

STEM KIT

EDUCATOR GUIDE

TREBUCHET

CREATED FOR BOTH HOME AND SCHOOL



PERFECT FOR
THE CLASSROOM

DESIGNED BY TEACHERS FOR TEACHERS

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LESSON OVERVIEW

Class Information

In this hands-on STEM lesson, students will build their own mini trebuchets while exploring the history and mechanics of this medieval siege engine. They will learn how trebuchets use simple machines, such as levers and counterweights, to launch projectiles with precision and force. Through experimentation, students will discover key physics concepts like potential and kinetic energy, force, and motion. By the end of the lesson, they will apply their knowledge to adjust their designs, test different variables, and analyze how science and engineering principles affect their trebuchet's performance.

CONCEPTS



History of Trebuchets



Simple Machines



Levers



Potential & Kinetic Energy



Counterweights



Force and Motions



LESSON OBJECTIVES

-  Understand the History of Trebuchets – Students will explore the origins and historical significance of trebuchets, learning how they were used in medieval warfare and their impact on engineering advancements.
-  Identify and Apply Simple Machines – Students will recognize how levers, counterweights, and fulcrums work together in a trebuchet and apply this knowledge in building their own model.
-  Explore Physics Concepts – Students will investigate key physics principles such as potential and kinetic energy, force, motion, and trajectory by testing and modifying their trebuchet designs.
-  Engage in the Engineering Design Process – Students will follow an iterative process to construct, test, and improve their trebuchets, analyzing how design changes affect performance.

EDUCATIONAL STANDARDS

NGSS - Next Generation Science Standards

4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.

[**Clarification Statement: Examples of evidence relating speed and energy could include change of shape on impact or other results of collisions.] [Assessment Boundary: Assessment does not include quantitative measures of changes in the speed of an object or on any precise or quantitative definition of energy.]

5-PS2-1 Support an argument that the gravitational force exerted by Earth on objects is directed down. [Clarification Statement: “Down” is a local description of the direction that points toward the center of the spherical Earth.]

[Assessment Boundary: Assessment does not include mathematical representation of gravitational force.]

MS-PS3-5. Construct, use, and present arguments to support the claim that when the kinetic energy of an object changes, energy is transferred to or from the object. [Clarification Statement: Examples of empirical evidence used in arguments could include an inventory or other representation of the energy before and after the transfer in the form of temperature changes or motion of object.] [Assessment Boundary: Assessment does not include calculations of energy.]

MS-PS2-2. Plan an investigation to provide evidence that the change in an object’s motion depends on the sum of the forces on the object and the mass of the object. [Clarification Statement: Emphasis is on balanced (Newton’s First Law) and unbalanced forces in a system, qualitative comparisons of forces, mass and changes in motion (Newton’s Second Law), frame of reference, and specification of units.] [Assessment Boundary: Assessment is limited to forces and changes in motion in one dimension in an inertial reference frame and to change in one variable at a time. Assessment does not include the use of trigonometry.]

HS-PS2-1. Analyze data to support the claim that Newton’s second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration. [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object rolling down a ramp, or a moving object being pulled by a constant force.] [Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.]

HS-PS2-2. Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system. [Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] [Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.]

HS-PS3-1. Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known. [Clarification Statement: Emphasis is on explaining the meaning of mathematical expressions used in the model.] [Assessment Boundary: Assessment is limited to basic algebraic expressions or computations; to systems of two or three components; and to thermal energy, kinetic energy, and/or the energies in gravitational, magnetic, or electric fields.]

HS-PS3-2. Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects). [Clarification Statement: Examples of phenomena at the macroscopic scale could include the conversion of kinetic energy to thermal energy, the energy stored due to position of an object above the earth, and the energy stored between two electrically charged plates. Examples of models could include diagrams, drawings, descriptions, and computer simulations.]

INTRODUCTION

Today, we're stepping back in time to the Middle Ages to explore one of the most powerful siege weapons in history the trebuchet! But this isn't just about history; we're also going to dive into the science and engineering behind how trebuchets work. We'll learn about simple machines like levers and counterweights, and how forces like gravity and motion help launch projectiles through the air. Then, you'll get to build your very own mini trebuchet, test different designs, and see how changes affect how far and how accurately it can launch. Get ready to think like engineers, experiment like scientists, and have fun bringing history to life with physics!

VOCABULARY

Trebuchet – A type of catapult that uses a counterweight to launch projectiles over long distances.

Simple Machine – A basic mechanical device, such as a lever or pulley, that makes work easier by reducing the amount of force needed.

Lever – A rigid bar that pivots around a fixed point (fulcrum) to move a load with less effort.

Fulcrum – The fixed point around which a lever rotates.

Counterweight – A heavy weight that provides the force needed to launch a projectile in a trebuchet.

Potential Energy – Stored energy that an object has due to its position, such as a raised counterweight before it drops.

Kinetic Energy – The energy of motion, which increases as the trebuchet arm swings and launches a projectile.

Force – A push or pull on an object that can cause it to move, stop, or change direction.

Trajectory – The curved path a projectile follows when launched through the air.

Gravity – The force that pulls objects toward the Earth, affecting the trajectory of projectiles and the motion of the trebuchet.

Engineering Design Process – A step-by-step method engineers use to create and improve designs through testing and modifications.

