

ROCKETS AWAY!

A Fun Approach to Exploring the Science of Rocketry

For 2-Liter Bottle Rockets



THE OHIO STATE UNIVERSITY

COLLEGE OF FOOD, AGRICULTURAL,
AND ENVIRONMENTAL SCIENCES



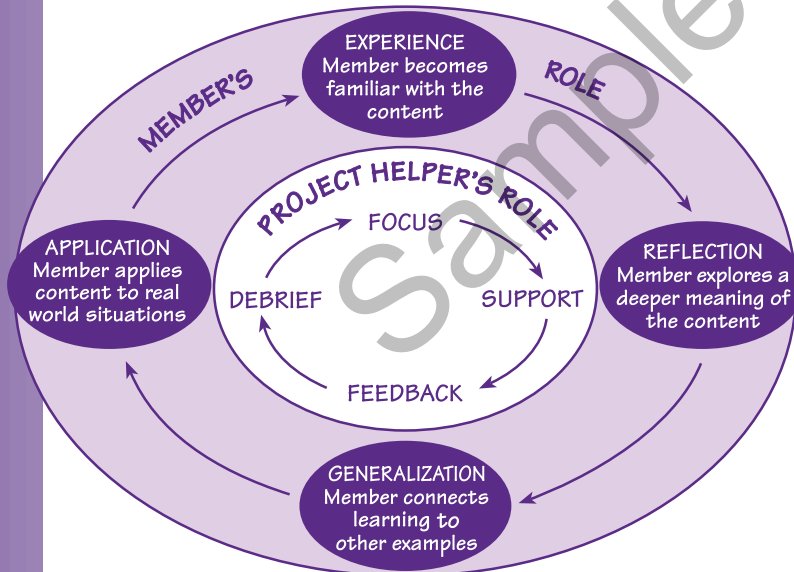
ohio4h.org/rocketry

Note to the Project Helper

As you know, 4-H project books are designed as self-study manuals for youth to explore and complete. The information and activities contained in this book are arranged in a unique experiential fashion (see below). In this way, youth are introduced to a particular concept through an opening *Experience*. This is followed by opportunities for *Reflection* through guiding questions, allowing youth to explore a deeper meaning of the content at hand. Following this, youth *Generalize* what they learn to other activities and *Apply* their learning to real world situations.

At the core of every member's project experience is the Project Helper. This can be a parent, relative, advisor, friend, or interested adult. The duties of this individual include helping the member **Focus** on the tasks at hand, providing **Support** and **Feedback** for the learning taking place, and conducting a **Debriefing** exercise to determine what was done well, what could have been done differently, and where to go from here. As a Project Helper, you can nurture and cultivate a member's interest in this project by guiding the member's planning, motivating the member to complete the project's activities, and recognizing the member for a job well done.

4-H Project Experience



Your Role

- Become familiar with the material in this project book.
- Support the member in his or her efforts to set goals and complete the recommended number of project activities.
- Provide feedback as requested or needed.
- Date and initial the activities that have been completed.
- Recognize the member for a job well done. Project completion certificates are available from your county Extension office.

Your involvement as a Project Helper is one of the eight critical elements for positive youth development. These elements affirm the need for youth to become actively engaged in meaningful learning activities with caring adults in a safe and supportive environment. For more information on the Eight Critical Elements for Positive Youth Development, visit our web page at ohio4h.org.



ROCKETS AWAY!

A Fun Approach to Exploring the Science of Rocketry

A variety of experiments and activities including the construction and launching of 2-liter bottle rockets

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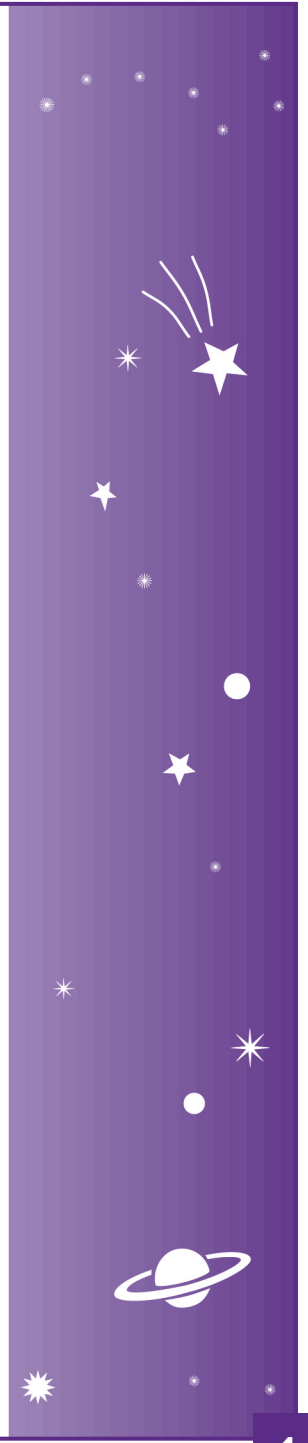
This book is dedicated to my daughters Christy and Carrie, and to the kids of the neighborhood for their invaluable curiosity and willingness to try.

