BrainStorm STEM EDUCATION

STEM KIT

EDUCATOR GUIDE

CATAPULT

CREATED FOR BOTH HOME AND SCHOOL

PERFECT FOR THE CLASSROOM

DESIGNED BY TEACHERS FOR TEACHERS

TABLE OF CONTENTS

LESSON OVERVIEW

Class Information

In this lesson, student will learn all about catapults. This will cover the overall history, science, and math concepts that apply to catapults. Students will test their knowledge by building and applying these concepts using the Brainstorm STEM Education Wooden Catapult STEM Kit.

CONCEPTS

- **History of Catapults**
- **Forces and Physics**
- **Simple Machines**
- **Types of Energy**
- **Projectile Motion**
- **Angles and Trajectory**

LESSON OBJECTIVES

- Describe the forces at play in the wooden catapult
- Explain how the angle of release will affect the projectiles motion
- Students will build and test their catapults to describe projectile motion.
- Explain what the most effective angle of release for launching the projectile the farthest distance.

EDUCATIONAL STANDARDS

NGSS - Next Generation Science Standards

Engineering Design

- K–2-ETS1-2. Develop a simple sketch, drawing, or physical model to illustrate how the shape of an object helps it function as needed to solve a given problem.
- 3–5-ETS1-2. Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 3–5-ETS1-3. Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

Motion and Stability: Forces and Interaction:

- K-PS2-2. Analyze data to determine if a design solution works as intended to change the speed or direction of an object with a push or a pull
- 5-PS2-1. Support an argument that the gravitational force exerted by Earth on objects is directed down.

Energy

- 4-PS3-1. Use evidence to construct an explanation relating the speed of an object to the energy of that object.
- 4-PS3-3. Ask questions and predict outcomes about the changes in energy that occur when objects collide
- 6-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.

CCSS MATH - Common Core State Standards Math

- CCSS.MATH.CONTENT.4.MD.C.5 Recognize angles as geometric shapes that are formed wherever two rays share a common endpoint, and understand concepts of angle measurement:
- CCSS.MATH.CONTENT.4.MD.C.6 Measure angles in whole-number degrees using a protractor. Sketch angles of specified measure.

INTRODUCTION

Today we will be discussing catapults! We will be learning about how the idea of the catapult was created and evolved for different objectives. We will discuss how the catapult was created to assist with siege warfare starting with the design of the ballista and evolving to the mangonel and the trebuchet designs for stronger firepower. Then we will break down the mechanics, forces and physics of the mangonel catapult as it pertains to the hands on project for the students today. As well as learning about angles and projectile motion to determine the most effective angle for launching the projectile. After the instruction portion of class, students will be able to build their wooden catapult using the provided stem kit from brainstorm stem education in order to test their knowledge on catapults!

VOCABULARY

Fulcrum- the point on which a lever rests or is supported and on which it pivots.

Energy- the property of matter and radiation which is manifest as a capacity to perform work (such as causing motion or the interaction of molecules)

Potential Energy- the energy possessed by a body by virtue of its position relative to others, stresses within itself, electric charge, and other factors.

Kinetic Energy- energy which a body possesses by virtue of being in motion.

Projectile- an object propelled through the air, especially one thrown as a weapon.

Projectile Motion- the motion of an object thrown or projected into the air

Tension- the state of being stretched tight.

Trajectory - the path followed by a projectile flying or an object moving under the action of given forces.

Simple Machine- A simple machine is a mechanical device that changes the direction or magnitude of a force

Force- a push or pull upon an object resulting from the object's interaction with another object. Whenever there is an interaction between two objects, there is a force upon each of the objects.

HISTORY OF CATAPULTS

One of the most well known, early weapons is the catapult. The invention of the catapult is most often attributed to the Greek Dionysius the Elder of Syracuse around 400 BCE. As siege warfare became more practiced, it brought the battles closer to home. In order to protect their communities, Leaders were having their castle walls built higher and stronger leading to the need for a new method of weaponry in order to win battles. The goal of catapults were to destroy the stronger castle walls or even throw projectiles over the walls. The mechanics of catapults allowed for then to be used to gain an advantage in siege warfare.

SIEGE WARFARE

Siege warfare was a method of fighting which allowed armies to fight from a distance instead of hand to hand combat. As castles and fortresses got taller and stronger, a different method of fighting was needed. A siege took place when enemy forces would surround the castle or town and cut off their essential supplies. This long term operation can be used to compel the community inside to surrender. This form of Siege warfare is called a passive siege and is very time consuming. Before improvements in weaponry, the Greeks were not known to be successful in active sieges and did not engage in passive sieges very often to not waste time and expense.

Catapults were an effective weapon for this type of warfare as they could be used to launch objects over the walls such as decomposing bodies of animals, rocks, fire, etc. These objects were thrown over the walls in order to potentially cause the people inside to be injured, get sick, or just ruin their moral. Catapults were also effective in knocking the walls of the castles down in order to allow the enemy troops to break into the castle and engage in hand to hand combat.

CATAPULT ENGINEERING

Catapults were engineered to be effective weapons in siege warfare. There are 3 main types of catapults that were designed for different objectives to magnify their strengths. The three main types of catapult designs are the Ballista, Trebuchet and the Mangonel.

BALLISTA [A]

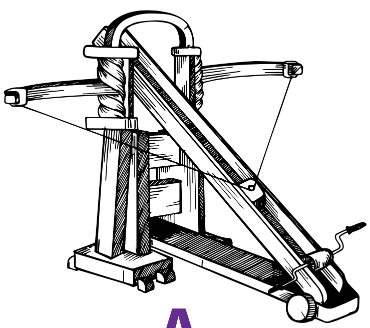
This catapult is very similar to a crossbow on a much larger scale. The projectile resembled a long arrow that was fired horizontally at a target. This design was very accurate but not very powerful making it not as effective in siege warfare.

