4-H 503

ROCKETS AWAY!

A fun approach to exploring the science of rocketry

For Solid-Fuel Model Rockets

Revised Edition, 2012

Member Project Guide

Project Background

This beginning level project is designed for 5th–8th grade members. Younger members may take this project only under the direct supervision of an adult. This project explores the basics of rocketry through a variety of hands-on experiments. Members are also encouraged to apply what they learned through the design, construction, and launching of rockets.

Check your county project guidelines for additional requirements for taking this project, especially if you choose to participate in county project judging or prepare an exhibit for the fair. Members who complete this project are encouraged to take a self-determined project in rocketry.

Project Guidelines

1. Complete the Planning Your Project section of this guide (steps 1-4).
2. Explore each of the three Project Interest Areas.
3. Complete all activities within each Project Interest Area. Going Beyond and Digging Deeper activities are optional.
4. Take part in at least two Organized Project Activities.
5. Become involved in at least two Leadership/Citizenship activities.
6. Members are required to build and launch a solid-fuel model rocket; scratch built or kit. At least four launches must be recorded in the Flight Data section on pages 19–22.

Before beginning your project, please read and sign the Model Rocket Safety Code on the inside back cover.

Planning Your Project

STEPS 1 and 2: Project Interest Areas and Activities

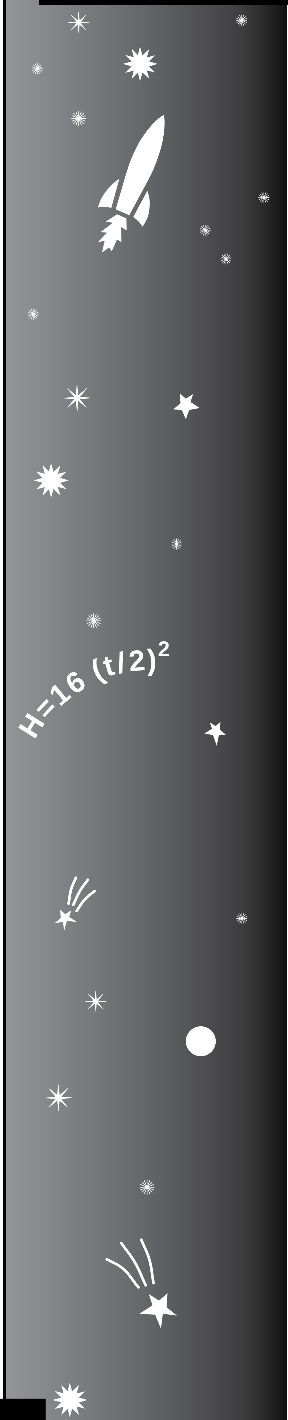
Explore each of the three Project Interest Areas listed below. As you begin to explore a Project Interest Area, place the current date (month/year) next to it. Plan to complete all activities in each Project Interest Area selected. Digging Deeper and Going Beyond activities are optional. Have your parent or advisor initial and date what you complete.

Date Started (mo/yr) — **Project Interest Areas**

__________ 1. Rockets and How They Move, Pages 6–10
[ ] Experiment 1—Testing Gravity
[ ] Experiment 2—Let's Get Lifting
[ ] Experiment 3—Bouncing Things
[ ] Experiment 4—Kicking Into Action
[ ] Digging Deeper—Coming and Going
[ ] Going Beyond—Build Your Own Hero Engine

__________ 2. Moving Questions About Rockets, Pages 11–16
[ ] Experiment 5—Try a Little Lift
[ ] Experiment 6—Action/Reaction
[ ] Experiment 7—Add a Nozzle
[ ] Digging Deeper—Nozzles in Everyday Use
[ ] Experiment 8—Add a Stick
[ ] Experiment 9—Add a Fin
[ ] Experiment 10—Testing Turbulence
[ ] Experiment 11—Broom Launch

__________ 3. Let's Get Launching, Pages 17–24
[ ] Build and launch a solid-fuel model rocket; scratch built or kit
[ ] Record at least four launches in the Fligh-Data section on pages 19–22
[ ] Digging Deeper—Tracking
[ ] Digging Deeper—Improving Your Rocket's Design



STEP 3: Organized Project Activities

Select two of the Organized Project Activities listed below, and plan your involvement in the “Report of Organized Project Activities” chart. Before starting your project, write your two choices in the section labeled “Plan to Take Part In.” Once you have taken part in an activity, record what you did and when. Organized Project Activities may be added or changed at any time.