Development of this project was supported by the National Center for Science Teaching and Learning under grant #R117Q00062 from the Office of Educational Research and Improvement, U.S. Department of Education

The 2019 edition features an updated design, no changes in the content or in project requirements have been made.

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Member Project Guide

Project Background

Welcome to *Rockets Away!* This beginning-level project explores the basics of rocketry through a variety of exciting hands-on experiments. After learning a few basics about forces and motion, you will be able to apply what you've learned by designing, building, and launching a 2-liter bottle rocket. Ready? Set? Rockets Away!

SAFETY FIRST! This project is for youth who have little or no experience in rocketry **and** who are in at least 5th grade. All youth, but especially anyone younger than the recommended age, must take this project under the direct supervision of an adult. A bottle rocket under pressure must be handled with caution.

Project Materials

Your county Extension office may be able to lend you a launcher for use with this project. If not, a list of launchers others have found helpful is available at ohio4h.org/rocketry. In addition to a launcher, you will need to have access to a tire pump or compressor, pressure gauge, duct tape, hobby knife, calculator, and a 2-liter plastic bottle.

Final Notes

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 another aerospace project.

Sample Page

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



Project Guidelines

1. Complete all activities within each Interest Area, including building and launching a 2-liter bottle rocket. Going Beyond and Digging Deeper Activities are optional.
2. Take part in at least two Organized Project Activities.
3. Become involved in at least two Citizenship/Leadership activities.

Step 1: Project Activities

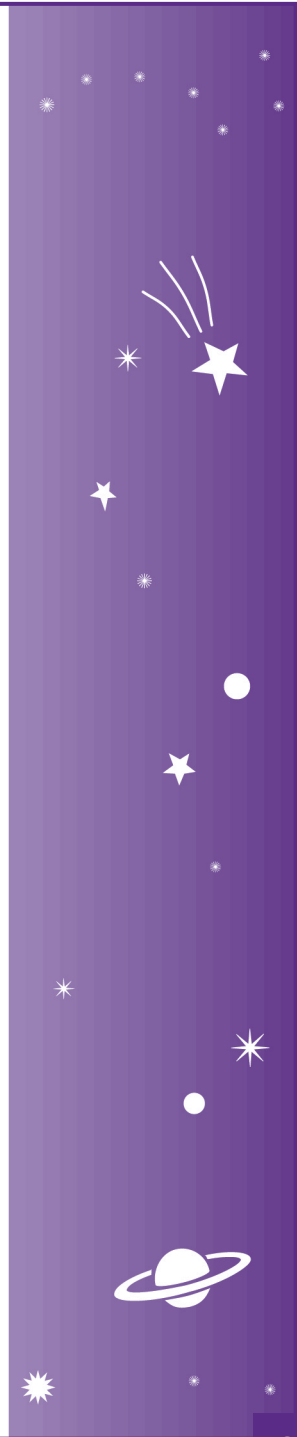
Explore each of the three Project Interest Areas listed below. As you begin to explore an Interest Area, place the current date (month/year) next to it. Plan to complete all activities in each Interest Area selected. Digging Deeper and Going Beyond Activities are optional. Have your parent or advisor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

Date Started
(mo/yr)

Interest Areas

- | | |
|-------|--|
| _____ | 1. Rockets and How They Move, Pages 6-10 |
| | <input type="checkbox"/> Experiment 1—Testing Gravity |
| | <input type="checkbox"/> Experiment 2—Let’s Get Lifting |
| | <input type="checkbox"/> Experiment 3—Bouncing Things |
| | <input type="checkbox"/> Experiment 4—Kicking Into Action |
| | <input type="checkbox"/> Digging Deeper—Coming and Going |
| | <input type="checkbox"/> Going Beyond—Build Your Own Hero Engine |

- | | |
|-------|---|
| _____ | 2. Moving Questions About Rockets, Pages 11-16 |
| | <input type="checkbox"/> Experiment 5—Try a Little Lift |
| | <input type="checkbox"/> Experiment 6—Action/Reaction |
| | <input type="checkbox"/> Experiment 7—Add a Nozzle |
| | <input type="checkbox"/> Digging Deeper—Nozzles in Everyday Use |
| | <input type="checkbox"/> Experiment 8—Add a Stick |
| | <input type="checkbox"/> Experiment 9—Add a Fin |
| | <input type="checkbox"/> Experiment 10—Testing Turbulence |
| | <input type="checkbox"/> Experiment 11—Broom Launch |
| _____ | 3. Let’s Get Launching, Pages 17-24 (bottle rocket members only). All others complete “The Alpha Book of Model Rocketry.” |
| | <input type="checkbox"/> Problem 1—Center of Pressure Too Close to the Center of Gravity |
| | <input type="checkbox"/> Problem 2—Too Much Resistance to Wind |
| | <input type="checkbox"/> Problem 3—Measuring the Altitude and Velocity of Your Rocket |
| | <input type="checkbox"/> Digging Deeper |
| | <input type="checkbox"/> Problem 4—Decrease Weight of Rocket Without Compromising Stability |
| | <input type="checkbox"/> Problem 5—Improving Your Rocket’s Design |
| | <input type="checkbox"/> Going Beyond—Rocket Staging |





