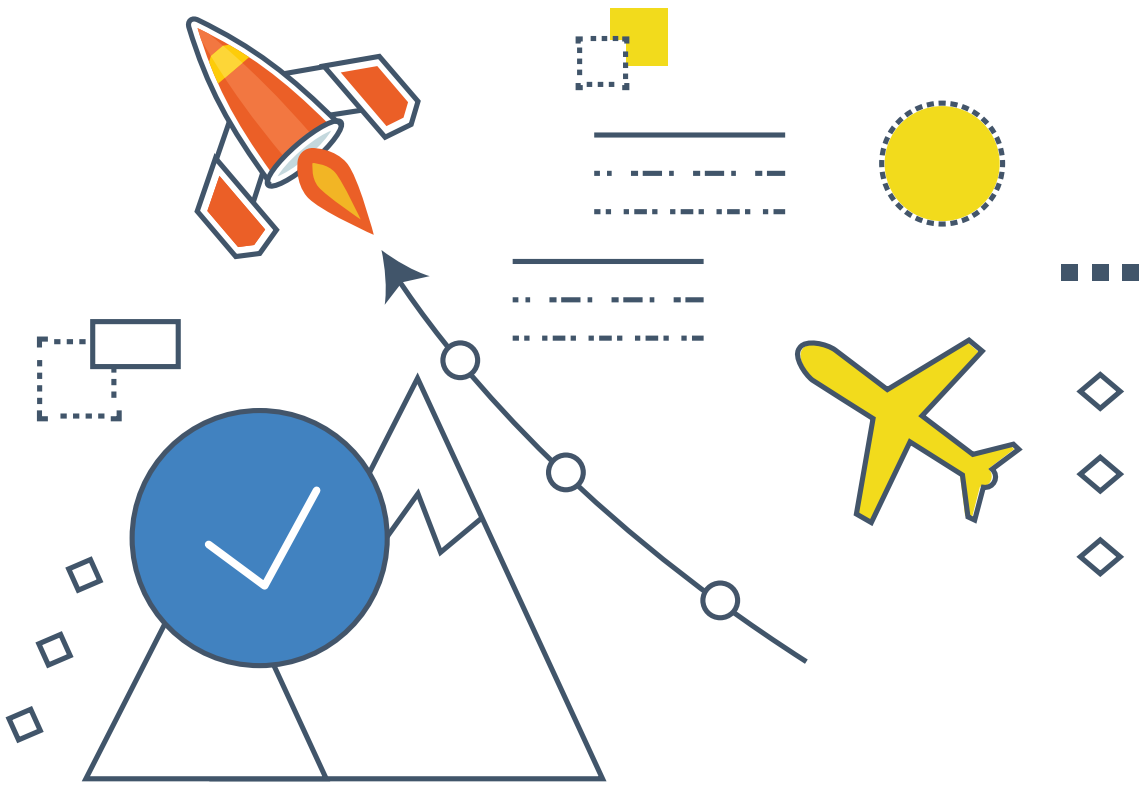
PROJECTILE SCIENCE

The Physics Behind Kicking a Field Goal and Launching a Rocket with Science Activities for Kids



Matthew Brenden Wood
Illustrated by Tom Casteel

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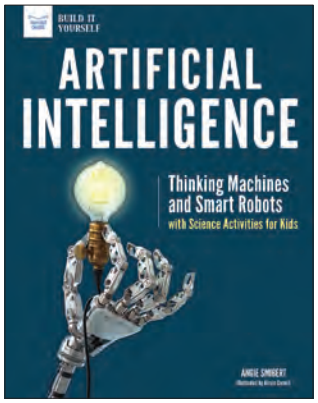

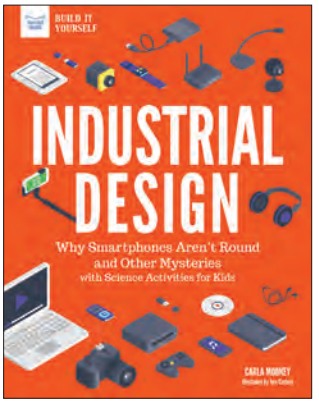

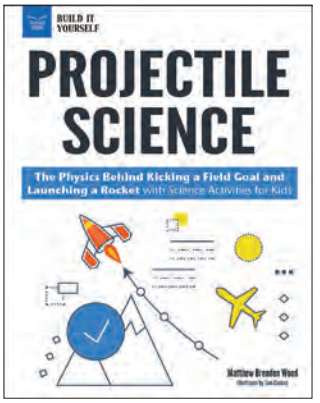

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Contents

Timeline . . . iv

Introduction
The Science of Projectiles . . . 1

Chapter 1
What Goes Up: The Laws of Motion . . . 9

Chapter 2
Projectile Motion: Tracking Trajectories . . . 28

Chapter 3
Slingshots, Catapults, and Cannons: Mechanical Energy . . . 50

Chapter 4
Curveballs and Spirals: Air Resistance . . . 75

Chapter 5
When What Goes Up Doesn't Come Down: Rockets . . . 93

Glossary | **Metric Conversions**
Resources | **Essential Questions** | **Index**