The History of the Trebuchet

The trebuchet is a fascinating and powerful siege weapon that was used during the Middle Ages to break down the walls of castles and fortresses. It was one of the most advanced weapons of its time and became the weapon of choice for many armies. Let's dive into the history of this amazing machine, how it was developed, and how it changed the way wars were fought.

Early Beginnings

The word "trebuchet" comes from the French word "trebucher," meaning "to fall" or "to topple." The trebuchet was invented in the 12th century and became widely used in Europe by the 13th century. Before the trebuchet, armies used simpler siege machines like catapults and battering rams to try and break through castle walls. While these machines could throw stones or other projectiles, they weren't very accurate, and they didn't have much power.

The trebuchet changed that. Unlike earlier siege machines, the trebuchet used a counterweight to create a powerful force that could launch large rocks, burning materials, or even dead animals over castle walls. The counterweight was a large mass that was raised and then released to swing the arm of the trebuchet, launching the projectile with incredible force. This innovation made the trebuchet one of the most effective siege weapons in history.

The Design of the Trebuchet

Trebuchets were large, often requiring teams of people to operate. A typical trebuchet had a long arm, one end of which would be loaded with a projectile, while the other end had a counterweight. The counterweight was lifted by a mechanism, usually a rope and pulley system, and when released, it would swing the arm down, throwing the projectile into the air toward its target. This action was powered entirely by gravity, as the counterweight's fall would generate the force needed to launch the object.

The Design of the Trebuchet Continued

Unlike earlier catapults, which used tension or torsion to launch projectiles, the trebuchet was much more powerful and accurate. Its design was so effective that it remained unchanged for centuries, and it was used well into the 16th century. The trebuchet was used not only in sieges but also in battles, where it could launch projectiles over enemy lines or into fortified positions.

The Golden Age of the Trebuchet

The trebuchet reached the height of its popularity during the Middle Ages, particularly during the period of castle-building and frequent warfare between kings and kingdoms. During a siege, a trebuchet could launch stones weighing as much as 300 pounds or more, causing massive damage to castle walls and fortifications. The trebuchet could also hurl flaming objects, which would set the wooden structures of a castle or city on fire, making it even more destructive.

One of the most famous uses of trebuchets was during the siege of Acre in 1191, part of the Third Crusade. Crusaders used trebuchets to break down the walls of the city, eventually capturing it after a long and difficult siege. This was just one example of how the trebuchet played a pivotal role in medieval warfare.

The Decline of the Trebuchet

As gunpowder and firearms were developed in the 16th century, the trebuchet gradually became obsolete. Cannons and guns could deliver more powerful and accurate strikes than a trebuchet could, and they were far easier to transport and operate. Though the trebuchet's era had ended by the early 1600s, it remains one of the most iconic and fascinating siege weapons in history.

Even today, trebuchets are still admired by engineers and history enthusiasts for their ingenious design and incredible power. Modern versions of the trebuchet are sometimes used in competitions, where teams build their own models and compete to launch projectiles the farthest.

What Are Simple Machines?

Simple machines are basic tools that make work easier by reducing the amount of force needed to complete a task. There are six types of simple machines: lever, pulley, wheel and axle, inclined plane, wedge, and screw. These machines help us apply force in different ways to move or lift objects more efficiently. Let's take a look at each type and how they work.

Lever

- A lever is a rigid bar that pivots on a point called the fulcrum. By applying force on one end, the other end can move an object. In a trebuchet, the long arm that swings to launch the projectile acts as a lever.

Pulley

- A pulley is a wheel with a groove for a rope to move through. It can change the direction of a force or make lifting easier. In a trebuchet, pulleys are used to lift the counterweight.

Wheel and Axle

- This simple machine consists of a wheel attached to a central axle. Turning the wheel moves the axle and helps reduce friction. While not a main feature of the trebuchet, wheels are used to move it.

Inclined Plane

- An inclined plane is a slanted surface that helps lift heavy objects with less effort. In a trebuchet, it may be used to adjust the angle of the machine for better launching.

Wedge

- A wedge consists of two inclined planes used to split or lift objects. It might be used in the construction of a trebuchet but not in the launching action.

Screw

- A screw is an inclined plane wrapped around a cylinder. It is used to hold things together. Screws may be used in assembling parts of the trebuchet.

Simple Machine: The Lever

In a trebuchet, the **lever** is the most important simple machine used to launch the projectile. A lever is a rigid bar that pivots around a fixed point called the fulcrum. The lever allows us to use a small amount of force (effort) to move a much heavier object (the load) over a short distance.

Parts of a Lever:

Fulcrum: The point where the lever pivots or balances. In a trebuchet, the fulcrum is typically located at the base where the arm is attached.

Effort: The force that is applied to one end of the lever to make it move. In a trebuchet, the effort comes from the counterweight, which is dropped to create a force that moves the arm.

Load: The object being moved or launched. In a trebuchet, the load is the projectile, which is launched from the other end of the arm when the lever moves.

How It Works in a Trebuchet:

The counterweight is lifted and then released, creating a downward force that acts on the long arm of the trebuchet. This force is applied at the effort end of the lever (near the counterweight). As the counterweight falls, it causes the arm to swing around the fulcrum, and the load (the projectile) at the other end is launched toward the target.