Sample Organized Project Activities

Demonstration	Speech	County Judging	Radio/TV Presentation
Illustrated Talk	Tour	Project Meetings	Mall Show
Project Exhibit	Workshop	Field Trip	Short Course

Report of Organized Project Activities

Plan to Take Part In	What You Did	Date
(example) Short Course	*Took part in a 3-week course on building model rockets.*	*4/7–4/21*

STEP 4: Leadership/Citizenship Activities

Check off the activities you wish to do, or plan your own in the space provided. Do at least two. Keep track of your progress by dating (mo/yr) what you complete. Leadership/Citizenship Activities may be added or changed at any time.

What I Plan to Do	When I Finished	Leadership/Citizenship Activities
______	______	• Encourage someone to take a rocketry project.
______	______	• Help someone with his or her rocketry project.
______	______	• Organize a rocket science program for your club or classroom.
______	______	• Invite someone to talk to your club on rockets.
______	______	• Prepare and exhibit a poster on rocketry.
______	______	• Teach someone something you learned about rocketry.
______	______	• Encourage a friend to join 4-H.
______	______	• Apply something you learned about rocketry to benefit another club member's family.
______	______	• Help a member prepare his or her rocketry project for judging.
______	______	• Help a member prepare a rocketry exhibit for the county fair.

Or, plan your own activities below.

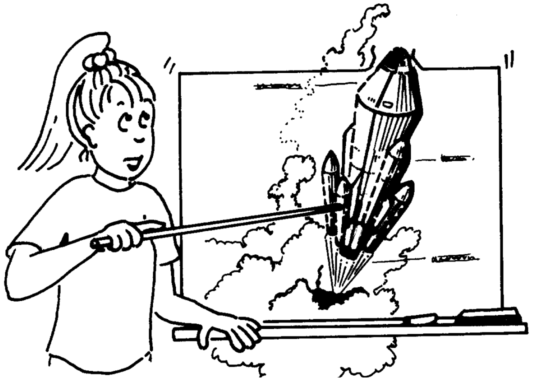
______	______	• ______
______	______	• ______

Project Review

Once you complete what you planned, arrange for local project review. This review can take part with your parent, project leader, or interested adult. It may also be part of a more comprehensive member evaluation at a time agreed upon by club members. Such evaluations are designed to help you evaluate what you learned as well as your growth as a 4-H member. Members who take part in this level of evaluation may receive special membership and project achievement awards like ribbons, pins, or certificates.

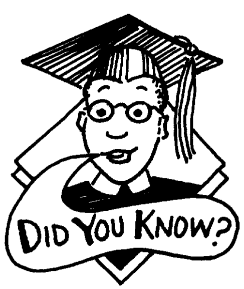
$H=16\ (t/2)^2$

I. Rockets and How They Move



A rocket in its simplest form is a chamber enclosing a gas under pressure. A small opening at one end of the chamber allows the gas to escape in one direction, and in doing so provides a thrust that propels the rocket skyward in the opposite direction. Most historians believe that rockets were invented by the Chinese around the 11th century AD. These early rockets were used by the Chinese to repel invaders, such as the Mongols.

By the thirteenth century, the use of rockets had spread to the Middle Eastern countries where they were known as "Chinese Fire Arrows." These early rockets were little more than tubes stuffed with gunpowder. When the gunpowder was ignited, it exploded and produced hot gases that "pushed" the rockets into flight. Eventually, the use of rockets for both warfare and entertainment spread worldwide. However, it has been only since the last three hundred years that rocket experimenters have actually understood the scientific principles behind the motion of rockets.