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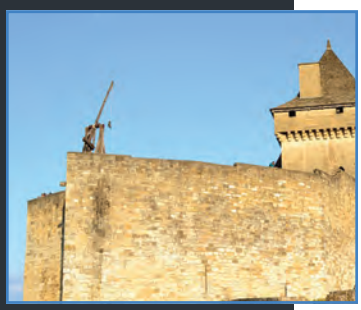
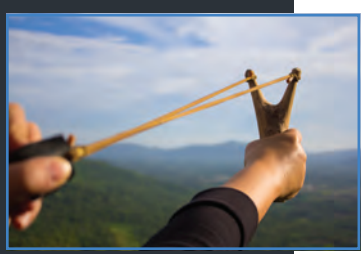
Look for this icon. Use a smartphone or tablet app to scan the QR code and explore more! Photos are also primary sources because a photograph takes a picture at the moment something happens.

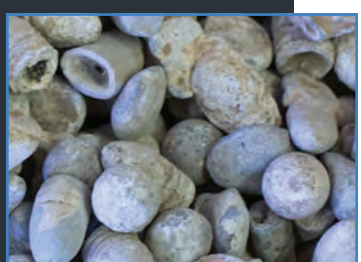
If the QR code doesn't work, there's a list of URLs on the Resources page. Or, try searching the internet with the Keyword Prompts to find other helpful sources.

projectiles

TIMELINE







1304 CE: King Edward of England uses a giant trebuchet known as the "Wolf of War" to help conquer Stirling Castle in Scotland.

1337 CE: The English longbow is used in the Hundred Years' War between England and France.

1346 CE: The Mongol army uses catapults to infect the city of Caffa with bubonic plague.

1415 CE: At the Battle of Agincourt, English forces use longbows to defeat a French army nearly 10 times larger.

1520 CE: Gun barrels are first made with spiral grooves that spin projectiles, called "rifles."

1638 CE: Galileo Galilei shows that the motion of a projectile is a curved path called a parabola.

1812 CE: The British Navy uses rockets to attack Fort McHenry, inspiring Francis Scott Key to write the words "the rocket's red glare."

1846 CE: Isaac Newton's law of universal gravitation is used to discover the planet Neptune.

1849 CE: Claude-Etienne Minié invents the modern, streamlined bullet.

c. 1850 CE: The first slingshots using rubber are made.

1853 CE: German physicist H.G. Magnus describes how spinning objects curve in flight.

c. 1853 CE: Scottish physicist William Rankine coins the term "potential energy."

October 7, 1867: William Arthur "Candy" Cummings throws the first curveball in a baseball game.

1905: Pitcher Eddie Cicotte earns the nickname "knuckles" for the strange grip he uses for a pitch that seems to zig and zag on its way to the plate.

September 5, 1906: Bradbury Robinson throws the first spiral pass in American football.

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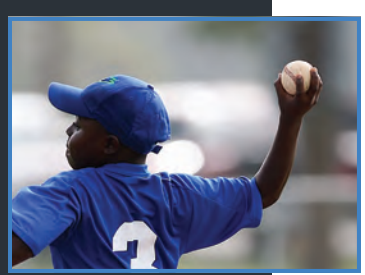

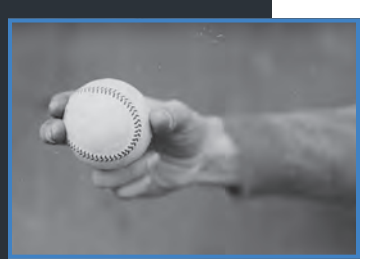

March 16, 1926: The first liquid-fueled rocket is launched by Robert Goddard.

September 8, 1944: The first V2 rocket attack happens on London, England.

1953: The Wiffle ball is invented.

1959: Engineer and physicist Lyman Briggs proves that a curveball really curves.

October 4, 1957: *Sputnik* becomes the world's first artificial satellite.