By adjusting the position of the fulcrum, engineers can change the mechanical advantage of the lever, allowing them to launch projectiles with greater force. The longer the arm and the heavier the counterweight, the more powerful the launch will be.

In this way, the lever in a trebuchet uses a small amount of force applied to the counterweight to create a large amount of force at the other end, launching the projectile.

The Science and Physics Behind a Trebuchet

The trebuchet works by using key principles of **energy and motion**, including **potential energy, kinetic energy, the slingshot effect, and trajectory**. Let's break these down to help you understand how all these forces come together to make a trebuchet launch projectiles with such power and precision.

1. Potential Energy and Kinetic Energy

- **Potential Energy** is stored energy that an object has because of its position. In a trebuchet, potential energy is stored in the counterweight as it is lifted to a high position. The higher the counterweight is raised, the more potential energy it stores.

- **Kinetic Energy** is the energy of motion. When the counterweight is released, its stored potential energy is converted into kinetic energy. As the counterweight falls, this energy is transferred through the arm, causing the arm to swing around the fulcrum and launch the projectile.

The amount of potential energy you start with depends on how high the counterweight is raised, and the kinetic energy transferred to the arm determines the speed and power with which the projectile is launched.

2. The Slingshot Effect

In a trebuchet, the slingshot effect refers to how the sling (a pouch or loop that holds the projectile) increases the speed of the projectile. The sling is attached to the end of the trebuchet arm, and as the arm swings forward, the sling tightens and accelerates the projectile. Just like in a real slingshot, when the arm is released, the sling extends quickly, and the projectile is released at a much higher speed than it would be from the arm alone. This slingshot effect allows the trebuchet to launch its projectile with greater force and speed, increasing its range and accuracy. The faster the projectile leaves the sling, the greater its

The Science and Physics Behind a Trebuchet

3. Launching and Flight

When the trebuchet's arm swings forward and releases the projectile, it follows a curved path called a parabolic trajectory. This means the projectile moves up and then down in an arc, influenced by gravity and air resistance.

- **Gravity** pulls the projectile downward, which is why it eventually hits the ground or a target.
- The angle at which the projectile is launched, and the speed it has when it leaves the sling, determine how far and how high it will go.

This is why it's important to set up the trebuchet at the right angle. Too steep of an angle means the projectile won't travel as far, and too shallow of an angle means it won't go high enough. A well-calibrated trebuchet uses both the right angle and the right speed to send the projectile on the perfect flight path.

4. Speed and Accuracy

The speed of the projectile is affected by the amount of kinetic energy transferred from the counterweight and how efficiently the slingshot effect works. A larger counterweight and a longer arm will generally give you more speed and distance, but there's a tradeoff – too much weight or too long of an arm can make the trebuchet less accurate.

Accuracy depends on how well the trebuchet is aimed and how consistent the release of the projectile is. If the release is not controlled (the projectile doesn't leave the sling at the right moment), the projectile may not travel in the desired path, affecting its accuracy. Fine-tuning the timing of the release, as well as ensuring the trebuchet is steady and correctly angled, helps improve the accuracy of the shots.

ENGINEER OVERVIEW

Are you ready for an epic adventure in physics, engineering and Medieval history? With this kit you will build your very own working trebuchet and explore the science behind how it launches projectiles. Play around with adjustable weights to see how changing them affects distance and power—it's learning, experimentation, and fun all in one kit!

WHAT YOU'LL LEARN

- 1. Understanding Energy:** Students will learn about potential energy and kinetic energy and how energy is transferred in a trebuchet to launch a projectile.
- 2. The Slingshot Effect:** Students will explore how the slingshot effect increases the speed of a projectile and how it contributes to the trebuchet's power.
- 3. Principles of Projectile Motion:** Students will gain an understanding of how the parabolic trajectory works and how gravity and launch angle affect the flight path of the projectile.
- 4. The Role of Accuracy in Design:** Students will learn how factors like counterweight size, angle, and timing affect the speed, distance, and accuracy of the trebuchet's launch.

LEARNING QUESTIONS

1. How does the potential energy of the counterweight in a trebuchet get converted into kinetic energy to launch the projectile?
2. What role does the slingshot effect play in increasing the speed and distance of the projectile launched from the trebuchet?
3. How do factors like the launch angle and counterweight size affect the accuracy and flight path of the projectile?

SAFETY WARNINGS:

