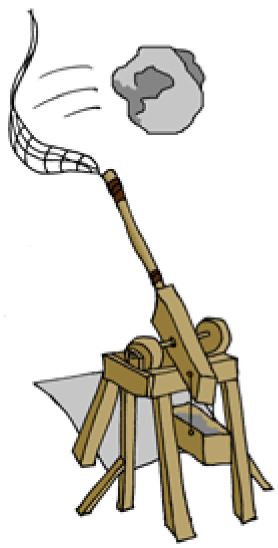
F-tWaNg!! ThW-uMP!!



Primary Objectives:

Students will:

- Understand the history of catapults and their roles in human warfare.
- Work in groups to build catapults out of everyday objects.
- Demonstrate their understanding of motion and forces by using the catapults to launch objects.
- Be able to through writing, or orally, relate how catapults use the forces and potential and kinetic energy.

Note: It is always a good idea to try out the experiments, projects, and variables prior to working on them with your students. This provides time to determine the best fits for your students, any necessary modifications, and the know-how to enable you to help and advise your students while they complete their own projects.

Examples of Possible Academic Standards to Incorporate:

The following are samples of what kinds of standards you might choose with a Science focus in your lesson. Go to the spreadsheet or the TN Curriculum site (http://www.state.tn.us/education/ci/arts/index.shtml) and choose the standards and vocabulary for each grade level that you are going to focus on. As with any lesson, part of your planning time will be spent making your own sample of the included projects so that you are aware of how much time and effort the projects will take as well as how you will want to modify them. Parents and everyone in the home is to be involved in this lesson and make their own projects as well.

Science:

Kindergarten Science Standard:

- 7.11.1 Explore different ways that objects move.

1st Grade Science Standard:

- 7.11.1 Investigate how forces (push, pull) can move an object or change its direction.

2nd Grade Science Standard:

- 7.12.2 Realize that things fall toward the ground unless something holds them up.

3rd Grade Science Standard:

- 7.11.2 Recognize the relationship between the mass of an object and the force needed to move it.

4th Grade Science Standard:

- 7.11.3 Investigate the relationship between the speed of an object and the distance traveled during a certain time period.

5th Grade Science Standard:

- 7.12.2 Identify the force that causes objects to fall to the earth.

6th Grade Science Standard:

- Inq.5 Communicate scientific understanding using descriptions, explanations, and models.

7th Grade Science Standard:

- 7.11.4 Recognize how a force impacts an object's motion.
- 7.11.2 Determine the amount of force needed to do work using different simple machines.

8th Grade Science Standard:

- 7.12.7 Explain how the motion of objects is affected by gravity.

High School: Physics

- 1.1.2 Analyze and apply Newton's three laws of motion.

Examples of Possible Academic Vocabulary to Incorporate:

The following are a very few samples of what kinds of vocabulary words from the K-12 Vocabulary Lists you might choose to incorporate naturally with your lesson.

Kindergarten:

- Tools
- Size
- Shape
- Collect
- observe

1st Grade:

- push/pull
- invent
- investigate
- Technology

- Past

2nd Grade:

- similarities/differences
- transform
- investigate
- infer
- observation
- Conflict

3rd Grade:

- force
- mixture
- Tools
- Weapons

4th Grade:

- Friction
- mass

5th Grade:

- potential energy
- kinetic energy
- gravity

6th Grade:

- Energy transformation
- Gravitational potential energy
- Control
- Cause and effect
- Medieval

7th Grade:

- Acceleration
- Momentum
- Simple Machines
- Speed
- Impact

8th Grade:

- Variation
- Vernacular

High School:

- Gravitational Potential Energy
- Efficiency
- Friction

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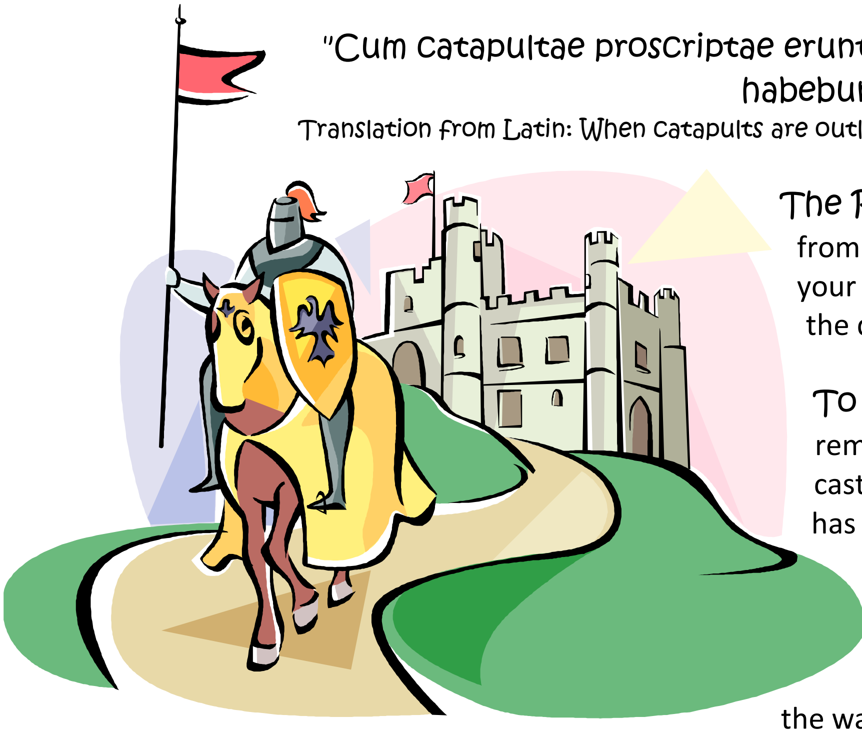