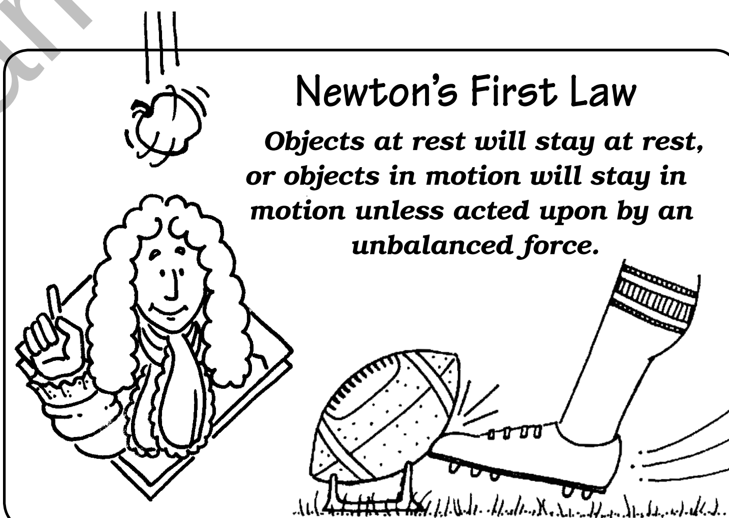


Did You Know?—Rockets were used in many battles including one famous battle against the United States during the War of 1812. During the battle, at Baltimore's Fort McHenry, a young poet named Francis Scott Key watched the rocket bombardment and wrote a poem about "the rocket's red glare/the bombs bursting in air." Later, set to music, that poem became the American national anthem, The Star-Spangled Banner.

The science of rocketry really began with the publishing of a book in 1687 by the English scientist Sir Isaac Newton. In his work, Newton stated three important scientific principles that govern the motion of all objects, whether on earth or in space. Over time, these principles have become known as Newton's laws of motion.

Newton's First Law

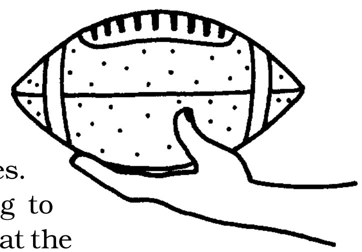
Objects at rest will stay at rest, or objects in motion will stay in motion unless acted upon by an unbalanced force.



In a model rocket's flight, forces become balanced and unbalanced all the time. A rocket sitting on the launch pad experiences a balance of forces. The surface of the pad provides a balanced force against the mass of the rocket being pulled down by gravity. When the engine ignites, its thrust unbalances the forces, allowing the rocket to travel upward. This thrust continues until the engine's fuel is exhausted. Once this occurs, the rocket becomes susceptible to the forces of gravity and atmospheric friction. These unbalanced forces act upon the model's forward motion causing it to slow and eventually fall back to earth.

Experiment 1—Testing Gravity

Materials: ball



Hold a ball in your hand. All the time the ball is held there it is being acted upon by forces. The force of gravity is trying to pull the ball downward, while at the same time your hand is pushing against the ball to hold it up. Now try unbalancing the forces by letting the ball fall from your hands or lifting the ball with your hand.

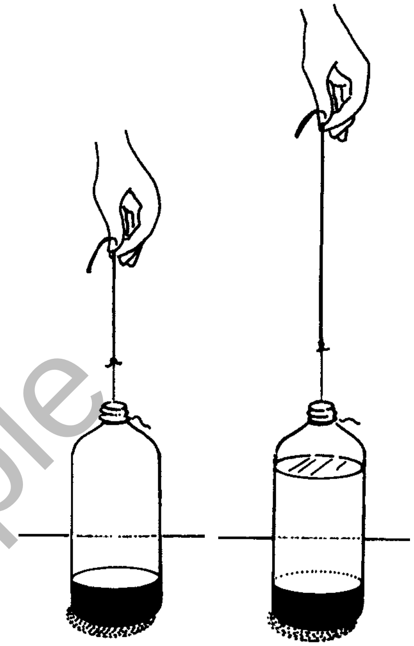
Explanation: By unbalancing either force, you transform the ball from a state of rest to a state of motion.

Experiment 2—Let's Get Lifting

Materials: 16 oz soft drink bottle
string
rubber band
water

Take an empty 16 oz soft drink bottle and tie a string around its neck. Next, take a rubber band and cut it so that you can attach one end to the string. Now, pull the rubber band and measure how much it stretches before the empty bottle lifts. Now take the bottle and fill it with water. Again, pull on the rubber band and measure how much it stretches before the bottle lifts.

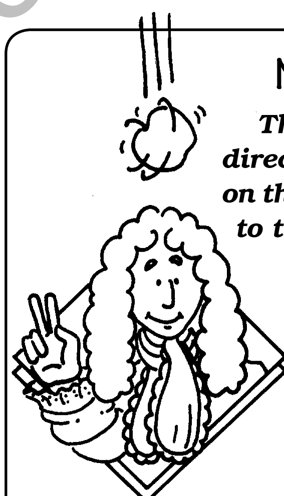
Explanation: As you discovered, a certain amount of unbalanced force was needed to lift the bottle. However, the greater the *mass* of the object, the greater the unbalanced force needed to lift it. Obviously, the idea of mass is an important factor to consider when calculating the unbalanced force necessary to lift the mass of an object like a rocket. This leads us to Newton's second law of motion.