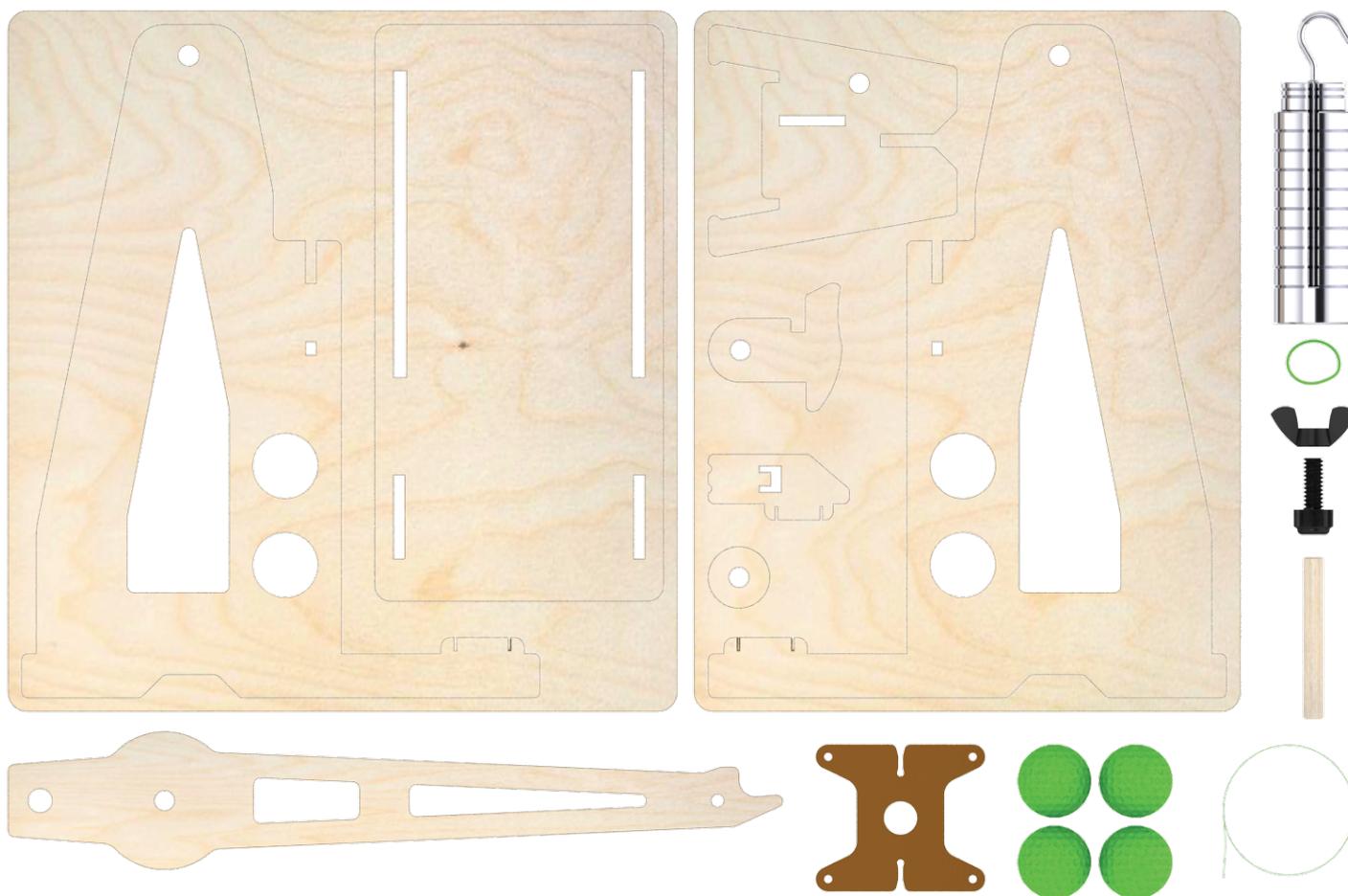
Please read all safety warnings before use:

Choking Hazard: Small parts not for children under 6 years or any individual who have a tendency to place inedible objects in their mouths.

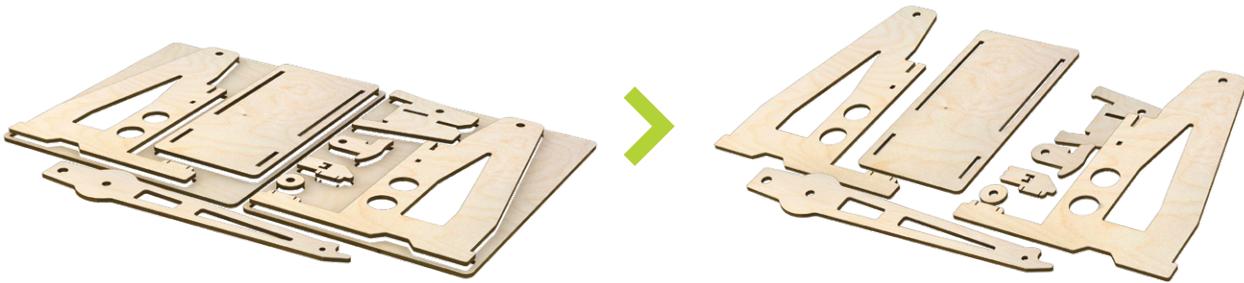
Eye protection should be worn at all times.

Adult supervision required.