"Cum catapultae proscriptae erunt tum soli proscripti catapultas habebunt."
Translation from Latin: When catapults are outlawed, only outlaws will have catapults

The Problem: Your child has been stolen from your castle and is being kept inside your enemy's fortress on the other side of the dangerous and deadly Red Forest.

To Make it Worse: Your enemy has remodeled (made some changes to his castle) since the last time you fought. He has remade the walls with huge bricks so smooth you slide off when you try to climb them. They are so tall and wide you can't throw a ladder over the top of them, and the bottom of the wall is buried so deep into the ground you couldn't dig under it in a year.

After searching for months and fighting your way through the Red Forest you and your warriors have finally have found the key to save your child and get him/her back, but it will only work if you find a way get a message or help to her/him somehow, send/get the _________ to him/her, or break down the wall.

What can you Do? The Solution: (***Have your students come up with the idea/Guide them towards the idea that they need to catapult something in. Get them thinking before you introduce the lesson subject*.**)

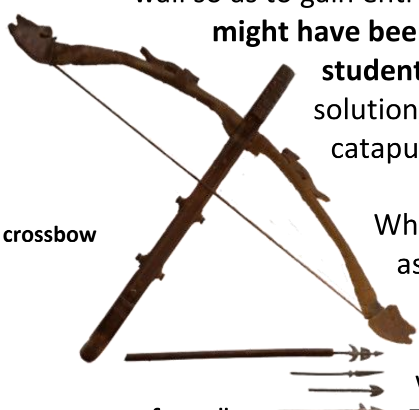
"catapult (n) - ancient device used for hurling cats at the enemy. It was later replaced by the rockapult, a much more effective weapon."

Okay, that really isn't true, probably, but seriously, weapons that once smashed castle and fortress walls are now great lessons in how basic mechanical principles can, and did, turn simple materials into very useful, effective, and protective tools. And, just in case you wanted to know, historians say the word "catapult" actually comes from the Greek *kata* meaning "downward," and *pultos*, meaning "shield." Its literal translation was "shield piercer [breaker],” which an angry enough cat just might be able to do.

Throughout this lesson are terms that may be too advanced for younger students but appropriate for others depending on their skill level. Be sure to modify appropriately, explanations are given in parentheses.

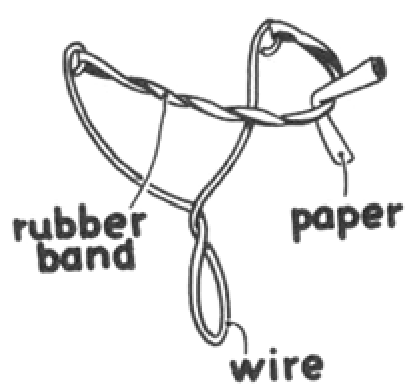
One of the problems with warfare (war) throughout history was that enemies had the annoying habit of hiding behind fortifications (A defensive wall or other reinforcement built to strengthen a place against attack. The solution: to find a way of breaking, piercing or otherwise destroying part of the wall so as to gain entry. And, if you were that annoying enemy hiding inside those walls, it was equally important to be able to stop those people from breaking, piercing or otherwise destroying part of the wall so as to gain entry and get to you. **What to do? Discuss with your students things that might have been tried to protect/defend castles and attack them. What ideas do your students have?** Eventually, after a lot of trial and error (experimenting until a solution/the right answer is found), both sides came up with the same answer, a catapult.

crossbow



What you and I know as a catapult is actually a mangonel, otherwise known as an onager. Onager was a slang term, or nickname, that came from the Greek name for ‘wild donkey’. This referred to the way the machine ‘kicks’ when it’s fired. The correct term for the catapult is mangonel – which comes from the ancient Greek term “manganon” meaning “engine of war”. The catapult/onager/mangonel is a machine used to throw projectiles (objects) over a great distance without the use of explosives, like gunpowder, to give it more power.

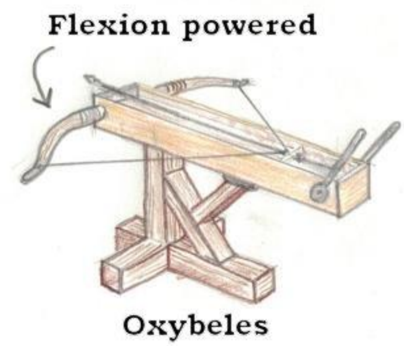
The earliest catapults date back to ancient Greece – and the way they worked was a lot like a crossbow or a sling **(Look at the picture of the crossbow and discuss with your students, by looking at it, how do they think it works? Have they ever shot a bow? Or a slingshot?)**