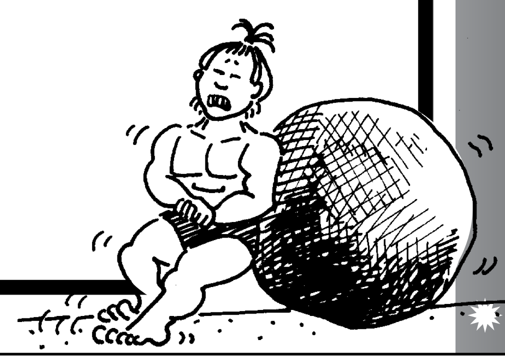


Word to Know—Mass: the amount of matter in an object

Newton's Second Law

The acceleration of an object is directly related to the force exerted on that object and oppositely related to the mass of that object.

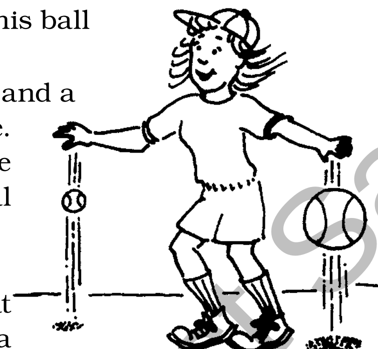




This law is especially useful when designing efficient rockets. To enable rockets to *accelerate* to higher elevations with greater payloads, designers must minimize the rocket's *mass* while maximizing the amount of *force* exerted from its engines. This is typically accomplished by igniting engines in stages. This allows for spent engines to be separated away from the main rocket, thereby decreasing the rocket's mass while increasing its acceleration.

Experiment 3—Bouncing Things

Materials: basketball, tennis ball

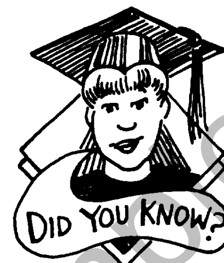


Try bouncing a basketball and a tennis ball at the same time. Compare the difference in force it takes to bounce them equal heights.

Explanation: You know that it takes more force to bounce a basketball than a tennis ball. Of course the basketball is heavier than a tennis ball, but it is not the weight that makes it harder to bounce. If there were no gravity, so that both were weightless, the basketball would still be harder to bounce. This is because the basketball has a greater amount of material in it (*mass*). Therefore, according to Newton's Second Law, the greater an object's mass, the greater its resistance to acceleration.

Next, place the tennis ball on top of the basketball and drop them from a height of about four feet. If done properly, the tennis ball should "shoot up" into the air while the basketball barely leaves the ground.

Explanation: Far more energy is required to make the basketball bounce the same distance as the tennis ball. This is because the basketball has more mass. (*Newton's Second Law*) When the tennis ball is placed on the basketball, a transfer of energy from the basketball to the tennis ball takes place. This is the same principle that is used in the staging of rockets. When separated, much of the energy in the massive lower stages is transferred to the lighter upper stages.

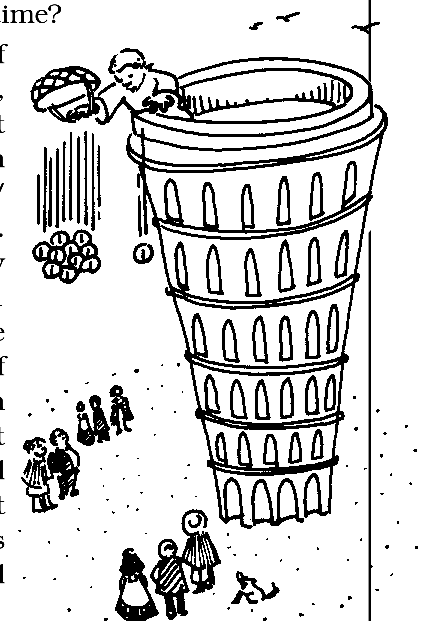


Did You Know?—The larger the mass of an object in motion, the greater the unbalanced force needed to stop it. That is why it is so difficult to stop a freight train once it gets moving. Its moving mass possesses a tremendous amount of inertia.

Word to Know—Inertia: A resistance to a change in motion. The greater the mass of a moving object, the greater its inertia.

