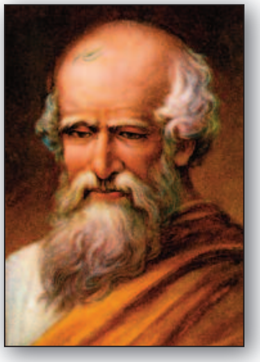
The Coal Stoker

National Railroad Museum

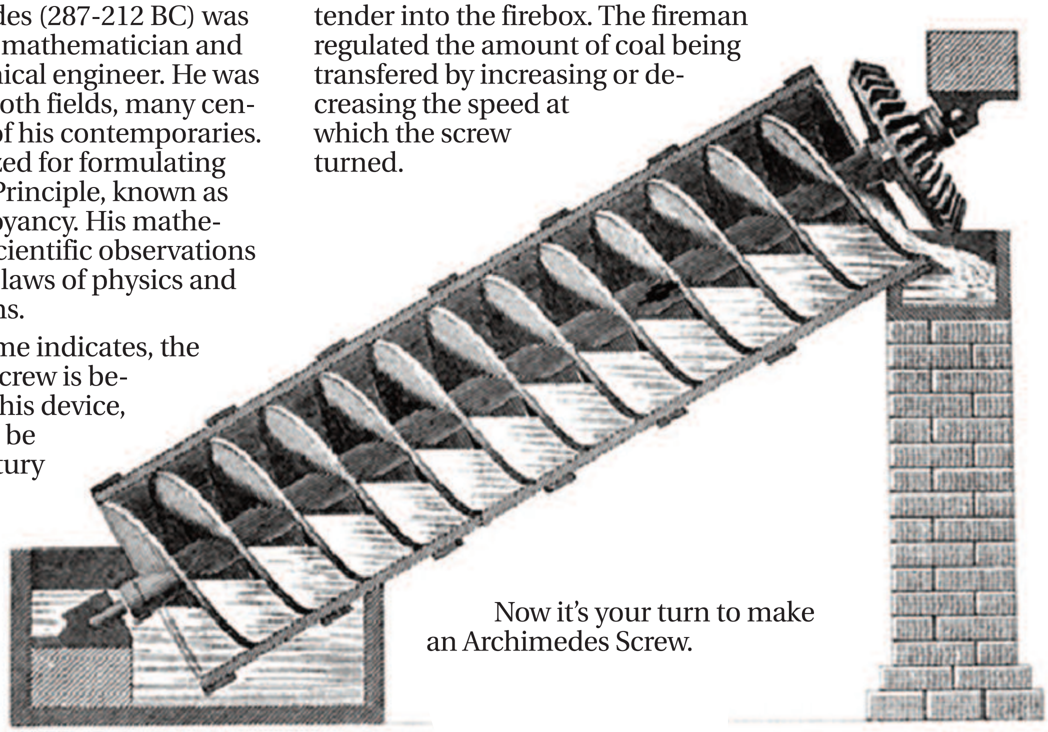
Experimenting with an Archimedes Screw



Archimedes (287-212 BC) was a Greek mathematician and mechanical engineer. He was a pioneer in both fields, many centuries ahead of his contemporaries. He is recognized for formulating Archimedes' Principle, known as the law of buoyancy. His mathematical and scientific observations include other laws of physics and math theorems.

As the name indicates, the Archimedes Screw is believed to be one of his inventions. This device, used for lifting water, can, however, be traced to Egypt prior to the 3rd century BC. Some accounts indicate that Archimedes adopted the idea as a means to pump water from the bilge or bottom of a boat's hull.

For the railroads, the Archimedes Screw was part of coal stoker on steam locomotives. The screw carried coal from the tender into the firebox. The fireman regulated the amount of coal being transfered by increasing or decreasing the speed at which the screw turned.



Now it's your turn to make an Archimedes Screw.

What you'll need

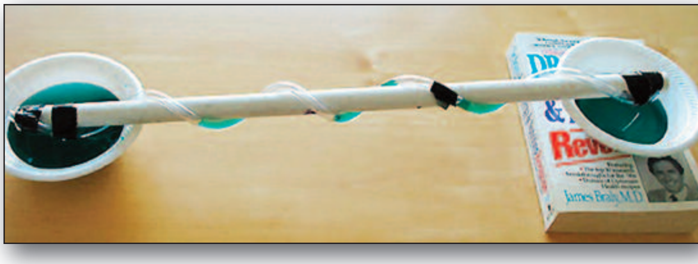
- PVC pipe, ½" inner dia., 2' length
- Clear vinyl tubing, 10' length, with a 3/8" outer dia. x ¼" inner dia.
- Clear vinyl tubing, 10', with a 3/4" outer dia. x ½" inner dia.
- Strong and sticky tape, such as Gorilla or duct tape
- Permanent marker
- Retractable blade knife or strong scissors
- Lab notebook
- Liquid measuring cup
- Spoon
- Water
- Food coloring
- Bowls, 12oz (2); plastic, glass, or ceramic
- Tape (clear tape works fine)
- Pen
- Books of various thickness or pieces of plywood
- A Helper
- Graph paper