To show your students a basic example of how the first catapults might have worked, and have them get a feel for what tension does, construct a slingshot. To make a slingshot that will shoot pieces of paper, all you need is wire (like the type you find from a wire hanger) and a rubber band. Twist the wire as shown in the picture and make loops at each end to hold the rubber band. Fold little pieces of paper, make a target, aim, and shoot. If you

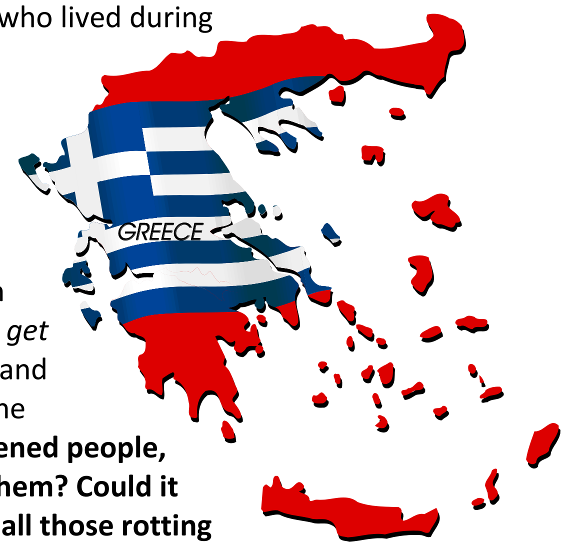
allow your students to try it, supervise them carefully, provide a target, and before use have them promise to never point the slingshot at people or animals and only use paper projectiles. Image and Instructions Credit: Artists Helping Children.
http://www.artistshelpingchildren.org/gamestoysartscraftstideaskids.html Accessed 8/25/11.

The ancient Greek catapults are thought to have weighed approximately 2,000 pounds and could throw an eight-pound stone (or a gallon of milk) some 500 yards/1500 feet/almost 3/10 of a mile. The lighter version of the catapult was thought to weigh about 1000 pounds and would have been able to hurl a 3-4 pound stone about 100 yards/300 feet. Heavier machines would have been able to throw stones even further, **(discuss with your students why they might not have wanted to build their catapults even larger. What might be some potential problems?)** but they wouldn't be practical. Just imagine trying to carry a 1,000 pounds worth of catapult parts to a battle miles away and then build it on the battlefield. (Which would have been hard to do if your enemies were attacking while you were trying to build!) **How do your students think they managed to build catapults in the middle of a battlefield? If you saw your enemies building one, how might you try and stop them?**

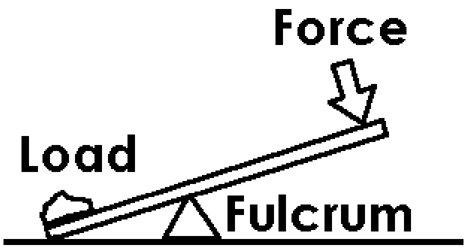


During the Medieval Era (400 to 1300 A.D), entire cities would be surrounded by seemingly unbreakable walls. These walls could be extremely tall and extremely thick - too tall to climb and too hard to break through. So some very smart scientists came up with a way to launch projectiles (objects) OVER the wall. **Why might this have been an important discovery?** If they could attack from the outside, they didn't have to try to climb over the wall, or if they were inside, they didn't have to go outside to fight.

First described by the historian *(writer of history)* Diodorus who lived during the first century B.C. *(from100 BC to the last day of 1 BC)*, catapults changed over time into arrow-shooting machines **(Why would it have been good to be able to shoot arrows really quickly and powerfully from far away?)** But catapults as we think of them were often-used in medieval times, as they were very helpful in breaking down a castle's strengthened walls. They were also the weapon of choice in early biological warfare *(trying to make your enemies die or get very sick by exposing them to germs)* – dead human bodies and diseased and dead animals were thrown over the walls of the enemy. **Why do your students think this might have frightened people, having dead animals and people thrown over the wall at them? Could it have made them sick? How would they have gotten rid of all those rotting bodies?**