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
<i>(example) Short Course</i>	<i>Took part in a 3-week course on building model rockets</i>	<i>4/7-21</i>

Sample Pages



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.

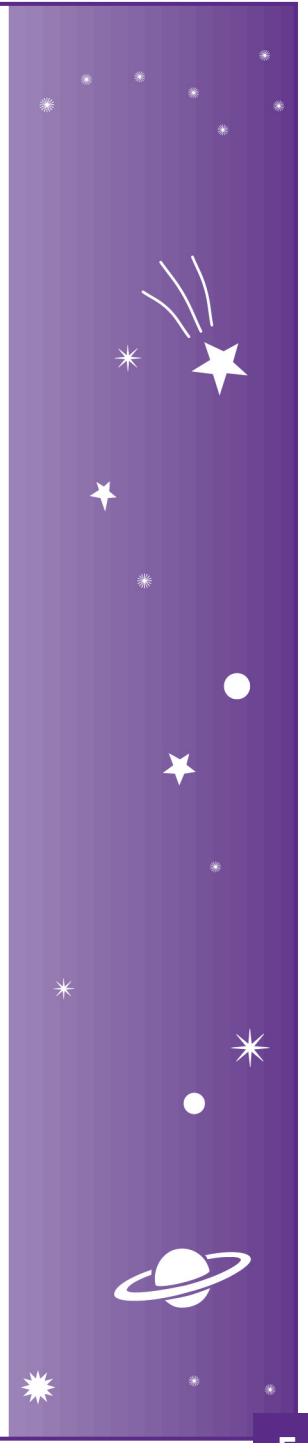
What I Plan to Do	When I Finished	Leadership/Citizenship Activities
_____	_____	• Encourage someone to take a rocketry project.
_____	_____	• Help someone with his or her rocketry project.
_____	_____	• Organize a rocket science program for your club or classroom.
_____	_____	• Invite someone to talk 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 other club members 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

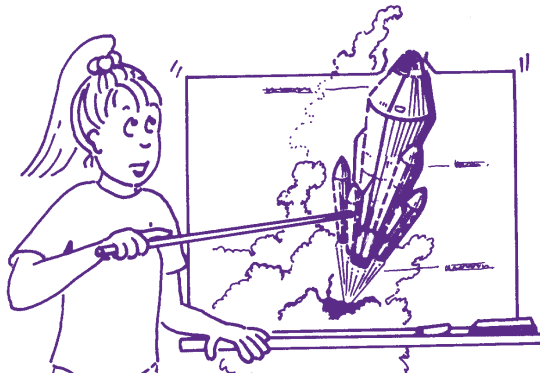
_____	_____	• _____
_____	_____	• _____

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.



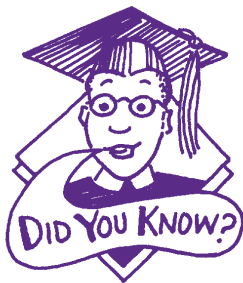
I. Rockets and How They Move



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.

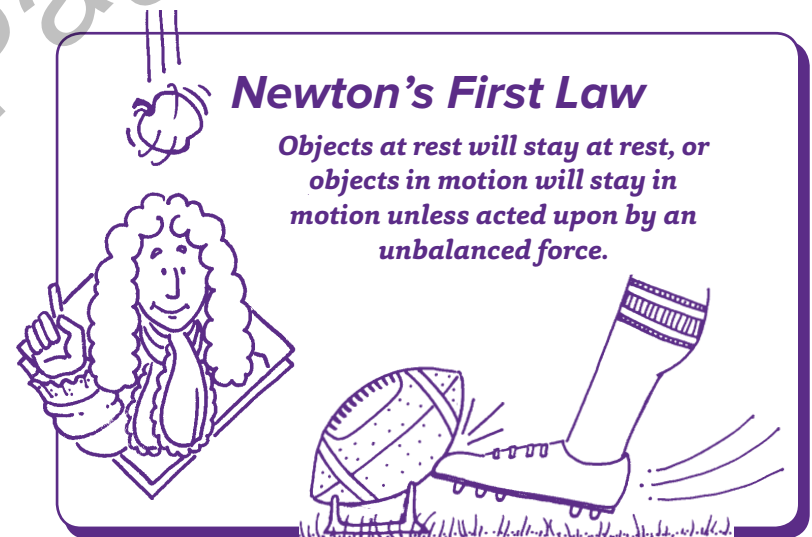


Did you know?