MATERIALS

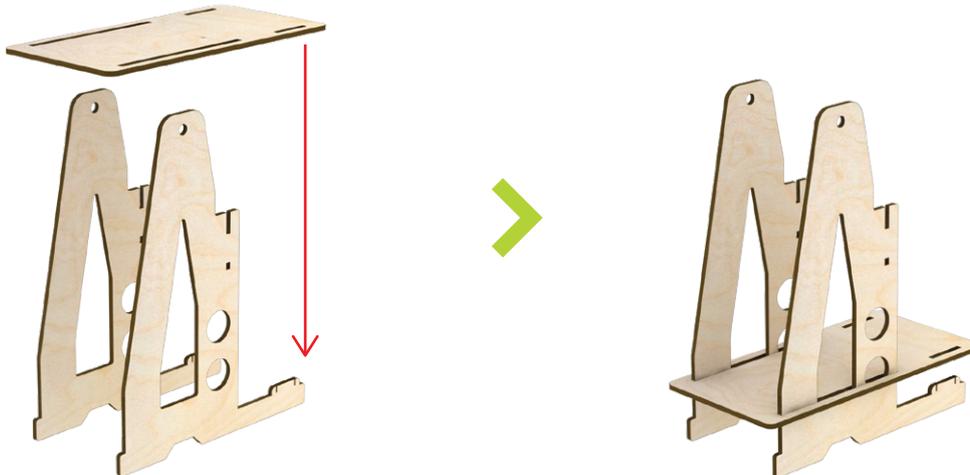


1



NOTE: If you can not break out the wooden pieces by hand, use a blunt tool to punch them out. If you have no experience with tools, get help from an adult. If there are any burrs, points or rough spots due to breaking, smooth them with a piece of sand paper.

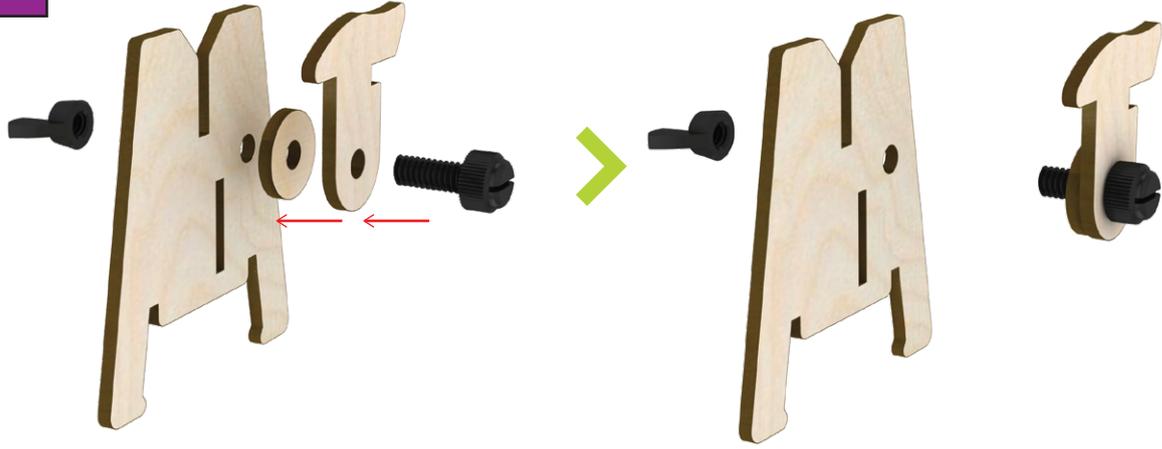
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3



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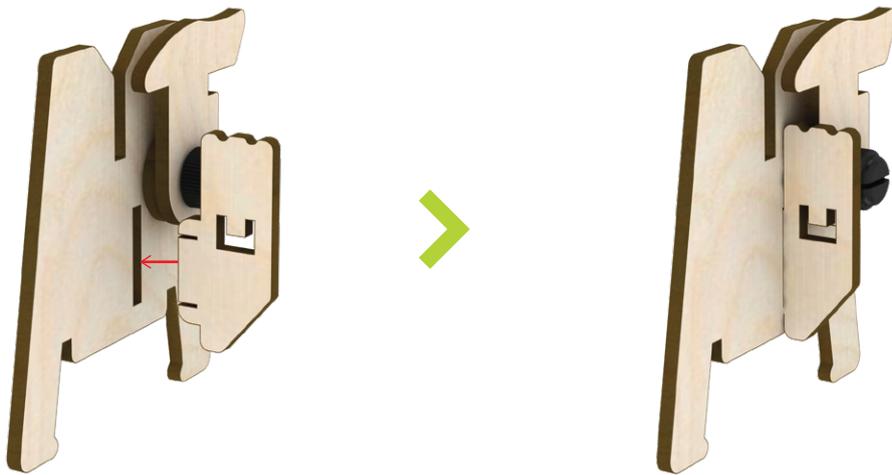


5



Screw wingnut onto screw. Trigger should move smoothly. Do not over-tighten.