TREBUCHET [B]

Trebuchets are built with a large frame and a long firing arm attached at a fulcrum point on a cross beam. One end of the arm has a large counterweight that uses gravity to launch the projectile. Due to the design of this catapult the projectiles can be launched up to 300 feet with immense power, knocking down castle walls with a single launch.

MANGONEL [C]

This is the most common image of a catapult as well as the design for the brainstorm catapult. This catapult design primarily consists of a long arm with a place to hold a projectile at the end. The other end was attached to the base at a fulcrum. Mangonels could throw their projectiles over 1,000 feet, making it very effective in siege warfare.



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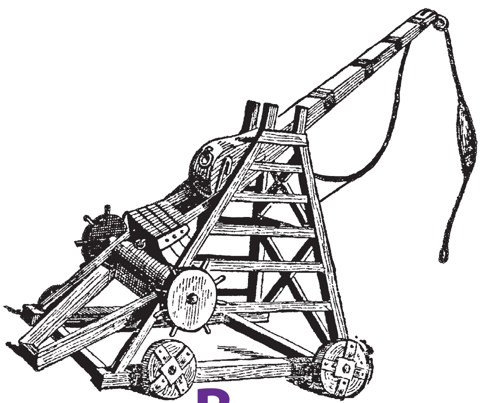

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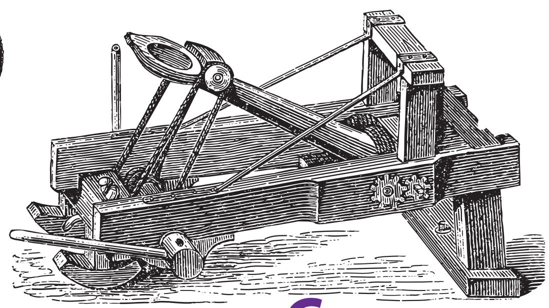


C

CATAPULT PHYSICS

In all catapult designs the idea is to store potential energy in the frame or components of the catapults, and then transfer the potential energy to kinetic energy to have the projectile fly through the air.

Potential Energy is the energy of an object that is stored due to its position or state.

The potential energy can be created in the catapults by creating tension or torsion.

Tension is a force created by stretching or pulling something. For example, pulling on a rope, or elastic potential energy created by stretching a rubber band tight.

Torsion is a force created by twisting. This torsion can be created by twisting a spring or twisting a rope so that it wants to unwind.

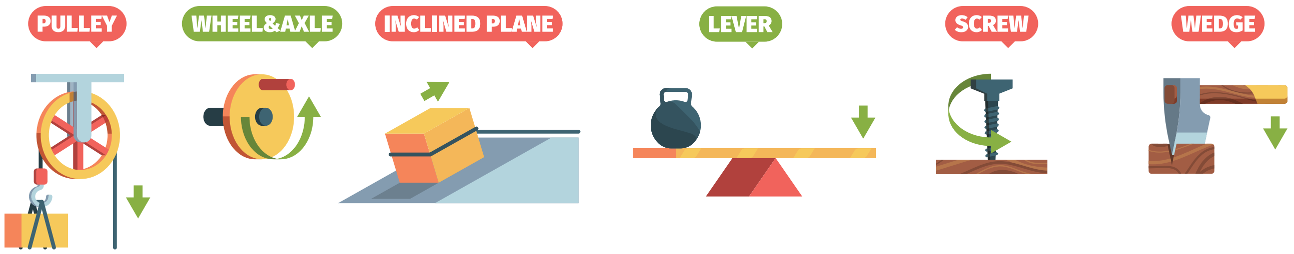
Kinetic Energy is the energy of an object due to its motion. This motion takes place due to the stored potential energy of the object.

Kinetic Energy is executed in projectile motion. As the Projectile is released from the catapult and it flies through the air, the path that the projectile is flying in is called its trajectory.

As the arm of the catapult is pulled back the elastic potential energy is being stored in the rubber band. When the rubber band is pulled tight, it increases the tension. The more tension the rubber band has, the more force that the rubber band will apply to the kinetic energy of the projectile upon its release. Once the arm is released, the tension of the rubber band will cause the arm to lift up and launch the projectile in its trajectory.

SIMPLE MACHINES

Simple machines are devices that help increase the magnitude or direction of a force. There are 6 types of simple machines:



Each simple machine is used to assist the user by amplifying the force that they apply to the machine to allow for a better output. Catapults are a great example of using simple machines, particularly using the lever and an axle to magnify the force of the projectile.

LEVER

A Lever is a long straight piece that rests on a support called the fulcrum. The fulcrum provides a pivot point for the lever to move up and down. When a downward force is put onto one end of the lever, it transfers the force in an upward direction at the other end. Depending on where the fulcrum is located on the lever it will change the resulting upward force. This allows for a small downward force to lift a heavy weight up. The arm of our catapult acts as a lever by using the downward force on the arm to store energy that can be transferred with a greater upward force through the projectile at the time of release.