February 9, 1959: The Soviet Union's R-7 becomes the world's first operational intercontinental ballistic missile (ICBM).

April 12, 1961: Cosmonaut Yuri Gagarin, riding on top of a Soviet R-7 ICBM, becomes the first human in space.

May 5, 1961: Alan Shepard becomes the first American in space.

1966: Hollis Wilbur Allen builds the first compound bow.

November 9, 1967: The first launch of the Saturn V, the rocket that took humans to the moon.

September 8, 1974: Daredevil Robert "Evel" Knievel jumps across the Snake River Canyon in his custom-built "Skycycle X-2."

June 2, 1987: Joey Meyer of the Denver Zephyrs hits a 582-foot home run, probably the longest home run in baseball history.

2009: The game Angry Birds uses projectile science to enterain humans for hours.

2010: The U.S. Navy fires the fastest projectile ever, traveling at more than 8,000 feet per second.

2011: "Chucky III" sets the world record for catapult distance, flinging a pumpkin 3,636 feet.

December 8, 2013: Matt Prater of the Denver Broncos kicks the longest field goal in NFL history—64 yards!

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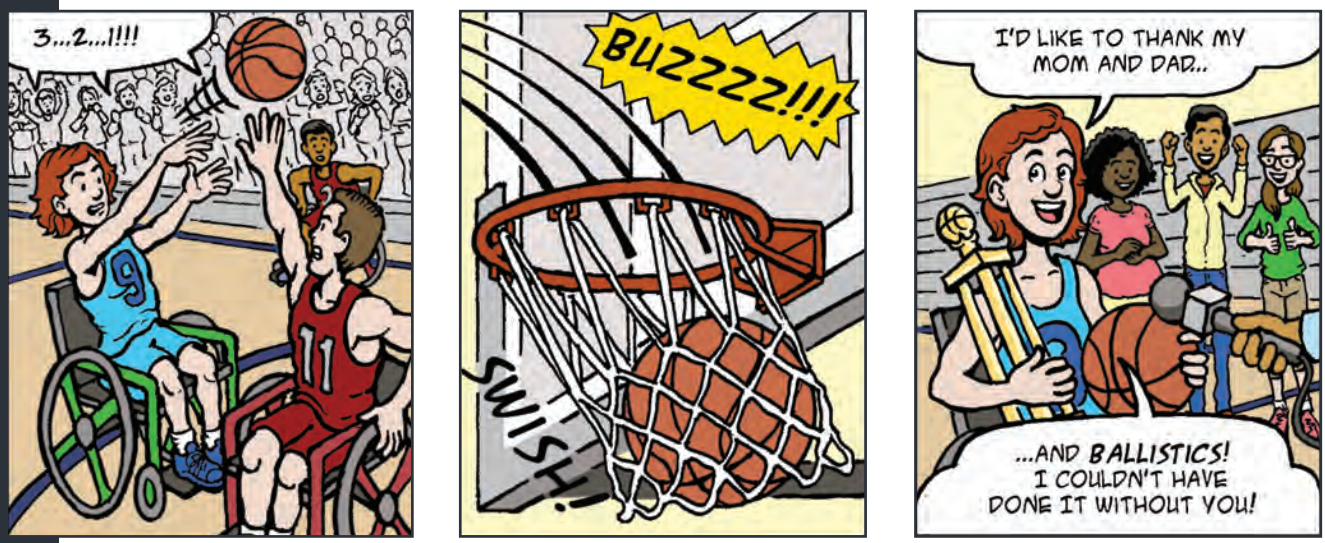
THE SCIENCE OF PROJECTILES



Down by a point with only seconds left in the game, you square up your shoulders to take the final shot. Over the outstretched hands of the defender, you release the basketball and watch as it soars through the air into the hoop with a swoosh. The buzzer sounds and the crowd cheers—you've won the game!

You might think that nailing a three-pointer is just luck. There are many **forces** at work, however, that determine if you've made a game-winning shot or the final out.

If you've ever thrown a ball, launched a model rocket, or even played video games, you've explored the amazing world of **ballistics**. Ballistics is the study of **projectiles** and of **projectile motion**—or how objects such as bullets and baseballs move. The study of **projectile science** can involve something as simple as tossing a soda can into a recycling bin from across the room or as complicated as sending a rocket into outer space. If it can be launched, thrown, fired, or flung, it's a projectile!

ESSENTIAL QUESTION

Why did ancient humans develop methods of sending projectiles farther, faster? How did this ability make life better?