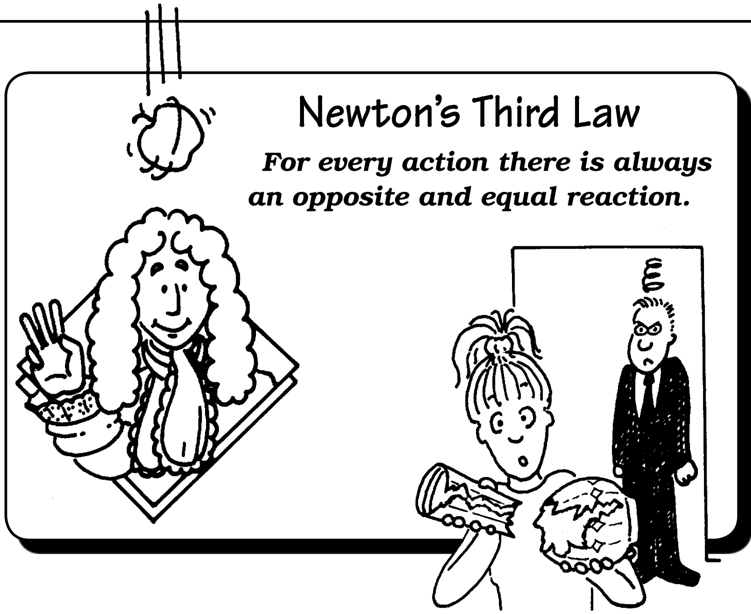
Did You Know?—If the force to bounce a tennis ball and a basketball 10 feet into the air differs, why then will they return to earth at the same time?

In 1590, a man by the name of Galileo (Gal-uh-LEE-oh) Galilei, from Pisa, Italy, discovered that gravity pulls all objects to earth with the same acceleration (*32 ft/second²*) regardless of their mass. It is said that he simultaneously dropped a 10 pound and a 1 pound weight from the top of the Leaning Tower of Pisa. A crowd of students and professors looked on as both weights hit the ground at the same time. Galileo explained that what he did was "no different than dropping ten 1 pound weights at the same time as the 1 pound weight."



Newton's Third Law

For every action there is always an opposite and equal reaction.



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. Of course you might think that a rocket moves by pushing off against the surrounding air. If this were the case, space travel would be impossible, due to the absence of air in space.

Experiment 4—Kicking Into Action

The best way to experience the principle of "action-reaction" is to do it yourself. Begin by finding a smooth surface on which to stretch out. While lying on your back, place your hands to your side and begin kicking your feet outward. If the surface is smooth enough, you should begin moving in the opposite direction of your kicks.

Questions to Answer

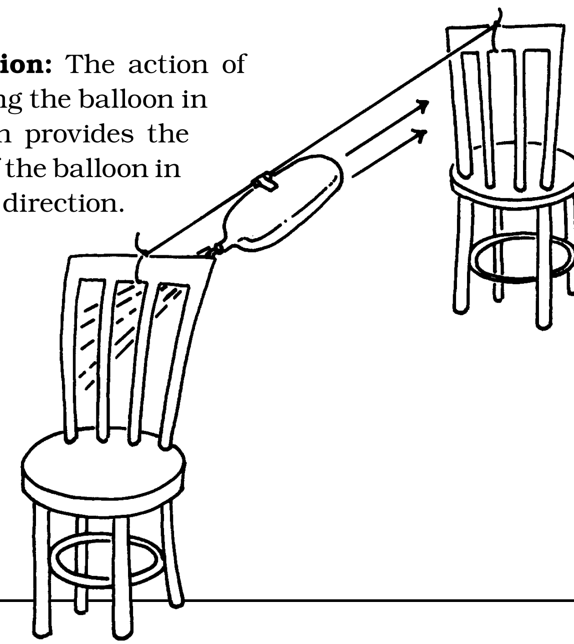
- How is your kicking like the thrust from a rocket's engine?
- Are you pushing against the air to move or is this an example of Newton's Third Law of Motion?
- What happens when you hold a stack of books on your stomach? Does it take more energy to move the same distance as before?
- How is adding weight an example of Newton's Second Law of Motion?