AXLE

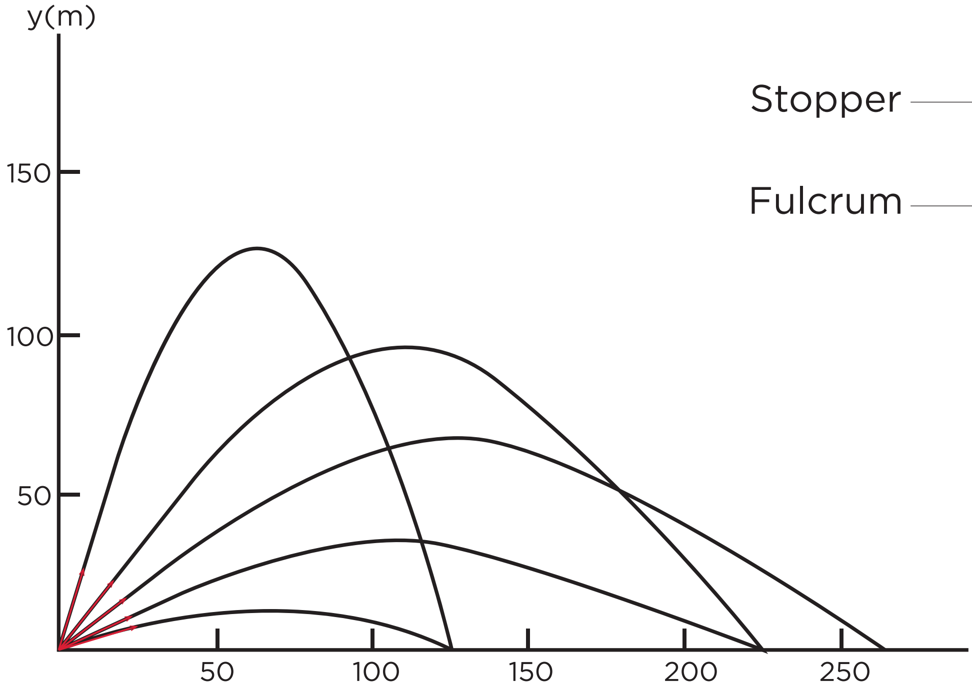
An axle is a rod that is placed in the middle of a wheel that allows for the wheel to revolve around it. In our catapults, the axle acts as our fulcrum for the arm. Instead of our fulcrum being a specific point, it is an axle that allows the arm to freely rotate around and allow the force of the lever to be magnified in its motion.

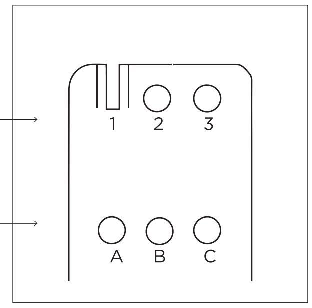
PROJECTILE MOTION

Projectile motion is the motion that an object follows as it is thrown into the air. The motion of a projectile depends on a few factors including the air resistance, the angle of release and the power of the throw. When the projectile is released, the path that it is traveling in is a parabola.

As it is flying through the air, it is constantly being subjected to gravitational pull as well as air resistance. As the object flies forward, the air resistance pushes against the object causing its forward acceleration to slow down. As the forward acceleration of the object decreases, the gravitational pull has more effect on the object pulling it down towards the ground. This causes the flight of the object to make a parabolic path.

The height and length of the parabolic path can be determined by the launch angle. The optimal angle for the furthest distance is 45°. If the projectile is launched at a lower angle, it will cause a much higher path, but it will not travel as far. Whereas if the projectile is launched at a higher angle,the parabolic path will travel at a much lower path meaning it will hit the ground faster since gravity doesn't have as high of a path to pull down.

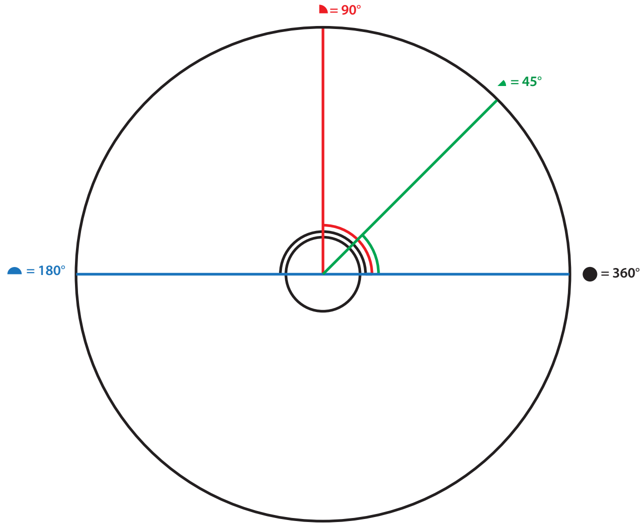




	1	2	3
A	55°	75°	90°
B	35°	55°	75°
C	25°	35°	45°

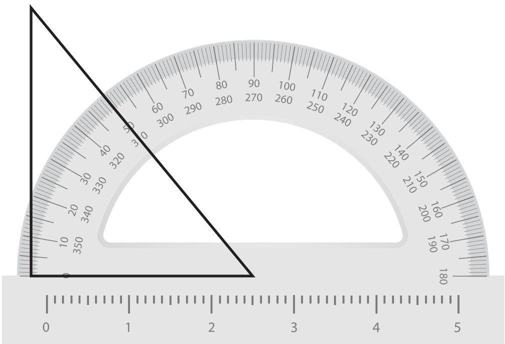
DETERMINING ANGLES

Angles are formed when 2 lines meet at a shared point. Angles are measured in degrees using the symbol ° When determining angles, it is helpful to visualize a circle.



Full circle = 360°
Half of a circle = 180°
Quarter of a circle = 90°
Eighth of a circle = 45°

We can figure out the launch angle of our catapult by visualizing it as the arm of the catapult is the long side of a triangle. The launch angle is going to be the angle that the long arm of the catapult makes with the base of the catapult. We can then figure out what the angle is by using a special measuring tool called a protractor. A Protractor is a half circle that measures the angles from 0° to 180° We can line up our protractor with the catapult to determine the angle that it makes.



Launch Angle = 50°

To determine the launch angle, you will need to measure the angle using a protractor. To Identify the angle of the launch, you can place the protractor at the fulcrum with the base of the protractor being parallel to the surface the catapult is sitting on. The end of the catapult arm will line up with a number on the edge of the protractor. This will determine the launch angle of the catapult. The launch angle will correspond with the inner angle of the right triangle shape the arm of the catapult makes.

PROJECT OVERVIEW

Today's project will be the students building and testing the wooden BrainStorm catapult. The catapult uses the mechanics of a mangonel catapult to store tension in the rubber band in the form of elastic potential energy and transfer that to kinetic energy to allow the projectile to fly. All of the materials that are needed to build the catapults can be found inside the BrainStorm STEM Education Wooden Catapult Kit.

