 to 20 ml) into the float. The precise amount is not important. The float can be filled through the top if you drilled an access hole or through the tubes by partially immersing the engine in a bowl of water with one tube submerged and the other out of the water.

2. Suspend the engine and heat its bottom with the torch according to the diagram. In a minute or two, the engine should begin spinning. Be careful not to operate the engine too long because it may not be balanced well and could wobble violently. If it begins to wobble, remove the heat.

QuickTime™ and a
TIFF (Uncompressed) decompressor
are needed to see this picture.

Making a Soda Pop Can Hero Engine:

1. Distribute one soda pop can and one screwdriver to each group. Tell the participants that you will demonstrate the procedure for making the Hero engine.
2. Lay the can on its side and use the screwdriver to punch a single hole near its bottom. Before removing the screwdriver, push the handle to one side to bend the metal, making the hole slant in that direction.
3. Remove the screwdriver and rotate the can approximately 90 degrees. Make a second hole like the first one. Repeat this procedure two more times to produce four equally spaced holes around the bottom of the can. All four holes should slant in the same direction going around the can.
4. Bend the can's opener lever straight up and tie a 40-50 centimeter length of fishing line to it. The Soda Pop Can Hero Engine is now complete.



Running the Engine:

1. Dip the can in the water tub until it fills with water. Ask the participants to predict what will happen when you pull the can out by the fishing line.
2. Have each group try out their Hero Engine.

Possible Interactive Questions:

- What were your observations? Why did the cans begin spinning when water poured out of the holes?
- What was the action? What was the reaction?
- Did all cans spin equally well? Why or why not?

What's Going On?
Hero of Alexandria invented the Hero engine in the first century B.C. His engine operated because of the propulsive force generated by escaping steam. A boiler produced steam that escaped to the outside through L-shaped tubes bent pinwheel fashion. The steam's escape produced an action-reaction force that caused the sphere to spin in the opposite direction. Hero's engine is an excellent demonstration of Newton's Third Law of Motion.

During the group activity, the action is the force produced by falling water, while the reaction is the spinning of the pop can.

Newton's Law states that every action has an equal and opposite reaction. If you have ever stepped off a small boat that has not been properly tied to a pier, you will know exactly what this law means.

With rockets, the action is the expelling of gas out of the engine. The reaction is the movement of the rocket in the opposite direction. To enable a rocket to lift off from the launch pad, the action, or thrust, from the engine must be greater than the weight of the rocket. While on the pad the weight of the rocket is balanced by the force of the ground pushing against it. Small amounts of thrust result in less force required by the ground to keep the rocket balanced. Only when the thrust is greater than the weight of the rocket does the force become unbalanced and the rocket lifts off. In space where unbalanced force is used to maintain the orbit, even tiny thrusts will cause a change in the unbalanced force and result in the rocket changing speed or direction.

One of the most commonly asked questions about rockets is how they can work in space where there is no air for them to push against. The answer to this question comes from the Third Law. Imagine the skateboard again. On the ground, the only part air plays in the motions of the rider and the skateboard is to slow them down. Moving through the air causes friction, or as scientists call it, drag. The surrounding air impedes the action-reaction.

As a result rockets actually work better in space than they do in air. As the exhaust gas leaves the rocket engine it must push away the surrounding air; this uses up some of the energy of the rocket. In space, the exhaust gases can escape freely.

Further Exploration:

1. Experiment with different ways of increasing the spin of the can. Does increasing the size of the holes increase spin?

- Provide each group with the materials listed above; however, this time screwdrivers should have different diameter shafts from the one used to make the first engine. Identify these screwdrivers as small (S) and large (L).
- Have the groups make two additional engines exactly like the first, except that the holes will be different sizes.
- Discuss how to count the times the engines rotate. To aid in counting the number of rotations, stick a brightly colored round gum label or some other marker on the can. Tell them to practice counting the rotations of the cans several times to become consistent in their measurements before running the actual experiment.
- Discuss the results of each group's experiment. Did the results confirm the experiment hypothesis?
- Ask the students to propose other ways of changing the can's rotation (Make holes at different distances above the bottom of the can, slant holes in different directions or not slanted at all, etc.) Be sure they compare the fourth Hero Engine they make with the engine previously made that has the same size holes.

Relevant Ohio Science Content Standards:

- Physical Sciences 3-5: Describe the forces that directly affect objects and their motion.
    - 3.4: Predict the changes when an object experiences a force (e.g., a push or pull, weight and friction).
- Physical Sciences 6-8: In simple cases, describe the motion of objects and conceptually describe the effects of forces on an object.
    - 8.3: Explain that an unbalanced force acting on an object changes that object's speed and/or direction.
- Physical Sciences 9-10: Explain the movement of objects by applying Newton's three laws of motion.
    - 9.22: Demonstrate that any object does not accelerate (remains at rest or maintains a constant speed and direction of motion) unless an unbalanced (net) force acts on it.
    - 9.23: Explain the change in motion (acceleration) of an object. Demonstrate that the acceleration is proportional to the net force acting on the object and inversely proportional to the mass of the object. (F net=ma. Note that weight is the gravitational force on a mass.)
    - 9.24: Demonstrate that whenever one object exerts a force on another, an equal amount of force is exerted back on the first object.