ProjectileScience_Interior_Rd-Final.indd 1 6/8/18 7:46 AM

WORDS TO KNOW

force: a push or pull applied to an object.

ballistics: the science that studies the movement of objects that are shot through the air.

projectile: an object that is thrown or launched and does not move by its own power.

projectile motion: the path that a projectile takes as it travels.

projectile science: the study of how projectiles move.

buoyancy: the force that makes something able to float, either in the air or in the water.

prehistoric: having to do with ancient times, before written human records.

tundra: a treeless Arctic region that is permanently frozen below the top layer of soil.

prey: an animal caught or hunted for food.

wary: suspicious.

lance: a long, straight wooden spear.

spear: a weapon with a long shaft and pointed tip, used for thrusting or throwing.

All projectiles follow the same rules of motion, no matter what they are. Understanding those rules is the science of ballistics. How hard do you need to throw a football to complete a pass? How do you aim an arrow to hit a bulls-eye? All these things require an understanding of ballistics and projectile motion.

If you think about it, you've been studying ballistics your whole life without knowing it! But to people throughout history, the study of ballistics was an even more important part of their lives.

Projectile or Not?

When is an object a projectile? Not all things flying through the air are projectiles! Projectiles don't move under their own power. Therefore, airplanes, helicopters, and hot air balloons are not projectiles because they use wings, engines, or **buoyancy** to determine how they move.

ANCIENT PROJECTILES

Imagine you're a **prehistoric** human, living with your prehistoric family in the harsh **tundra** of northern Siberia 20,000 years ago. Survival isn't easy! You must hunt large and dangerous beasts to provide for your family. But getting close to a bear or giant woolly mammoth is difficult. How do you hunt a fearsome animal without putting yourself in danger?

ProjectileScience_Interior_Rd-Final.indd 2 6/8/18 7:46 AM

Ancient humans painting images of woolly mammoths on cave walls
credit: Charles R. Knight

Ancient people around the world solved this problem by using projectiles. Many used rounded stones as weapons, hurling them with great force to stun or knock down their **prey**. Others made slings, which allowed them to throw rocks with even greater force. Using projectiles to hunt had two big advantages for ancient people—it allowed them to sneak up on **wary** prey, and it kept them away from dangerous teeth and tusks.

An even more dangerous weapon made by ancient people was the **lance**, or **spear**. The first spears were simple, sharp sticks that could be thrown. People learned pretty quickly that attaching a small, sharpened rock to the tip made spears more accurate—and even more deadly.

ProjectileScience_Interior_Rd-Final.indd 3 6/8/18 7:46 AM

WORDS TO KNOW

catapult: a large war machine used to hurl objects at an enemy.

Middle Ages: the period of European history after the fall of the Roman Empire, from about 350 to 1450 CE.

trebuchet: a large, catapult-like structure with a moveable arm that launched damaging items into or over castle walls.

siege: surrounding and attacking a fortified place, such as a fort, and cutting it off from help and supplies.

siege engine: a machine built to help forces break through walls—or go over them.

culture: the beliefs and way of life of a group of people, which can include religion, language, art, clothing, food, holidays, tools, and more.

fire lance: a very early gunpowder weapon.

Hurling spears worked well, but you still needed to be pretty close to your prey. A new tool, the bow and arrow, gave hunters an even better way to hunt from afar. For the first archers, making bows and arrows was much harder than fashioning a spear. They needed to find the right kind of wood to make a bow—something that could bend but not break. Plant and animal materials were needed to make the bow string, and the arrows needed to be shaped and carved as straight as possible.

Finding all the right materials and creating the bows and arrows would have been difficult, but worth it. A well-made bow and arrow is much easier to aim than a spear. It's also lighter and easier to carry.

Projectiles were terrific for hunting food more easily and more efficiently. They were also used in battle.

ProjectileScience_Interior_Rd-Final.indd 4 6/8/18 7:46 AM

ANCIENT WEAPONS

Have you ever seen a **catapult**? During the **Middle Ages**, catapults were used to send boulders over castle walls or even break them down. Catapults work a lot like a bow. A flexible piece of wood is pulled back into a firing position and loaded with a projectile. When it's released, the wood springs back, hurling the boulder at its target.

Trebuchets were another kind of catapult used in ancient warfare. Trebuchets used a large weight to send heavy objects flying. These **siege engines** dominated battlefields for hundreds of years until a new invention replaced them—firearms.

In the tenth century, a new kind of weapon was invented in China. The **fire lance** was a hollow bamboo tube filled with black powder and attached to the end of a spear. When it was lit, the black-powder exploded, sending fire and small projectiles toward the enemy.

DID YOU KNOW?