SAFTEY WARNINGS:

Please read all saftey 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

Durable wooden construction pieces
Rubber Bands
Adjustment Dowels
O-Rings
Screws
Screwdriver
Foam Balls

1

NOTE: If you can not break out the 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 do to breaking or cutting, smooth them with a piece of sand paper.

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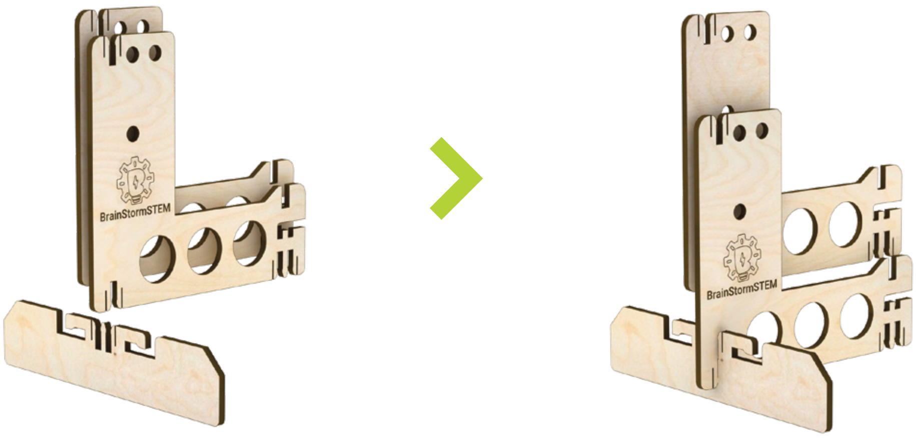

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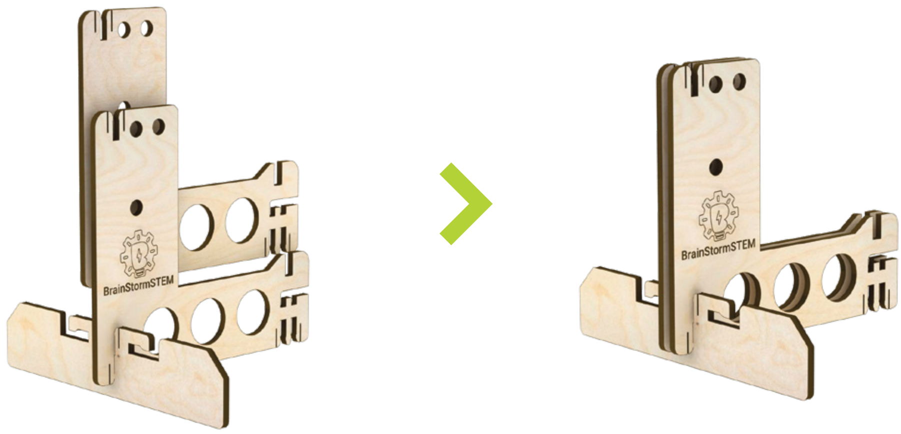

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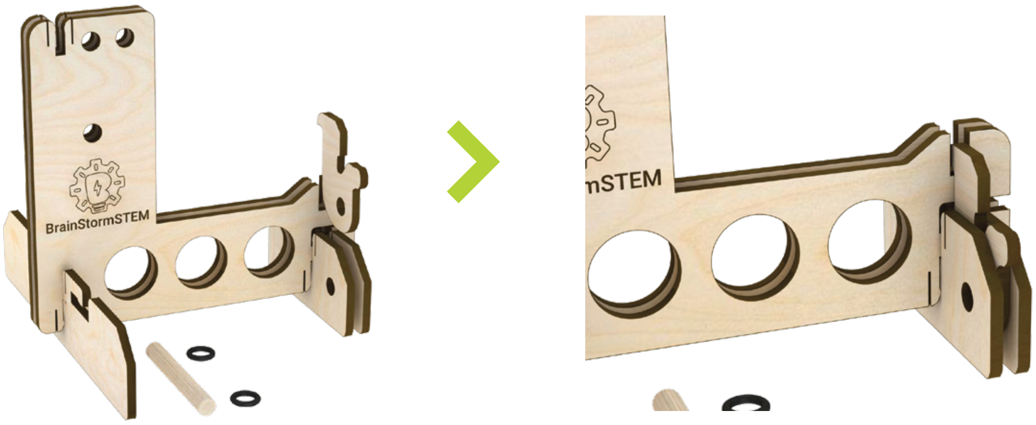

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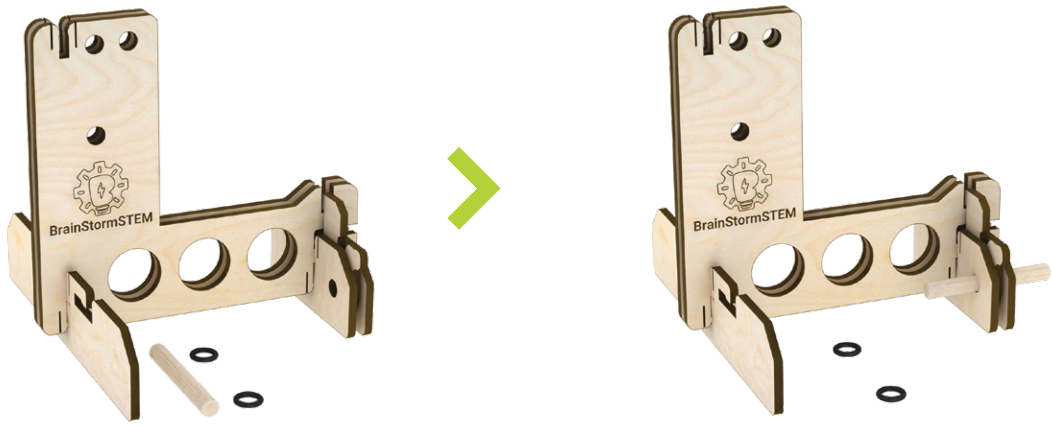

