

Bottle Rocket Lab

Physics Concepts: **Newton's 1st Law** - Every object in a state of uniform motion tends to remain in that state of motion unless an external force is applied to it.

This we recognize as Galileo's concept of inertia, and this is often termed simply the "Law of Inertia."

Newton's 2nd Law – If an unbalanced (net) force acts on an object, that object will accelerate (or decelerate) in the direction of the force.

Newton's 3rd Law – For every action force, there is an equal and opposite reaction force.

A body at rest is considered to have zero speed (a constant speed). So any force that causes a body to move is an unbalanced force. Also, any force, such as friction, or gravity, that causes a body to low down or speed up, is an unbalanced force. This law can be shown by the following formula.

$$F=ma$$

- **F** is the unbalanced force (vector)
- **m** is the object's mass (scalar)
- **a** is the acceleration that the force causes (vector)

Force and acceleration are both vector quantities. In this law the direction of the force vector is the same as the direction of the acceleration vector.

Vector and Scalar Quantities: An understanding of vectors is essential for understanding of physics and Newton's Second Law. A vector is a quantity that has two aspects. It has a size, or magnitude, and a direction. In contrast, there are quantities called scalars that have only size.

If a quantity has only a size, it is called a scalar. Mass, distance, speed, time and temperature are examples of scalars.

If a quantity has a size and a direction, it is a vector quantity. Force, acceleration, velocity, displacement, gravitational field, torque, and electric and magnetic fields are all vectors.

The following excerpt is borrowed from the NASA website:
<http://exploration.grc.nasa.gov/education/rocket/newton1r.html>

It explains how Newton's three laws apply in rocket flight.

Sir Isaac Newton first presented his three **laws of motion** in the "Principia Mathematica Philosophiae Naturalis" in 1686. His first law states that every object remains at rest or in uniform motion in a straight line unless compelled to change its state by the action of an external force. This is normally taken as the definition of inertia. The key point here is that if there is no net **force** acting on an object (if all the external forces cancel each other out) then the object maintains a constant velocity. If that velocity is zero, then the object remains at rest. If the velocity is not zero, then the object maintains that velocity and travels in a straight line. If a net external force is applied, the velocity changes because of the force.

The liftoff of a rocket from the launch pad is a good example of this principle. Just prior to engine ignition, the velocity of the rocket is zero and the rocket is at rest. If the rocket is sitting on its fins, the **weight** of the rocket is balanced by the re-action of the earth to the weight as described by Newton's **third law** of motion. There is no net force on the object, and the rocket would remain at rest indefinitely. When the engine is ignited, the **thrust** of the engine creates an additional force opposed to the weight. As long as the thrust is less than the weight, the combination of the thrust and the re-action force through the fins balance the weight and there is no net external force. The rocket stays on the pad. When the thrust is equal to the weight, there is no longer any re-action force through the fins, but the net force on the rocket is still zero. When the thrust is greater than the weight, there is a net external force equal to the thrust minus the weight, and the rocket begins to rise. The velocity of the rocket increases from zero to some positive value under the acceleration produced by the net external force.

As the rocket velocity increases, it encounters air resistance, or **aerodynamic drag**, which opposes the motion. Drag increases as the square of the **velocity**. The thrust of the rocket must be greater than the weight plus the drag for the rocket to continue accelerating. If the thrust becomes equal to the weight plus the drag, the rocket continues to climb at a fixed velocity, but it does not accelerate. This flight condition is often encountered by **model rockets** because of the low thrust and high drag of their design. Full scale rockets usually have sufficient excess thrust to continue accelerating. Drag eventually begins to decrease because drag depends on the air **density** and density decreases with increasing **altitude**.

Newton's 3rd law applies to bottle rockets in the same manner except that the fuel is not burned. A rocket gets its lift from the built up air pressure and the water pushing out of its tail. The force of these fluids is the action force. They force the rocket up in the opposite direction creating the reaction force.

Directions for building the bottle rockets:

Materials:

- 2 liter soda bottles
- Construction paper
- Heavy paper
- Modeling clay
- Garbage bags
- Rulers
- String
- Duct tape
- Scissors
- Rulers
- Tag Board

Design Ideas:

- Fins:
 - Fins should be firm
 - Fins should be secure: duct tape works well
 - The size of the fin matters. It works well to make a few patterns for students to model their fins from.
Check out Mr. Hayhurst's Quick and Easy Bottle Rocket site for some great patterns and ideas:
<http://www.lnhs.org/hayhurst/rockets/>
 - Use the string to measure the diameter of the bottle and divide the length of the string by three. Make two marks on the string dividing it into three equal parts and use those marks to mark the bottle for accurate placement of the fins.

- Nose Cone:
 - Tag board builds a firm secure nose cone
 - The nose cone should have a higher mass to surface area ratio
 - Modeling clay can be used to allow students to add mass to the nose cone.
 - The nose cone must go through the air easier than the body of the rocket.
 - If students choose to add a parachute...the nose cone needs to be able to separate from the rocket body
 - After applying the the nose cone and fins, a string should be tied around the middle of the rocket to see if the rocket hangs evenly. If it doesn't, then it has too much weight on one end or the other and should be balanced. You can also fly it overhead on the string to see if it is balanced in flight.



- Parachute: (optional)
 - A garbage bag parachute will work
 - Cut open the bag so that it can lay flat.
 - Attach strings to the end of the bag
 - Place bag inside the nose cone and attach the loose end of the strings to the inside of the sleeve on the body of the rocket.
 - Use a “z” fold to insert the parachute, do not wrap the strings around the parachute. (see Mr. Hayhurst’s web site referenced above for a pattern)



Preliminary Questions to ask:

- What is a bottle rocket and what does it have to do with science?
- Why do bottle rockets fly?
- What is the expected outcome for these rockets?
- Why do we have to use water...or do we?
- Will it fly without water?
- If a little water works, will a lot of water work better?

Proceeding Questions to ask:

- Why did the rocket that was full of water barely take off?
 - It was too heavy or massive. This can be explained with Newton’s first law of motion.
- The rocket didn’t have enough “oomph” (force) to make it take off. Why?
 - There was not enough force for the relatively huge mass. The force from the pressurized water leaving the rocket must be greater than the force due to gravity (weight of rocket and water). More mass can cause less acceleration using the same force. This can be explained with Newton’s second law of motion.
- Why did the water go one way and the rocket the other:
 - There is an equal force in both directions. This can be explained by Newton’s third law of motion.

Assessment:

Assessment will be performance based with weight given to rocket construction, data recording and analysis.

National Standards:

- Content Standard A—Science as Inquiry
- Content Standard B—Physical Science
- Content Standard E—Science and Technology