Bows, spears and other tools were invented by diverse **cultures** in different ways. The earliest evidence of archery comes from projectile points that are nearly 70,000 years old and found in South African caves. In Europe, the oldest bows and arrows are about 15,000 years old.

SAFETY FIRST

While you're building, exploring, and experimenting, remember to be safe. When working with projectiles, **ALWAYS** wear eye protection. Never point a projectile at something you don't want to hunt or damage, including people, pets, and valuable items. As you build and experiment, remember that things can pinch, snap, and even break, so be careful of your fingers and hands. Always practice safe science!

ProjectileScience_Interior_Rd-Final.indd 5 6/8/18 7:46 AM

WORDS TO KNOW

physics: the study of physical forces, including matter, energy, and motion, and how these forces interact with each other.

air resistance: the force that acts on an object as it travels through the air.

spear-thrower: a stick that makes it possible to throw spears farther and faster.

prototype: a model of something that allows engineers to test their idea.

Eventually, the bamboo tube was replaced by a metal tube. A single projectile—the first bullet—was put inside. Loaded with gunpowder, the weapon was more powerful than a bow and deadlier than an arrow. Cannons, mortars, and modern rifles came later, firing larger projectiles even greater distances.

In 1961, Yuri Gagarin (1934–1968) became the first person to go into space, riding atop a ballistic missile that followed the same basic laws as basketballs and bullets. How does it work? What's behind the motion projectiles make once they leave your hand or shoot out of a device?

Projectile Science: The Physics Behind Kicking a Field Goal and Launching a Rocket examines the ups and downs of projectile motion by exploring the math and **physics** behind hitting the bulls-eye and reaching orbit. Along the way, you'll conduct experiments and safely build your own devices, such as slingshots, catapults, and water rockets.

You'll learn how to predict the paths of objects, including how far they'll fly and where they'll land. You'll also discover how things such as **air resistance** and spin can affect the flight of projectiles, including how curveballs curve and how bullets can be so accurate. Ballistics is an exciting way to explore the math and physics behind projectile motion!

Heads Up!

Many cultures created a tool to help throw spears farther and faster. Called an "atlatl" by the Aztecs and "woomera" by aboriginal Australians, a **spear-thrower** acts like an extension of the hunter's arm, giving greater power and accuracy.

You can watch modern people using ancient throwing tools in this video.

spear thrower Ice Age

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Engineering Design Process

Every engineer keeps a notebook to keep track of their ideas and their steps in the engineering design process. As you read through this book and do the activities, keep track of your observations, data, and designs in an engineering design worksheet, like the one shown here. When doing an activity, remember that there is no right answer or right way to approach a project. Be creative and have fun!

Problem: What problem are we trying to solve?
Research: Has anything been invented to help solve the problem? What can we learn?
Question: Are there any special requirements for the device? An example of this is a car that must go a certain distance in a certain amount of time.
Brainstorm: Draw lots of designs for your device and list the materials you are using!
Prototype: Build the design you drew during brainstorming.
Test: Test your **prototype** and record your observations.
Evaluate: Analyze your test results. Do you need to make adjustments? Do you need to try a different prototype?

Each chapter of this book begins with an essential question to help guide your exploration of ballistics. Keep the question in your mind as you read the chapter. At the end of each chapter, use your engineering notebook to record your thoughts and answers.

ESSENTIAL QUESTION

Why did ancient humans develop methods of sending projectiles farther, faster? How did this ability make life better?

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Activity

FIND PROJECTILES AROUND YOU

Projectiles can be almost anything—a ball, an arrow, and a bullet are all examples. While these are very different objects, do they move the same?

Observe the motion of several different projectiles you can find around you. They can be a ball, stone, arrow—anything that can be safely thrown.

* What does it take to get the objects moving? Can you throw it or kick it? Does it need a device to move? Remember to practice safe science. Never point a projectile at something you don't want to hurt, including people, pets, and valuable items.
* What are the motions of your projectiles like? How are they alike and how are they different?
* What brings them to a halt? Are they fired at a target or do they simply land on the ground? What do you think happens when the objects stop moving?

Try This!

Play *Angry Birds* online! Using a slingshot, you can hurl birds, which are the projectiles, and follow their paths to the target. What do you notice about the motion of the projectiles in *Angry Birds*? Record your observations. How does changing the angle of the launch change the flight of projectiles? How does changing the stretch of the slingshot change the path of a bird? What is more important, the angle or how fast the bird flies?

play Angry Birds

ProjectileScience_Interior_Rd-Final.indd 8 6/8/18 7:46 AM