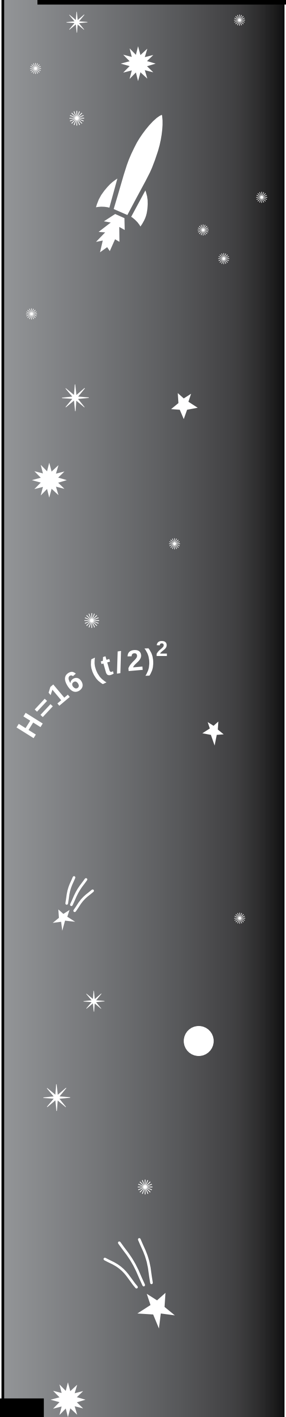
Digging Deeper—Coming and Going

Materials: nylon string
drinking straw
2 chairs
tape
long balloon

Take an 8-foot piece of sewing thread and thread it through a 1-inch piece of drinking straw. Suspend the string between two chairs or a wide doorway as shown. Next, inflate a long balloon and attach it to the 1-inch straw with a piece of tape. Starting at one end of the string, release the balloon and observe how it travels along the string.

Explanation: The action of the air leaving the balloon in one direction provides the movement of the balloon in the opposite direction.



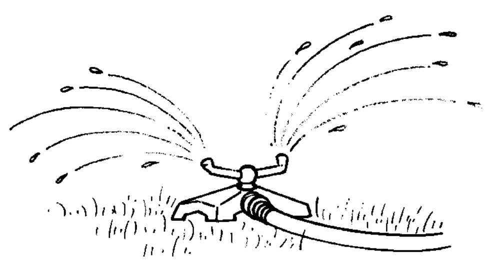


Let's Summarize: For a rocket to lift off from a launch pad, force must be exerted (*First Law*) to unbalance the present forces at work. The rate at which the rocket leaves the launch pad (*Second Law*) will be determined by the mass of the rocket and its fuel, along with the force that is produced when the fuel is burned. The reaction, or motion, of the rocket away from the launch pad (*Third Law*) is equal to and opposite from the action or thrust of the engine.

Going Beyond—Build Your Own Hero Engine

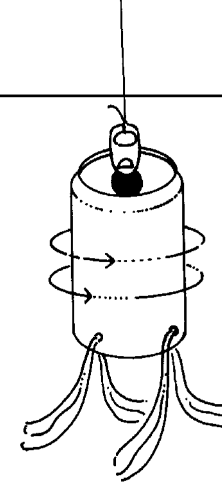
Around 700 BC a Greek man by the name of Heron of Alexandria invented a rocket-like device later known as a "Hero Engine." Heron mounted a sphere on top of a water kettle. A fire mounted below the kettle turned the water into steam, and the gas traveled through pipes to the sphere. Two L-shaped tubes on opposite sides of the sphere allowed the gas to escape, and in doing so gave a thrust to the sphere causing it to rotate.

Little did Heron know that his engine was an excellent example of Newton's three laws of motion. Also, little did he know that his invention would give birth to the lawn sprinkler.



Use the following instructions to create your own Hero type engine.

Materials: aluminum can
nail
hammer
nylon string
bucket
water



1. Lay an aluminum can on its side and using a nail, carefully punch four equally spaced holes just above and around the bottom rim. Then before removing the nail from each hole, push it to the right so that the hole is in a slanted direction.
2. Bend the can's opener lever straight up and tie a short length of nylon string to it.
3. Immerse the can in water until it is filled. As you lift the can by its string, watch how water leaving the can through the holes starts it spinning.

Explanation: First Law—The can spins because gravity pulling water through the holes creates an imbalance of forces on the can. Second Law—The rate of *acceleration* will vary with the *mass* of the can and the water in it. It will also vary with the *force* at which the water leaves the holes. This force is dependent upon the number and size of holes used, along with the volume of water above the holes. Third Law—The can rotates opposite from the direction of the water leaving the can.

Questions to Answer

- If you added weight to the can would it take a longer or shorter amount of time for the can to begin spinning?
- Once the weighted can started to spin, would it take a longer or shorter amount of time for it to stop?
- How does the twist of Earth's gravity (Coriolis effect), caused by the rotation of the planet, influence the motion of the can? [Hint: In the northern hemispere, an unpunctured can filled half-way with water and suspended by a thread will spin counterclockwise just like hurricanes, tornadoes, and water down a drain.]