NOTE: You can instead use a wing nut and thumbscrew

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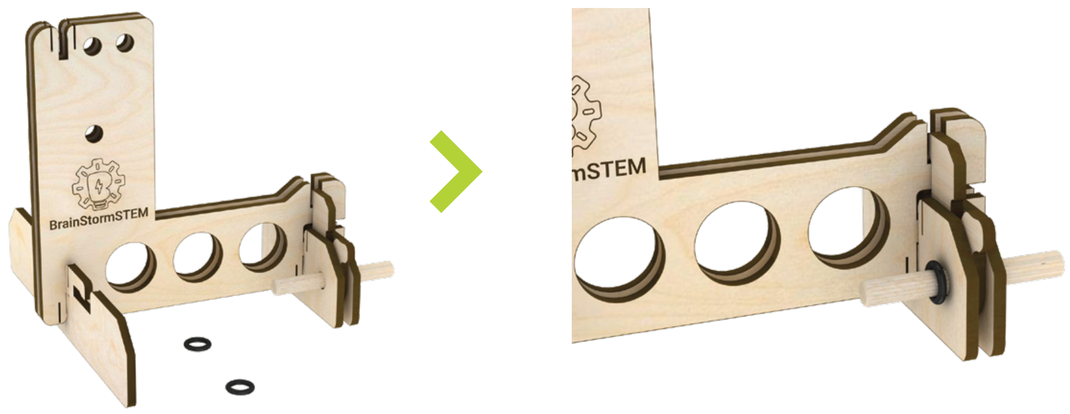

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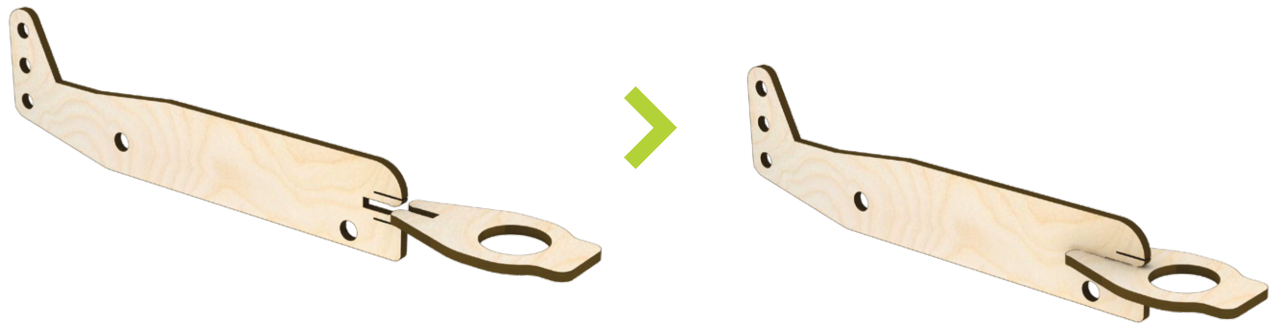

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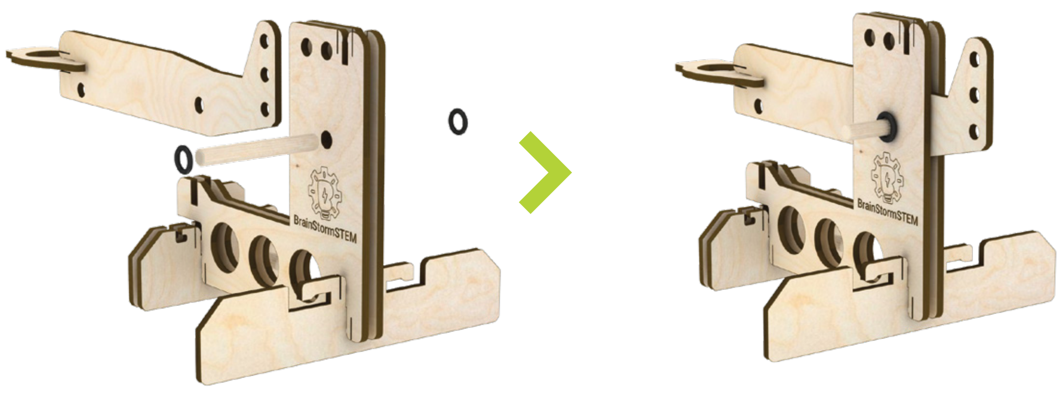

NOTE: You can instead use a wing nut and thumbscrew

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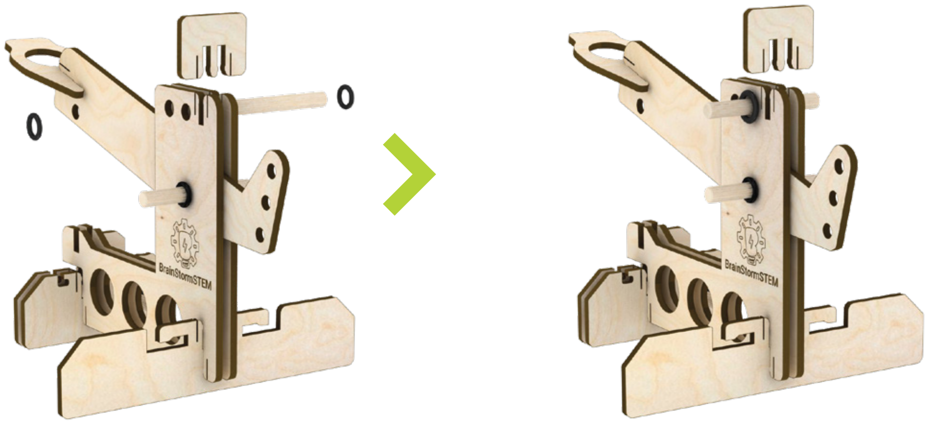

