

Newton's Laws and Water Rockets

This is a two week lesson. In the first week, students go over the theory behind Newtonian mechanics (and how this relates to rockets) and build their rockets. In the second week, students will finish building their rockets, launch them, and then discuss the results of their launches.

Lesson Objectives:

1. Have a general understanding of Newton's three laws of motion
2. Learn about a real-world application of Newton's laws with water rockets, and be able to explain how Newton's laws affect different aspects of rocket flight

Materials:

For each team of 3-4 students:

- One empty 2 liter soda bottle
- Scissors (from class) and construction paper/cardboard
- Duct tape

Other materials:

- Water rocket launch pad (1 for each class)
- Bicycle pump (1 for each class)
- Water measurement device (graduated cylinder or measuring cup) (1 for each class)
- Protractor with an attached washer (attached by a piece of string) (1 for each class)
- Tape measure (1 for each class)

Introduction Lecture to Newton's Laws of Motion (20 min.)

Ask students if they've ever heard of Isaac Newton, and see if they can name some things they know about him. Explain that he was a physicist who lived in the 1600's, and studied things about how objects move. Some students may have heard of the story about Newton "discovering" gravity when an apple hits him on the head. Explain that people have always known about gravity, but Newton was the first person to come up with a **theory** describing how gravity works. Explain to the students how scientists observe the world around them and come up with theories on how different things work. A scientific theory is a well-proven explanation of the physical world we live in. See if they can name some other scientific theories.

Introduce Newton's laws of motion. Newton came up with three laws to describe how objects move. Before you ask the students what the three laws are, talk about the idea of a **force**. Don't move on until the students have a fairly firm grasp on what a force is.

Newton's 3 laws:

1. An object in motion stays in motion (inertia) and an object at rest stays at rest unless acted upon by a net external force
2. Force = mass · acceleration
3. Every action has an equal and opposite reaction

Explain what each of these laws mean.

1. For the first law, you can give the example that a ball lying on the ground doesn't suddenly start moving unless someone kicks it (exerts a net external force on it).
2. The second law may be the most difficult to explain due to its mathematical nature, but try to have them understand that if the mass of an object increases, it takes a bigger force to move it (the heavier an object, the harder it is to accelerate), and that to make something move faster you need to apply a larger force. Make sure they understand what is meant by acceleration, and that they understand the difference between velocity (which is how fast something moves) and acceleration (which is the change in time of velocity).
3. For the third law, an effective demonstration is to stand up against the wall and push (you are exerting a force against the wall) so they can see that the wall exerts an equal and opposite force on you (you are pushed backwards).

Talk about how we can use Newton's laws to very accurately predict the path of everything from basketballs to ballistic missiles to spaceships and satellites in space.

Build Water Rockets

(Rest of the time on the first day and 10 minutes on the second day)