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

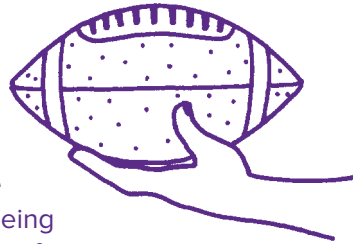
$$H=16(t/2)^2$$

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.



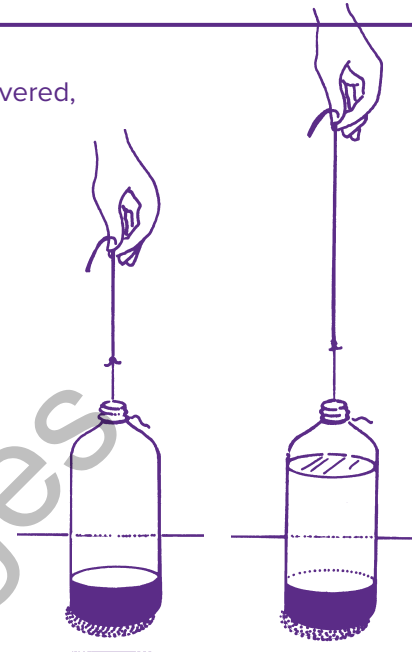
Explanation: By unbalancing either force, you transform the ball from a state of rest to a state of motion.

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.

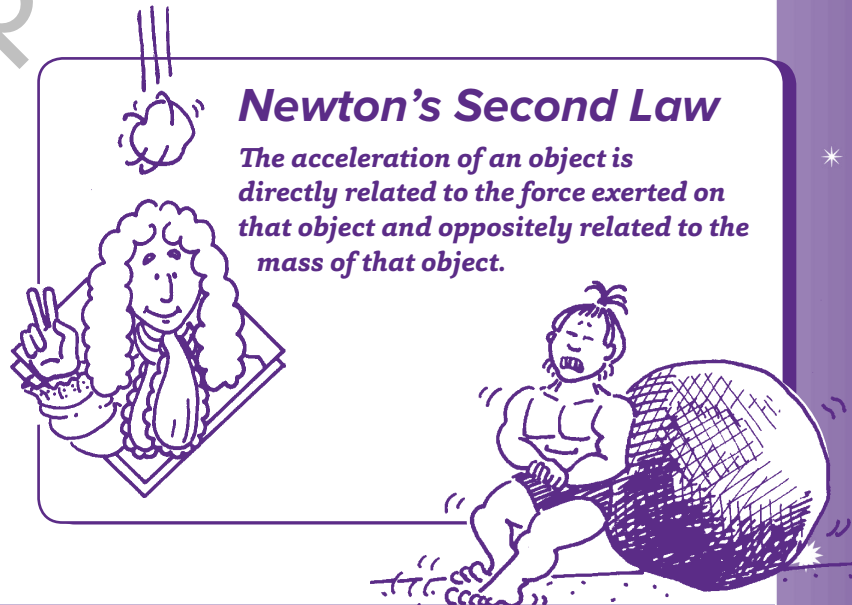
Explanation: As you discovered, a certain amount of unbalanced force was needed to lift the bottle. However, the greater the *mass* of the object, the greater the unbalanced force needed to lift it. Obviously, the idea of mass is an important factor to consider when calculating the unbalanced force necessary 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.





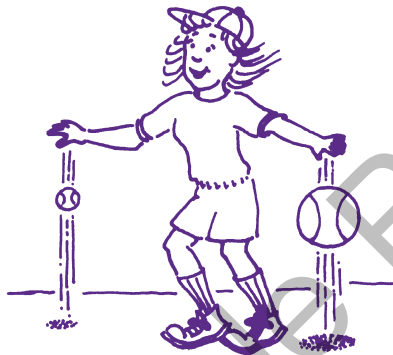
$$H = 16 (t/2)^2$$

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.

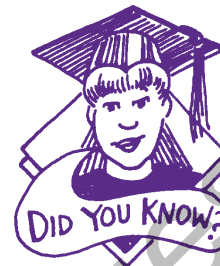


Explanation: You know that it takes more force to bounce a basketball than a tennis ball. Of course the basketball is heavier than a tennis ball, but it is not the weight that makes it harder to bounce. If there were no gravity, so that both were weightless, the basketball would still be harder to bounce. 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 4 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's 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's why it's 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/second^2) 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 10 1-pound weights at the same time as the 1-pound weight."