6



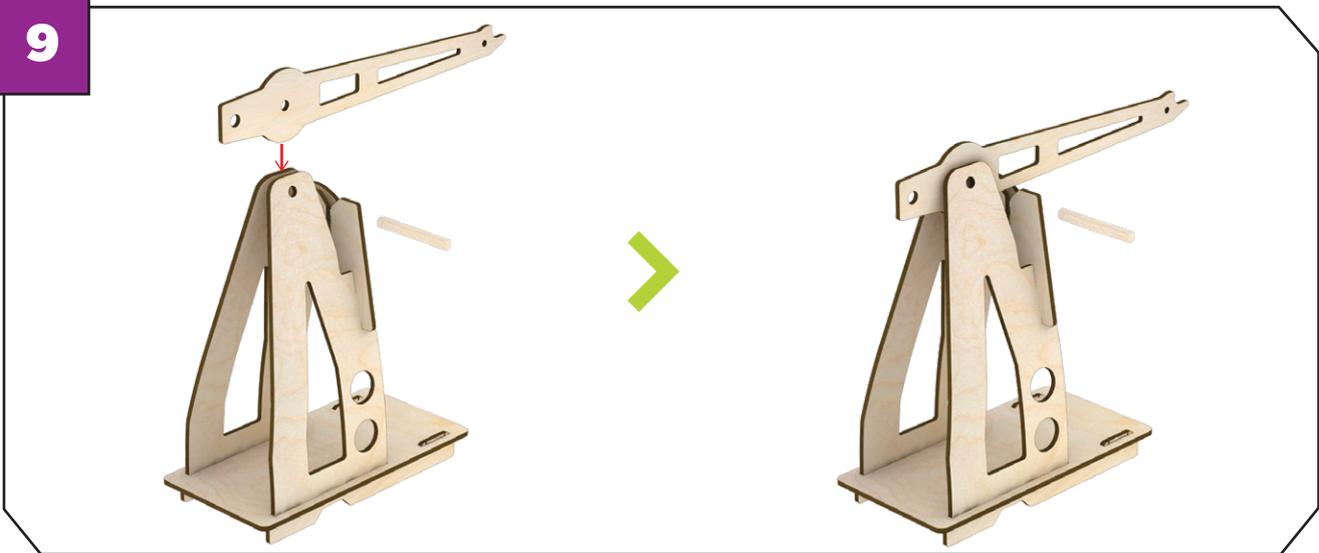
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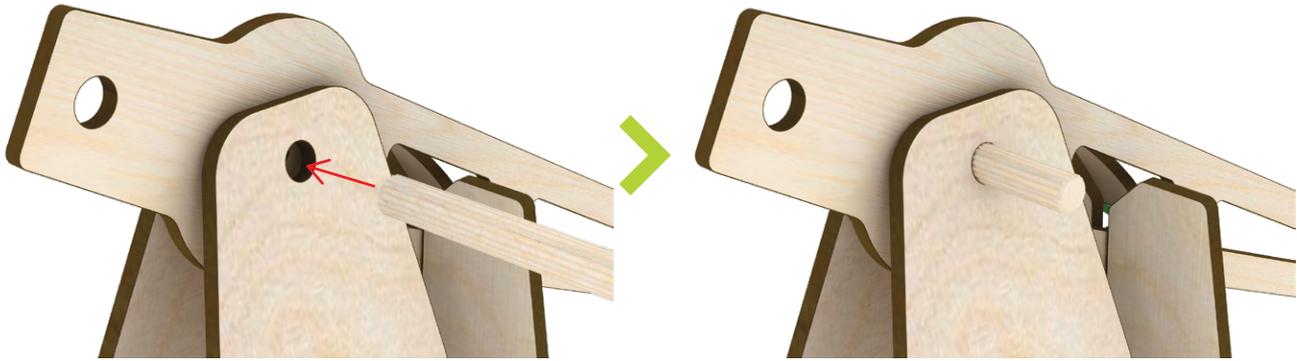
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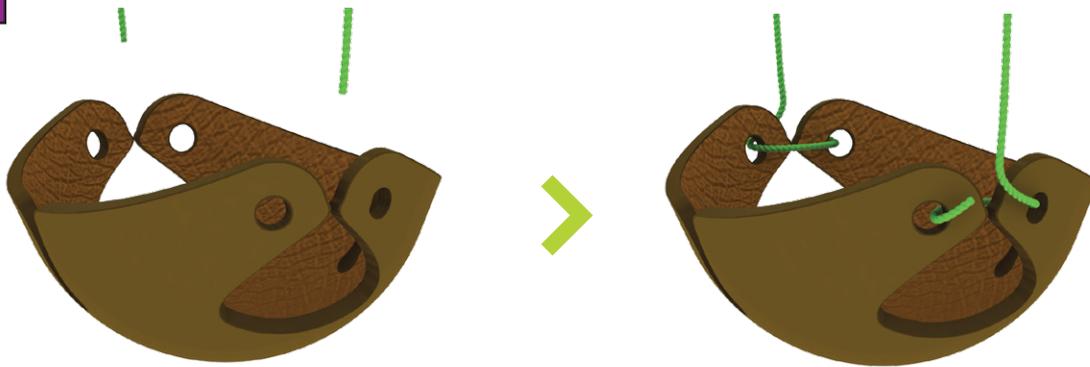
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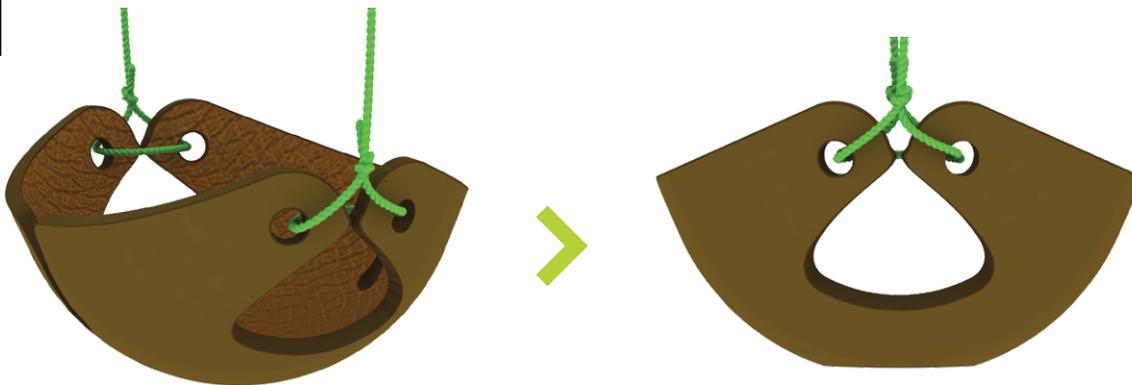


11



Insert **String A** through the holes and secure with a simple double knot.