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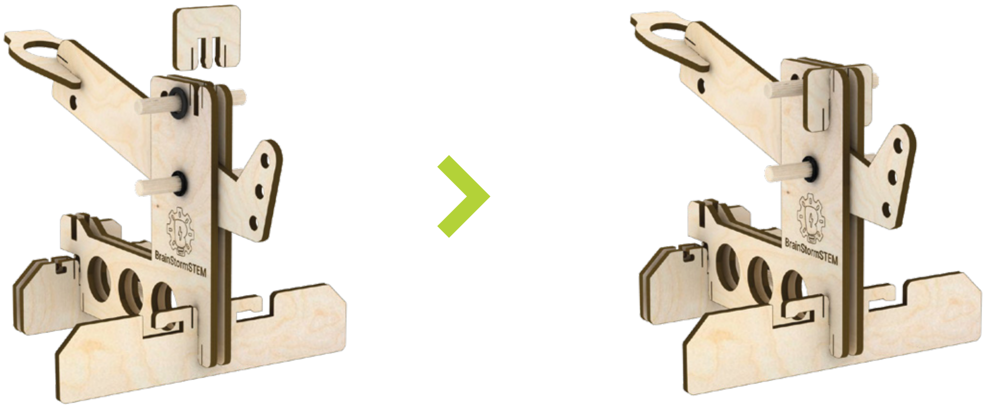

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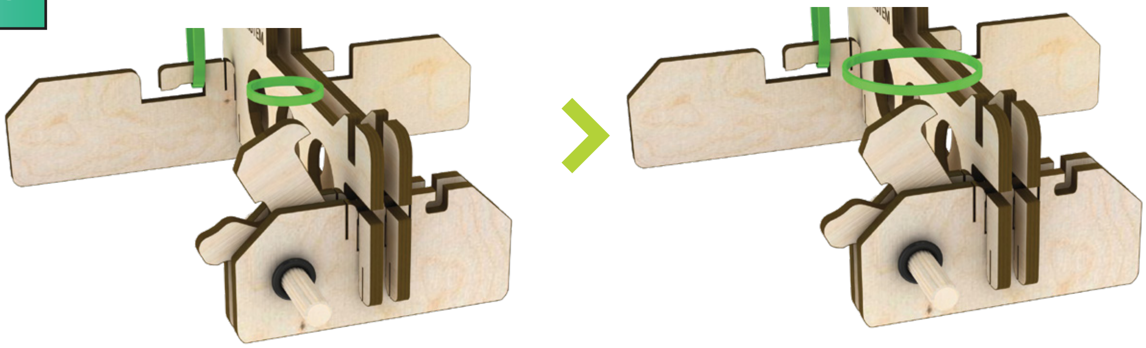

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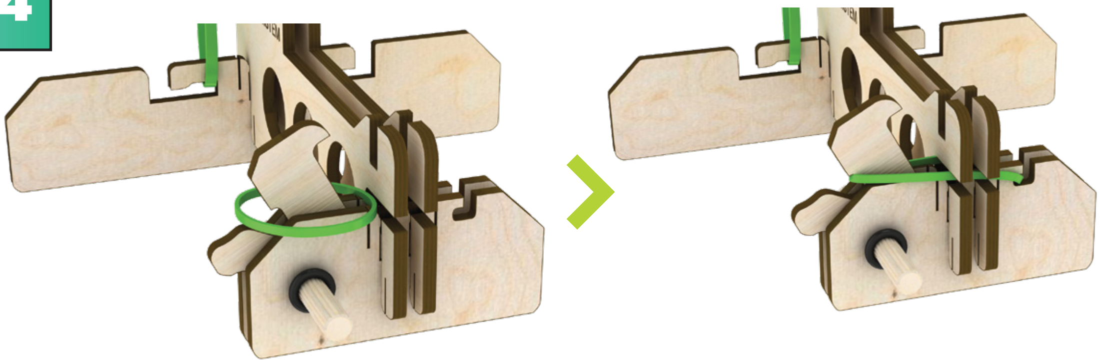

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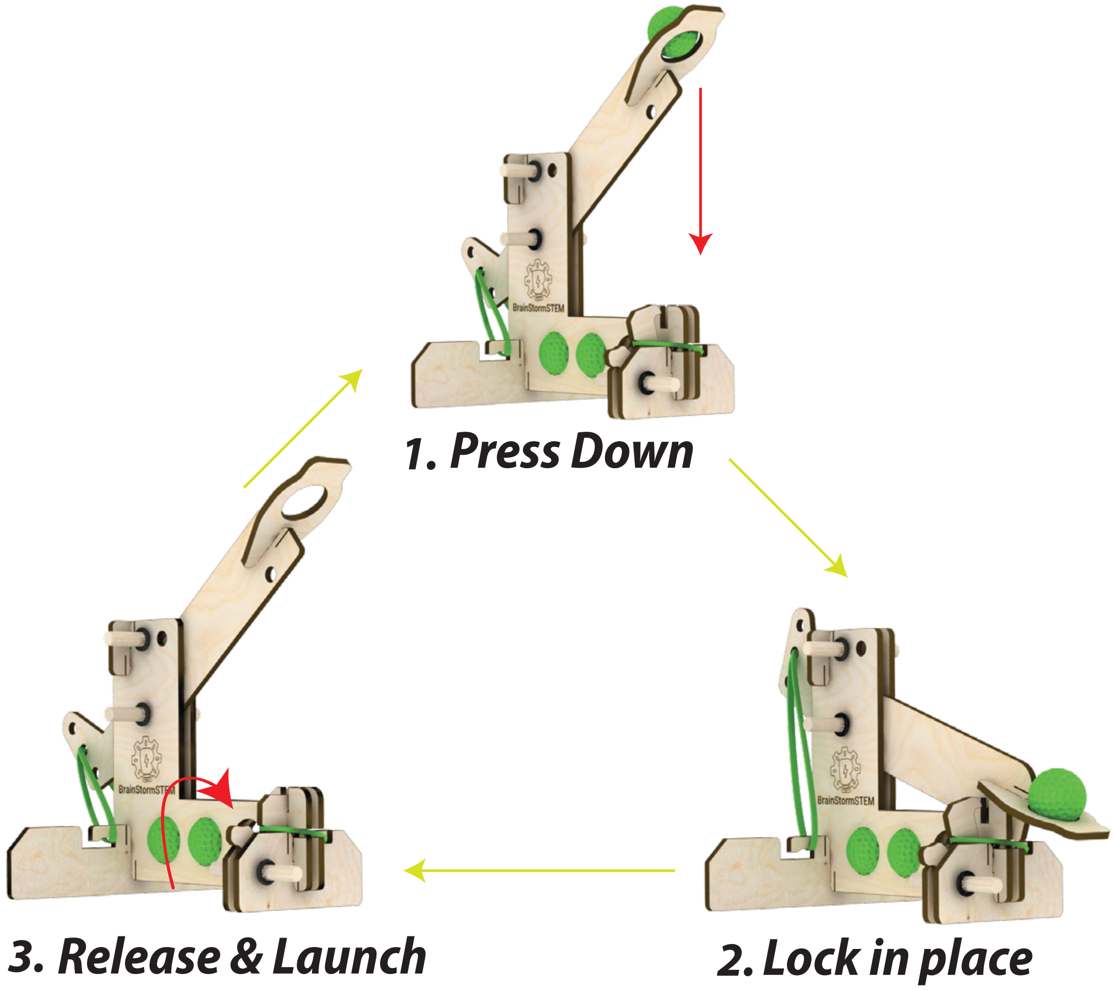
The Catapult STEM Kit comes with another way to build! Use the thumb screw and wing nut instead of the dowels on Step 6 and Step 9.