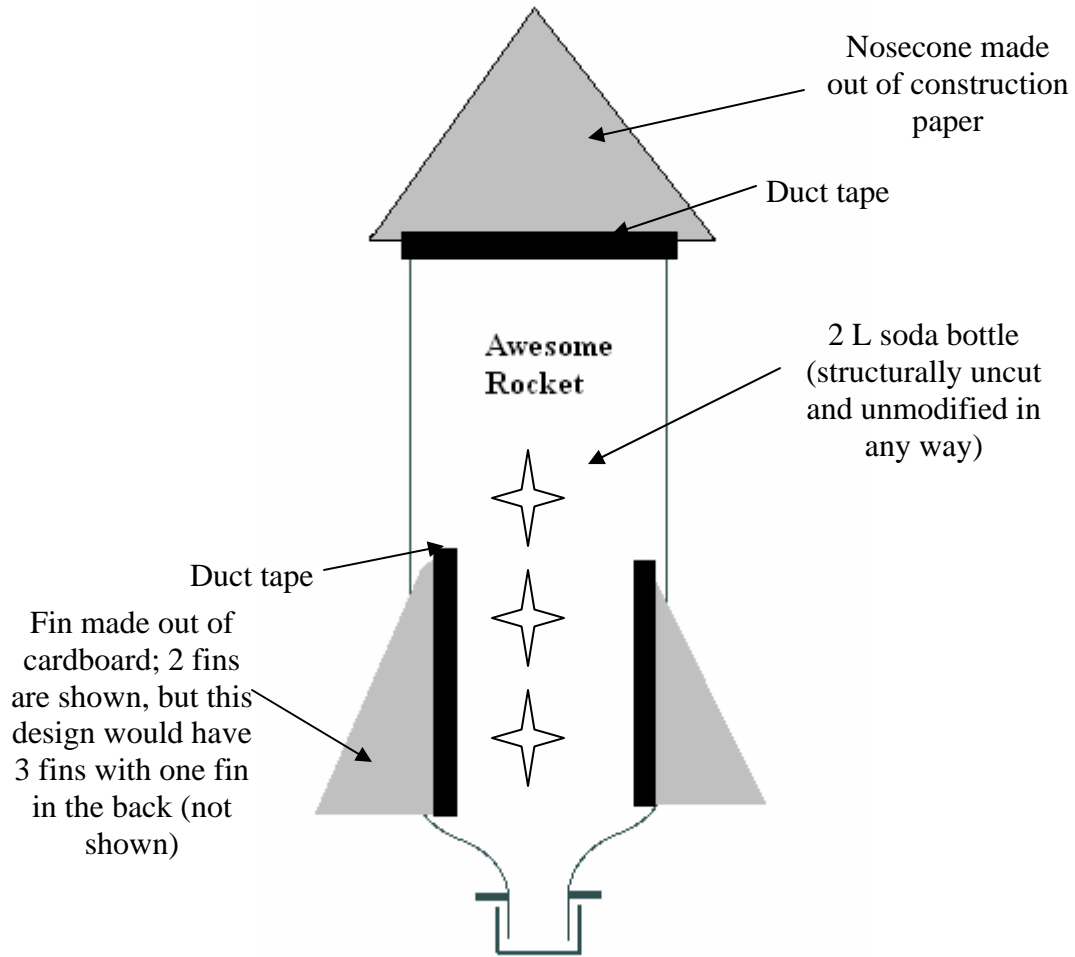
Before you hand out the supplies for the water rockets, explain how they work and ask the students which of Newton's laws apply to them. You should talk about **what forces are acting on the water rocket** to make it move (talk conceptually about the idea of a free body diagram). You should have the force from the ejected propellant acting upwards, and the weight and air resistance acting downwards.

Talk about **how each law applies to the physics of the water rocket**. Try to have the students identify which of Newton's laws applies to the following descriptions of the rocket's physics. The rocket moves because the ejected combusting propellant exerts and opposite and equal force on the bottle which pushes the bottle up (3rd law), and the larger that force is, the faster it will accelerate and move (2nd law). Eventually the rocket

reaches a peak height because external forces (air friction/drag and gravity) act on it (1st law).

Now talk about **what happens if we add too much water**. The mass of the bottle will increase, so it takes a larger force to make it accelerate and hence it won't go as high as when we give it the same force as a rocket with less water. But if there is too little water, there isn't as much force exerted from the propellant because the propellant mass is small and as in the case of too much water, the rocket does not go as high as when it has an optimal amount of water.

If there is time, talk about how the water rockets are simple models of actual rockets that travel up into space. Each group will design its own water rocket, and decide how much water to put in. For the design, you can suggest to the students ideas on how to reduce drag/air friction (i.e., a cone top), or that they might want to add fins. We will not have the students add a parachute to their rockets. In addition, **do not allow the students to cut into the bottle since this prevents the bottle from being pressurized which is essential to launching the rockets; If students cut into their bottles in any way, they will not be able to launch their rockets. Also, do not allow the students to wash their bottles out with warm water since this degrades the plastic, and presents a potential danger when pressurizing the rockets; Rockets with degraded plastic may fail when being pressurized.** Other than that, the students should try to be creative in designing their rockets! They are also welcome to decorate their rockets using paper cutouts or other art supplies that they might have in their class. A simple example of what students might come up with is shown below:



Next week there will be 10 minutes to finish building the water rockets, and then the class will go outside to test them.