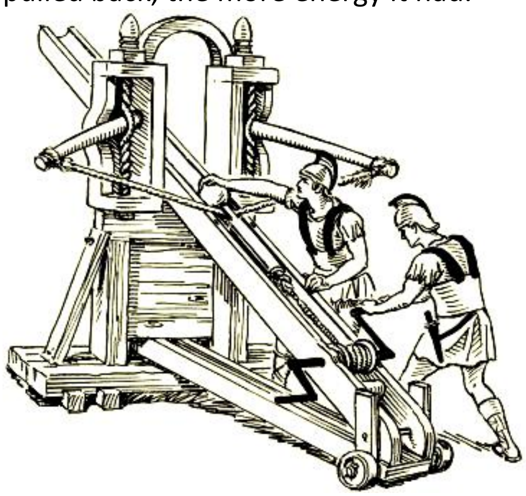


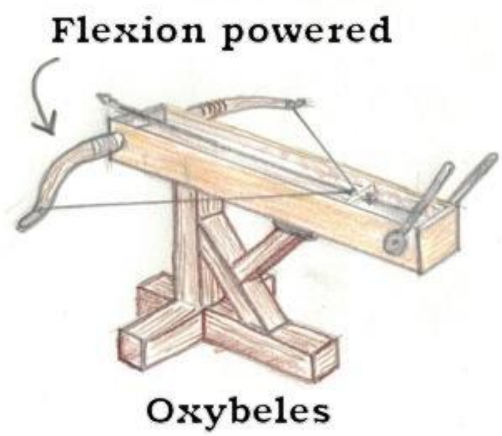
So how did they come up with this clever idea? **(Ask students, where might they have gotten the idea from?)** Well, the catapult is actually a couple of simple ideas combined into one more complex/complicated machine. By combining a simple machine, the lever *(like a teeter-totter, it is a stiff bar resting on a pivot, used to help move a heavy load with one end when pressure is applied to the other)*, with a spring and add in another lever, you've got a catapult. (*Simple machines make our lives easier by allowing us to use less energy & force to do work. Simple machines can be combined to form compound/more complex machines, allowing simple machines to be used in greater variety of ways.)* **Have your students ever used a lever or tool to help them move something? Have them test out whether it is easier to move objects using a lever by testing the theory using a variety of objects. Ex: a ruler, something for the fulcrum, and a book.**



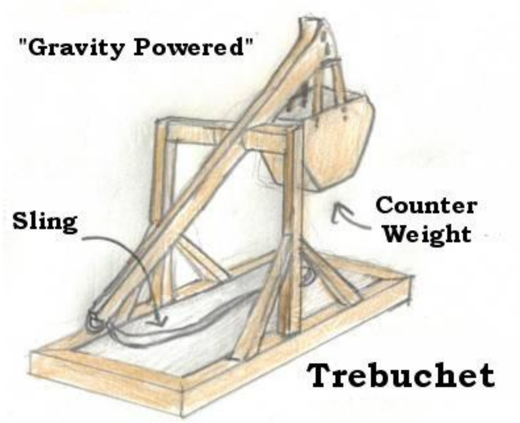
There were different types of catapults used in the Middle Ages. They included:

- Ballista/Oxybeles -- Like a crossbow, they worked by using tension, the farther it was pulled back, the more energy it had.

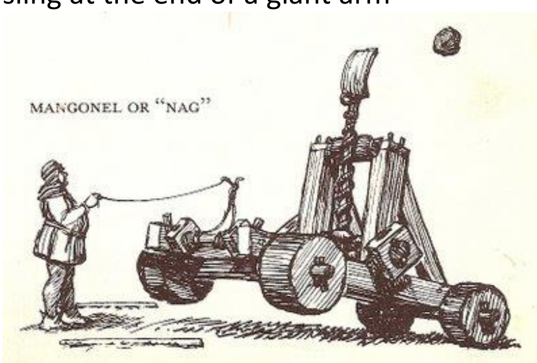


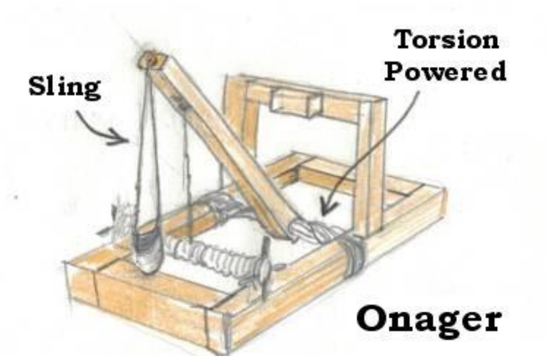


- Trebuchet -- It included a lever and sling, and could throw up to 200 pounds nearly a mile.



- Mangonel/Onager -- Projectiles *(objects)* were thrown from a bowl-shaped bucket or sling at the end of a giant arm