HOW TO USE

DO NOT SHOOT AT PEOPLE OR ANIMALS.



HAVE FUN & BE SAFE

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

CIRCUIT SWORD | AIR-POWERED ROCKET | DRAGSTER | AND MORE!

ACTIVITY FOR PROJECT

The Wooden catapult can be used just to build, launch and have fun. But if you would like the catapult to be used as a more engaging classroom activity, it can be paired with the provided worksheets. There is a beginner worksheet and an advanced worksheet that are provided to adjust to the level of your student's understanding.

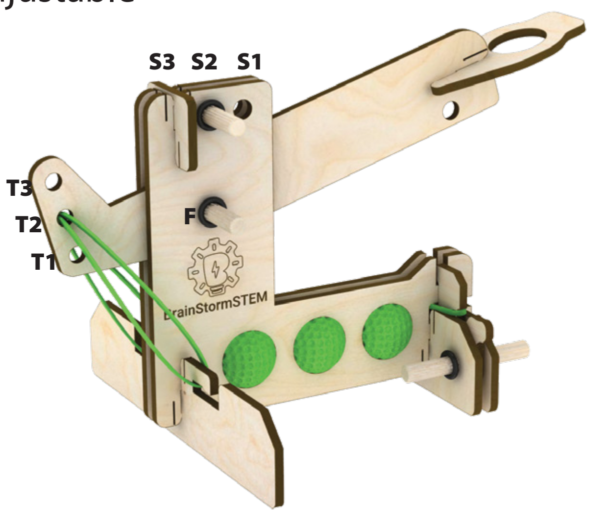
The catapults can be adjusted for different Tensions and Stopping points in order to affect the launch distance of the projectiles.

Inform students of the different adjustable components as seen below.

F = Fulcrum

S (1,2,3) = Stopping Point (1,2,3)

T (1,2,3) = Tension (1,2,3)



Each of the worksheets is geared towards having the students figure out what angle is the best for the furthest launch distance. On the beginner worksheet, the students will experiment with different settings to see what will get them to the furthest target. On the advanced worksheet, the students will use a protractor to measure the specific angles at each setting to determine the most optimal angle to launch at.

The students will be able to see how adjusting the components will change the launch angle and can verify that the launch angles closest to 45° will inevitably launch the furthest!

PLEASE NOTE: This activity requires students to launch their catapults that send projectiles at least 13 feet away You will need to do this activity in a room with lots of space or outside.

WORKSHEET (BEGINNER)

Name(s): ______________________

Date: ______________________

INSTRUCTIONS:

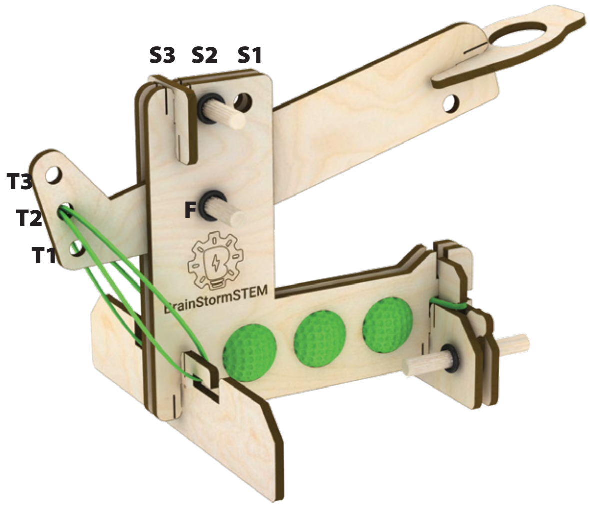
Begin by setting a target approximately 12 feet away from the catapult.

Your goal is to figure out what settings on the catapult will allow you to launch a projectile and hit the target.