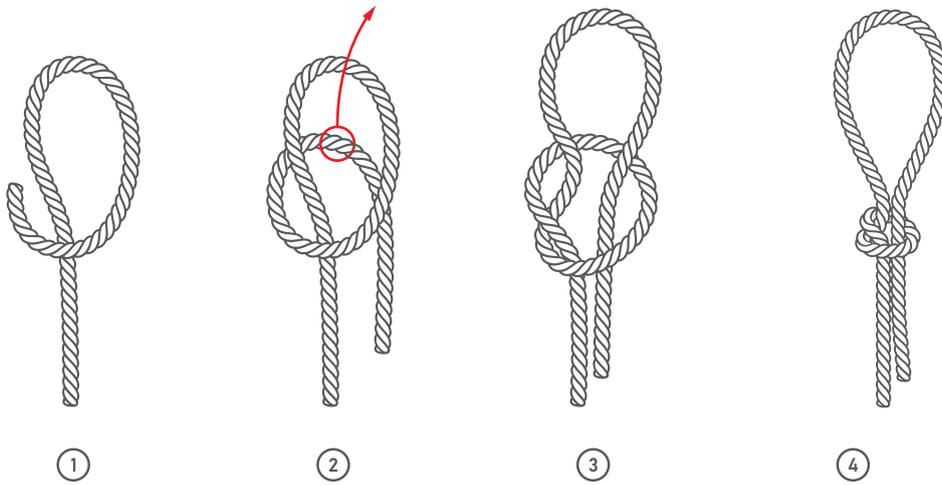
12



Repeat with **String B** on the other side of the pouch

13

How to tie a slipped overhand knot



IMPORTANT:

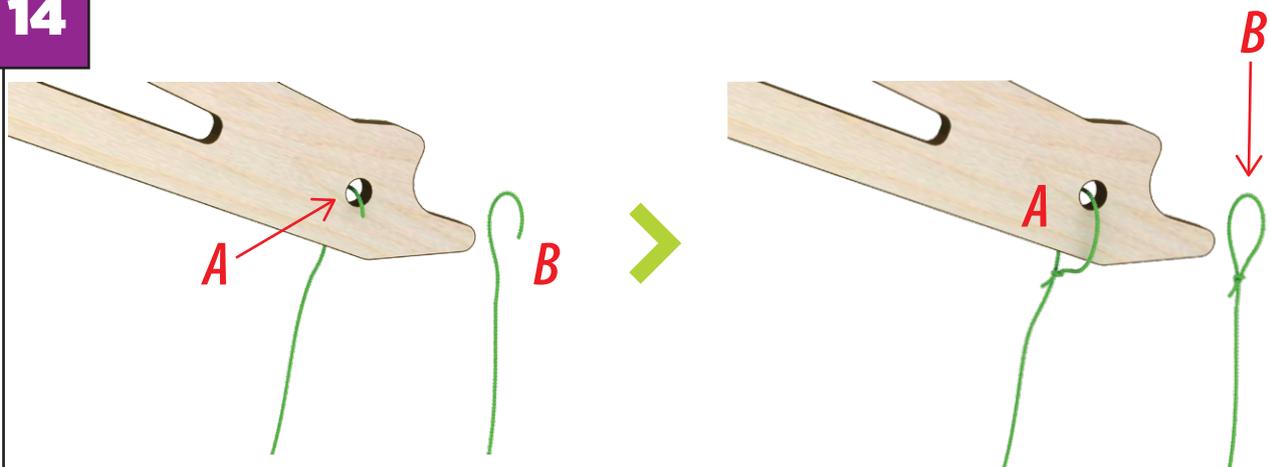
A. Tie string A through the hole on the end of the arm.

Make sure the length of the string from the hole to the pouch is 6 inches.

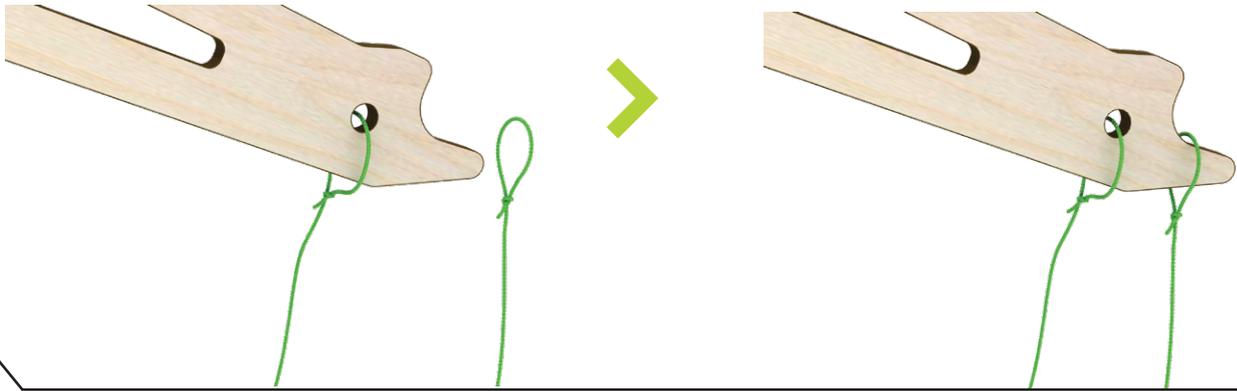
B. Create a 1/2 inch loop on the String B which should be 6 inches from the hook to the pouch.