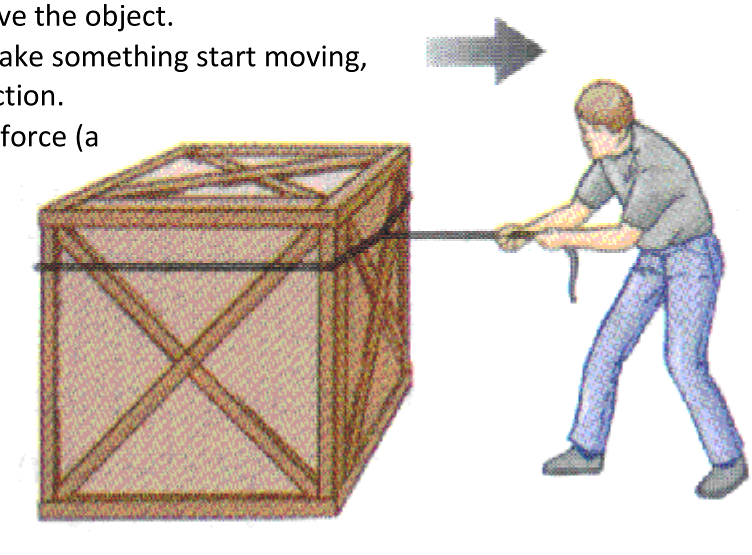




How it all Works

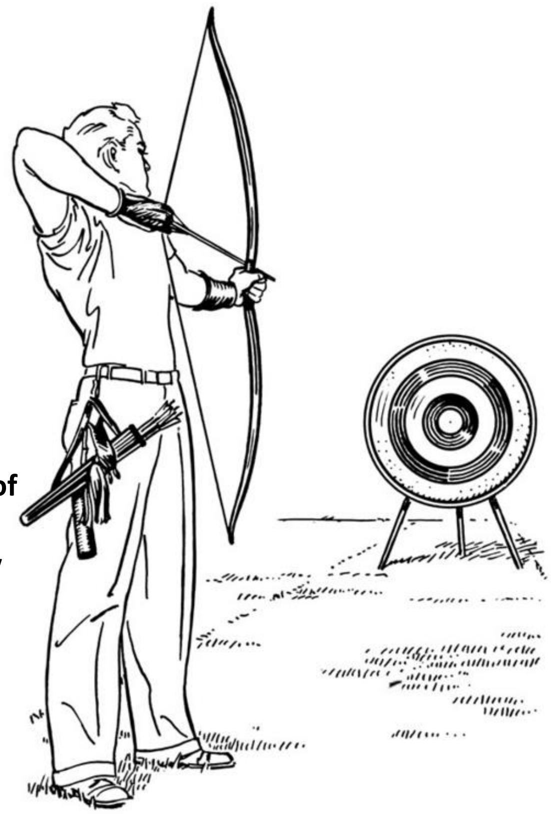
A couple of factors can affect the distance an object can be launched, such as the mass of the object, and the amount of force used to move the object.

- Force - a push or pull…A force can make something start moving, stop moving, or make it change direction.
- Work – work is done when we use a force (a push or pull) to move something over a distance.
- Energy - the ability to do work. If I have no energy, I can't use force to make something move!



There are two different kinds of energy

- Kinetic Energy – the energy of motion.
- Potential Energy – is stored energy – it has "potential" to do something.



Archer Image Credit: Claudia. Students of the World. Accessed 8/24/11. http://www.studentsoftheworld.info/sites/science/claudia.php

Potential energy is the energy of position, usually related to the relative position of two things. Potential energy is the energy waiting to be released into kinetic energy. **(Discuss various examples of potential and kinetic energy around you. Roller coasters, bows and arrows, etc. Which might have more potential energy: a book teetering on the edge of a cliff/a book sitting on the ground? Why?)**
Ex: Potential energy is stored in the drawn (pulled back) bow and is converted/changed to kinetic energy as the arrow speeds toward its target.
Like bows, all varieties of catapults rely on some way to store potential energy, and then convert/change it quickly into kinetic energy to throw a projectile *(object).* Energy is stored by pulling the lever back or winding the ropes on a real catapult, a projectile is loaded, and the trigger (a small device that releases a spring or catch and so sets off a mechanism, like on a gun) releases the arm. The arm is designed in such a way that leverage (the push down on one end, like on a teeter totter) changes the tremendous stored energy of the coil (or rubber band) into kinetic energy very very quickly.

The catapult used a bundle of twisted ropes (known as the skein) to create torsion *(twist/tension)* and the catapult is, therefore, known as a torsion (twisting) engine. In the Middle Ages, or in the time of Ancient Rome, these ropes would have been made from either horse hair or human hair (**Can your students hypothesize why human hair might have been used?**) as they provide the best tensile strength *(ability to stretch)* in a fiber.

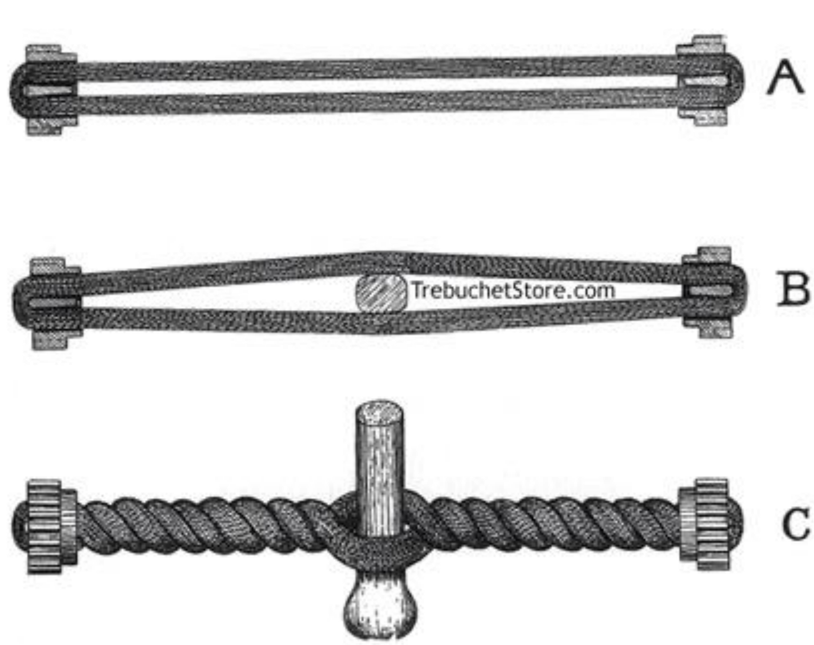


FIG. 199.—THE SKEIN OF CORD IN VARIOUS STAGES.

Winch and Skein Images Credit: Trebuchet Store.com All Rights Reserved. Accessed 8/24/11. http://www.redstoneprojects.com/trebuchetstore/build_a_catapult.html

Whatever was used, the material of the skein was often thoroughly soaked in oil for some days previously, (**Can your students have any ideas on why it might have been soaked in oil?**) or would have frayed and fallen apart under the friction *(rubbing)* of being so tightly twisted. Oil kept the skein from rotting and falling apart for many years. The ropes are strung across a frame, and in the middle of the twisted cords the wooden throwing arm was inserted upright. In some versions, a sling was attached to the end of the arm.