F = Fulcrum

S (1,2,3) = Stopping Point (1,2,3)

T (1,2,3) = Tension (1,2,3)



Write the settings that were on your catapult when your projectile hit the target in the chart below	
Tension Setting (1, 2, 3)	Stopping Point Setting (1, 2, 3)

WORKSHEET (BEGINNER) ANSWER KEY

INSTRUCTIONS:

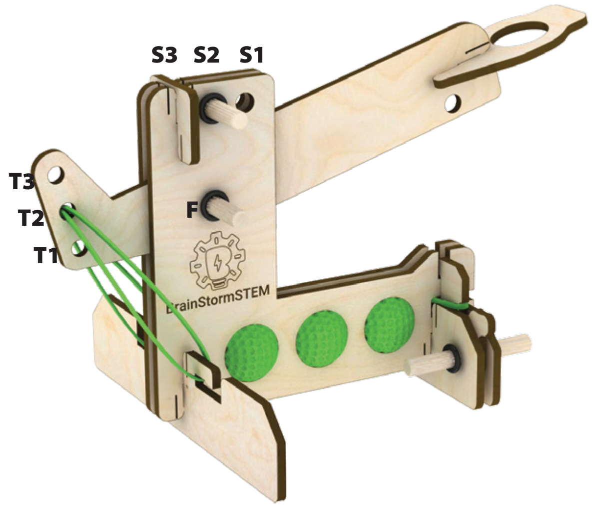
Begin by setting a target approximately 12 feet away from the catapult.

Your goal is to figure out what settings on the catapult will allow you to launch a projectile and hit the target.

F = Fulcrum

S (1,2,3) = Stopping Point (1,2,3)

T (1,2,3) = Tension (1,2,3)



Write the settings that were on your catapult when your projectile hit the target in the chart below	
Tension Setting (1, 2, 3)	Stopping Point Setting (1, 2, 3)
T1	**S1**
T2	**S2**
T3	**S3**

45° is the ideal angle to launch projectiles when attempting to reach the furthest distance.

WORKSHEET (ADVANCED)

Name(s): ______________________________

Date: ______________________________

INSTRUCTIONS:

Instructions: You will set the catapult Tension & Stopping Point to match the table(s) below.

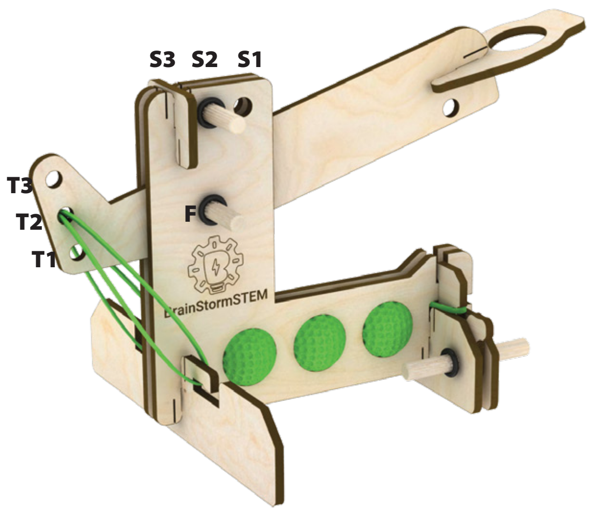
Measure the launch angle using your protractor and record that data in the table under the matching settings.

Next launch the catapult and measure how far from the catapult the projectile landed and record that data in the table below!

F = Fulcrum

S (1,2,3) = Stopping Point (1,2,3)

T (1,2,3) = Tension (1,2,3)



	STOPPING POINT 1			STOPPING POINT 2			STOPPING POINT 3		
	T1	*T2*	*T3*	*T1*	*T2*	*T3*	*T1*	*T2*	*T3*
LAUNCH ANGLE(°)									
LAUNCH DISTANCE(in)									

Circle the greatest Launch Distances in your table.

What angle(s) produced the longest launch distances? ______________________

WORKSHEET (ADVANCED) ANSWER KEY

INSTRUCTIONS:

Instructions: You will set the catapult Tension & Stopping Point to match the table(s) below.

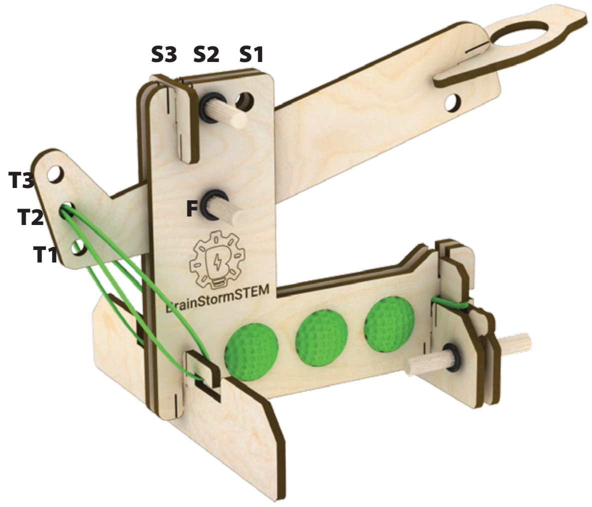
Measure the launch angle using your protractor and record that data in the table under the matching settings.

Next launch the catapult and measure how far from the catapult the projectile landed and record that data in the table below!

F = Fulcrum

S (1,2,3) = Stopping Point (1,2,3)

T (1,2,3) = Tension (1,2,3)



	STOPPING POINT 1			STOPPING POINT 2			STOPPING POINT 3		
	T1	*T2*	*T3*	*T1*	*T2*	*T3*	*T1*	*T2*	*T3*
LAUNCH ANGLE(°)	**45°**	**75°**	**90°**	**35°**	**45°**	**75°**	**25°**	**35°**	**45°**
LAUNCH DISTANCE(in)	*Distances are subjective to the amount of force used to launch*								

Circle the greatest Launch Distances in your table.

What angle(s) produced the longest launch distances? ______________________

PRINTABLES


0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180
350 340 330 320 310 300 290 280 270 260 250 240 230 220 210 200 190
BrainStorm
0 1 2 3 4 5


0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180
350 340 330 320 310 300 290 280 270 260 250 240 230 220 210 200 190
BrainStorm
0 1 2 3 4 5