Experimental Procedure

Making Your Archimedes Screw

1. Using the PVC pipe and the ¼"-inner-diameter vinyl tubing, take a piece of strong tape and tape one end of the tubing to the outside of one end of the pipe such that a ¼" length of tubing is hanging off the end.
2. Carefully wrap the tubing around the pipe in regular intervals until you come to the other end of the pipe. From that point, add a ¼" and mark that spot on the vinyl tubing with a permanent marker.
3. Unwrap the tubing and cut it with scissors or a knife at the mark. Ask an adult for assistance.
4. Rewrap the cut piece of tubing around the pipe in regular intervals and tape it down with pieces of strong tape along the pipe. There should be a ¼" of tubing hanging off both ends of the pipe, past the sections that you taped down. The starting section will reach into the water, allowing it to travel through the tube and the end section will help get the water out. By wrapping the tubing in regular intervals you are establishing the period of the tubing.
5. Count the number of times you have wrapped the tubing around the PVC pipe. Divide 2' (the length of the PVC pipe) by the number of times you wrapped the tubing around the PVC pipe. This value is the period and is in units of feet. Note this in your lab notebook.

Experimenting with an Archimedes Screw



Here's what your experimental Archimedes Screw could look like.

Setting Up Your Bowls

1. In your liquid measuring cup, mix a few drops of food coloring in 1 cup of water. This makes the water easier to see.
2. Now make tape loops with the Scotch tape to stick to the bottom of one of the Styrofoam bowls and press the bowl onto a table so it stays in place.
3. Pour a ½ cup of the colored water into the other bowl. With a pen, mark the level of the water on the bowl. Pour the water back into the measuring cup.
4. Making more tape loops, carefully tape the marked bowl onto one of the books or plywood boards so that it will stay in place during the experiment. This bowl is the discharge bowl.

Testing Your Experimental Setup

1. Now you are ready to test your experimental setup and determine what slope works best so you can run your trials. Place the marked bowl on the book or plywood about 2 feet away from the bowl taped to the table. Pour 1 cup of water into the first bowl.
2. Place your Archimedes screw across the two bowls. Be sure the extra ¼" of tubing hanging off the end is in the bowl of water on the table. Turn the screw so that every time the end of the tube goes into the water it scoops up some of the water.
3. Tilt the screw so that one end is in the water and the other end is in or close to the bowl that you want to move the water to, which in this case, is the bowl taped to the book or plywood.

   Make sure that as you turn the screw, the water doesn't fall back out of the screw. If the water does fall out, adjust the tilt of the screw, the placement of the bowls, and/or the height of the discharge bowl. Use an extra book or board if needed.
4. Turn the screw a few times to make sure that the water is traveling through the tubing. Experiment with how fast you can turn the screw and still move water through the tube. Going too fast might not lead to positive results.

Running Your Trials

1. Now you're ready to start running your trials. Hold the screw vertically and empty all of the water from the tubing and the discharge bowl back into the bowl on the table.
2. Using your permanent marker, make a mark on the middle of the pipe at the position when the vinyl tubing is just about to enter the water. This will help you keep track of the number of turns you make. Turn the pipe so the mark is facing up, and then start turning the screw until the mark is facing up again. You have made one turn and should see some water in the tubing. On each successive turn, the opening of the tubing should be completely under water so that you scoop as much as possible.
3. Continue turning the screw until a ½ cup of water is in the discharge bowl. Make sure that you maintain the same tilt the whole time you are turning the screw. Also make sure that you are scooping up water on every turn. Have your helper help you count the number of turns as you go along. You can gauge when you have about a ½ cup in the discharge bowl, based on the pen marking you made when you first started. To be exact, confirm that you have a ½ cup of water in the discharge bowl by pouring it into the measuring cup. One person should hold the screw in place and the other person should carefully remove the bowl from under the screw and measure the water.

   a. If the amount of water in the discharge bowl is not a ½ cup, continue turning the screw until you get a ½ cup.

   b. If the amount of water in the discharge bowl is greater than a ½ cup, empty all of the water back into the first bowl and restart this step.
4. Keep track of the number of turns it takes to move a ½ cup of water from the starting bowl into the discharge bowl. Note this in your lab notebook.
5. Repeat "Running Your Trials" two more times. Every time that you start a new trial, empty all of the water back into the measuring cup. Make sure that you have a full cup of water at the start of each trial. If you do not, then add water into the measuring cup until you have 1 cup. For each trial, note the information in your lab notebook.
6. Calculate the average of the results of the three different trials and record them in your data table.
7. Now unwrap the ¼"-inner-diameter tubing from the pipe. Take the ½"-inner-diameter tubing and wrap that around the ½"-inner-diameter PVC pipe. Use the same period as you did for the ¼" tubing. Wrapping this tubing will be harder than it was with the ¼" tubing because the tubing is larger and stiffer. Have your helper assist you with wrapping. Repeat the entire experiment with the new Archimedes screw. Remember to record the data you collect in your lab notebook.
8. Plot your data. Label the x-axis Design and the y-axis the Average Number of Turns to Move a ½ Cup of Water. Which design is more effective at moving water? Why?

Experimental procedures courtesy of sciencebuddies.org