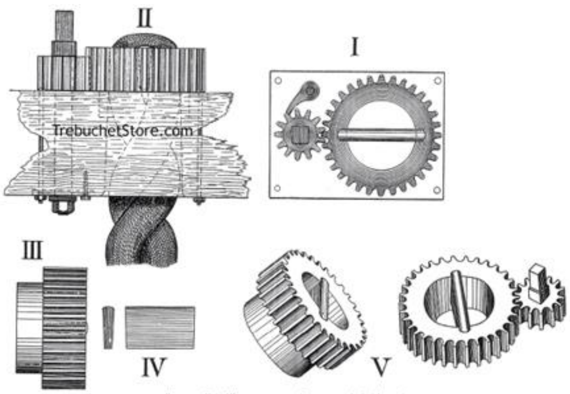
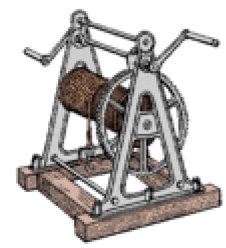


FIG. 197.—THE WINCHES OF THE CATAPULT. Scale ⅛ in. = 1 in.

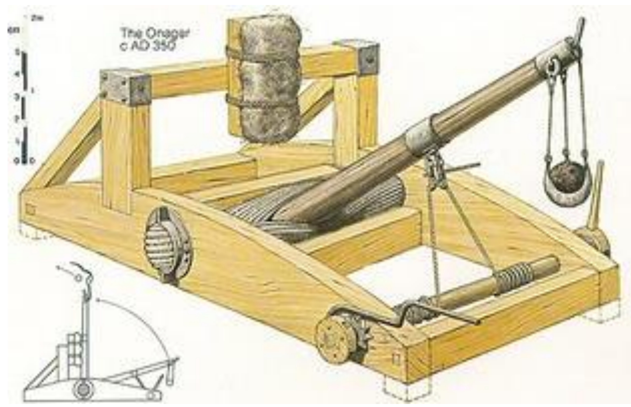
As the skein of the cord was being twisted by the very powerful winches *(A hauling or lifting device made of a rope or chain that was wound around a round tube and, turned by a crank*), the arm gradually pressed with increasing force against the cross-beam between the uprights.



The arm would be so tightly pressed against the fender *(like a bumper on a car or a cushion made of straw),* attached to the centre of this beam, that it couldn't be pulled back, even by several men.

Then it would be pulled down and back by men turning powerful windlasses (*turning cranks that wound ropes hooded to the catapult around a round pipe, the more they were wound, the farther down it would come as the rope got shorter and pulled it down*) using the strength of between four and eight men, when the engine was made ready for throwing projectiles. **(Just like the students have to pull their catapult spoons down and back in order to throw, they would pull the real ones down too)** When the arm was as low as they wanted it, or as was desired, it had to be instantly released. If they waited even a moment, **(what might happen?)** keeping the arm under all that pressure, would cause that huge piece of wood to crack and break when it would not have otherwise done so, and it would take dangerous amounts of time to replace when you're in the middle of a battle.

Many drawings from those times show the catapult as having a bucket or cup at the end of the throwing arm, and this is the version most commonly shown in Hollywood movies. This, however, is not the best way of throwing a rock - in fact, a sling was much more effective. **(Why might a sling be more effective? Greater range of motion? More potential/kinetic energy? Test it out.)**



Fire!

In lowering the arm, and stretching the rope, potential energy was stored in the rope, and when released, the arm was thrown forwards, converting all that stored energy into kinetic energy. The skein/rope holds the most energy, it is at its greatest amount, when the arm first starts to move, and since most of it is used up by the end, there is very little, or the least energy left, when it hits the padded buffer, which stops it from moving. This allows the missile to leave the sling at maximum speed before stopping.

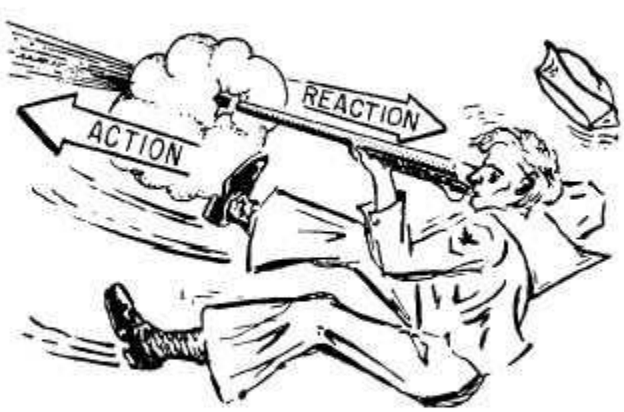
On a trebuchet, the sling unhooks/detaches from its hook before the arm hits the stopper, and the projectile flies away. When that happens depends on the length of the strings holding the sling. Adjusting the length of the string is how trajectory (the object's path as it flew) could be changed so accurately, though it took a lot of practice to know just how to do it. If the sling was shortened, the projectile would be thrown at a high elevation *(high but slower)*. If the sling was lengthened, the ball would travel at a lower angle and with much more velocity *(low and fast)*.