When completed, both strings should be even in length and the pouch should sit evenly.

14



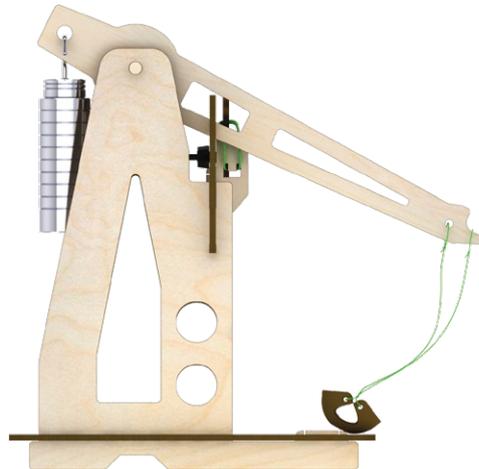
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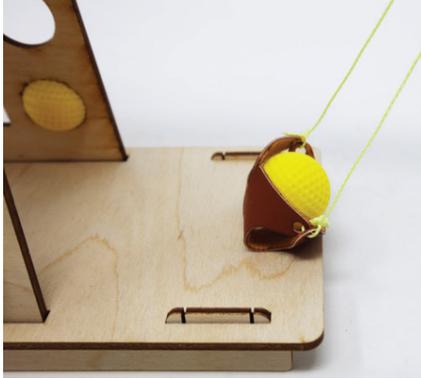


17



HOW TO USE

1. Load Projectile



2. Hang Weight



3. Lock Arm



4. PRESS TRIGGER AND LAUNCH!

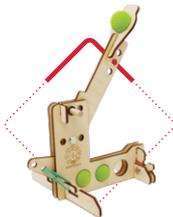
HAVE FUN & BE SAFE

EXTENSION

Add/remove weights to see how a heavier counterweight affects the different outcomes of your launches



If you enjoyed this STEM Kit, check out some of our other Kits!



CATAPULT



SEED SCIENCE



WIND TURBINE



AND MORE!

CLASSROOM ACTIVITIES

1. Distance Challenge

Have students test how far their trebuchets can launch a projectile.

- Let them adjust variables like counterweight size, arm length, or sling length and record the differences in launch distance.

2. Accuracy Target Practice

Set up a bullseye target at a fixed distance.

- Students must fine-tune their trebuchets (adjust angles, release points, etc.) to hit the target accurately.
- Keep score based on where the projectile lands!

3. Historical Siege Simulation

Divide the class into small groups, each representing a medieval army.

- Set up castle models (cardboard or paper cups) and challenge students to knock them down using their trebuchets.
- Discuss real-world trebuchet use in history and compare strategies!

4. Trebuchet Tournament

Host a friendly competition where students earn points for distance, accuracy, and power.

- Offer small prizes or certificates for categories like "Most Accurate Launch," "Longest Distance," and "Best Design."

5. Scientific Method Experiment

Have students design their own experiments by formulating a hypothesis about how trebuchet modifications will affect performance.

- Conduct tests, analyze data, and present findings to the class.

Worksheet 1: Trebuchet Physics & Energy

Name(s): _____

Date: _____

Part 1: Understanding Energy

Define potential energy in your own words.

Define kinetic energy in your own words.

In a trebuchet, where is the potential energy stored?

What happens to the potential energy when the counterweight is released?

Part 2: Forces and Motion

Label the parts of a lever in a trebuchet: Fulcrum, Effort, Load (Draw a simple diagram if needed).

How does the slingshot effect improve the trebuchet's performance?

What two factors affect the accuracy of a trebuchet's launch?

Part 3: Critical Thinking

asdwlf we increase the counterweight's mass, how do you think the projectile's distance will change? Why?

How does changing the length of the trebuchet arm affect the projectile's speed and distance?

Worksheet 2: Trebuchet Design & Experiment

Name(s): _____

Date: _____

Part 1: Designing Your Trebuchet

Sketch a simple trebuchet and label the following parts: fulcrum, counterweight, lever arm, sling, projectile.

(Draw your trebuchet in the space below)

Part 2: Experiment and Data Collection

Conduct a trebuchet launch and record the results.

Trial #	Counterweight Mass	Launch Angle	Distance Traveled
1			
2			
3			

Part 3: Analysis

What changes in your setup affected the projectile's distance the most?

How could you improve your trebuchet's performance in future trials?

Conclusion: What did you learn from building and testing your trebuchet?