Notes on Newton's Laws and Catapults:

Newton's laws are everywhere. Even in the middle of a battle. Think about the following and apply it to catapults. **Discuss this part while using the models you've build, Newton's laws are always easier to understand when you see them in action.**

First law- An object at rest will stay at rest, until acted on by an outside force. *The projectile is at rest in the sling and will stay at rest (won't move) until the force of the counterweight and gravity forces it to move.*

Second law- An object in motion tends to stay in motion, with the same direction and speed until acted on by an outside force. This law tells us not just that something changes its motion if something pushes, pulls, or otherwise exerts a force on it, but it tells us how that motion changes. *The net force, which is created by the counterweight, causes the ball to accelerate, proportionally to the acceleration of the counterweight. The projectile would keep going in a straight line forever, but gravity, a force, pulls it down.*



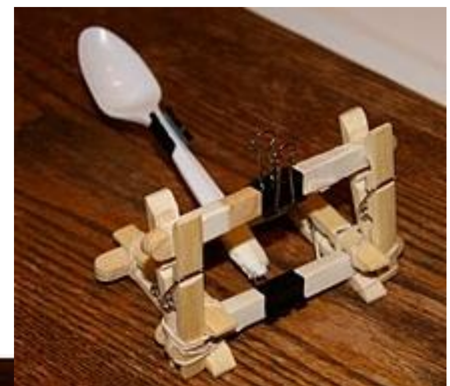
Third law- The third law says that for every action (force) there is an equal and opposite reaction (force). Forces are found in pairs. Think about the time you sit in a chair. Your body exerts a force downward and that chair needs to exert an equal force upward or the chair will collapse. It's an issue of symmetry. Acting forces encounter other forces in the opposite direction. *The counterweight pulls on the arm, and the arm pulls back on the counterweight, so in result, the arm travels down. The sling pulls on the arm and the arm pulls on the sling. In result, the sling throws the projectile.*

Popsicle Seige

Images and directions for this project modified from a project found at http://raisingleafs.blogspot.com/2011/04/theory-thursday-siege-catapult.html.

This Siege Catapult requires:
9 craft sticks (popsicle sticks)
Masking Tape
4 clothes pins
7+ rubber bands
3 small binder clips
1 plastic spoon

First, separate your sticks into sets of three and tape them in stacks. One stack gets tape right at both of the ends and the other two stacks are taped half an inch from the end, on both ends.

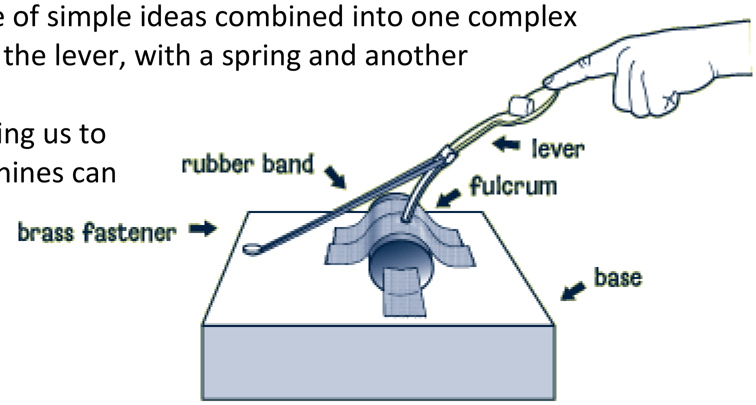


Then clip two clothes pins on to two sets of sticks and another set of clothes pins

between that and the other set of sticks, making a 90 degree angle. Then wrap a bunch of rubber bands around the bottom to support it. Add a binder clip on the top cross piece, one on the bottom cross piece, another on the spoon. Tape the spoon to the clip on the lower crosspiece. Put the rubber band around upper clip and the clip around the spoon and.... viola! You have a functional catapult.

Keep them thinking: Turn it into science, research different objects, the difference in flight if the spoon is pulled all the way back or if you only pulled it back halfway. Also what happens if you try a heavier object? Have them write their hypotheses and test, test, test!

Sure, making and using a catapult is a ton of fun, but do you understand how and why it works? Remember how the catapult is actually a couple of simple ideas combined into one complex machine? That by combining a simple machine, the lever, with a spring and another lever, you've got a catapult.



Simple machines make our lives easier by allowing us to use less energy & force to do work. Simple machines can be combined to form compound machines, allowing simple machines to be used in greater variety of ways.

There are six simple machines for performing work. The lever is one of these simple machines. A lever consists of a plank that is free at both ends, and a steady object on which the plank can rest. The object that does not move is called the fulcrum. The object that one is trying to move is called the load. The distance from the load to the fulcrum is called the effort arm.

Cotton Ball Catapult

Materials:

- cotton balls (colored cotton balls may help differentiate between siege engines)
- plastic spoon
- a ruler
- masking tape
- 2 rubber bands

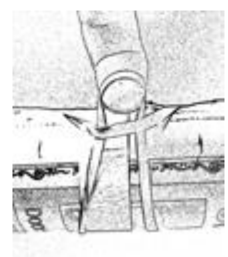


figure 4

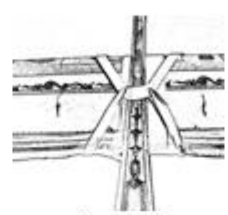


figure 5

Teacher Background Information:

Stretch a rubber band. Place the ruler on top of it. Loop the two ends of the rubber band to the top of the ruler. Pass one end of the rubber band through the other. Hold the surplus with your finger. Stick the end of a tablespoon through the surplus rubber band. *(figure 5)* Adjust the spoon so that its length is approximately 1/2 way through the rubber band. Tape the ends of the ruler to your tabletop (or to a place mat so you can move it around). The catapult is now complete. **What Objects to Hurl:** Cotton balls, Q-tips, cut up sponge pieces.

How to Hurl Objects: Use three or more fingers. Press down quickly on the handle of the spoon. *(Tip: to hurl objects further, adjust the spoon so that the greater length is to the rounded end of the spoon.)*

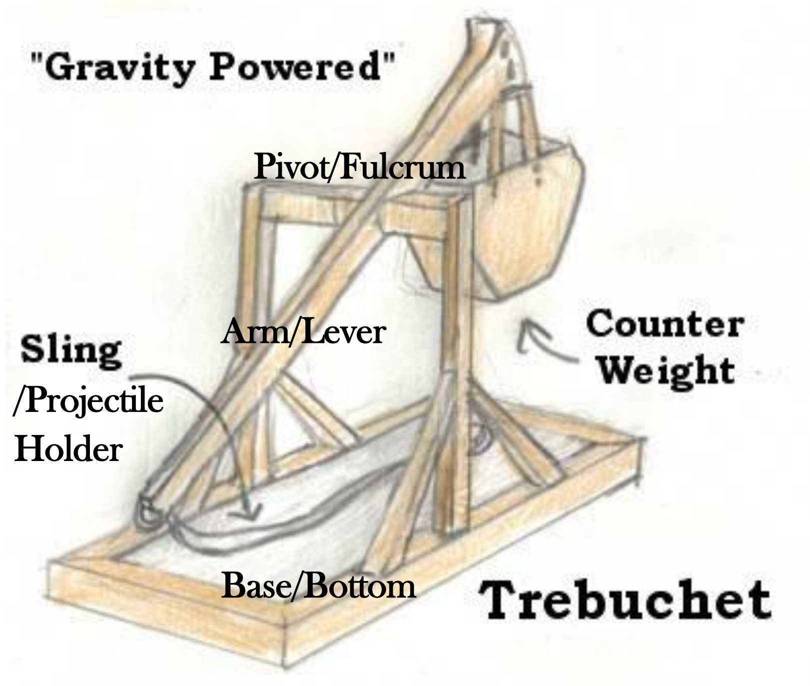
Have students test out different variables and make predictions:

Example: They could try a regular cotton ball, a cotton ball with one piece of masking tape on it, a cotton ball covered with masking tape, and a cotton ball with two rubber bands, predicting that adding weight to a cotton ball would make it go farther. In one trial the regular cotton ball went 8 feet on the first try and 9 feet on the second. The cotton ball with one piece of masking tape went 8 and a half feet on the first try and 12 feet on the second. The cotton ball that was covered with masking tape went 18 and a half feet on the first try and 18 feet and 7 and a half inches. The cotton ball with two rubber bands went 10 feet 5 inches on the first try and 10 feet on the second.

What about using a longer spoon? Two spoons?

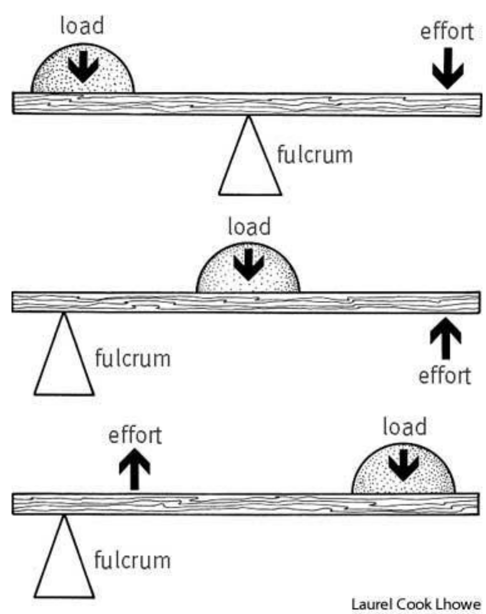
Trebuchets!

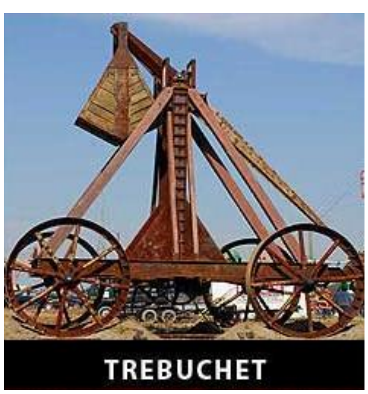
The real monsters of the siege engine world were a kind of catapult called trebuchets ("trench buckets"). The trebuchet has been around since at least the twelfth century. Operated by 20 men, with up to a ten-ton counterweight (about 10,000 lbs), trebuchets were capable of hurling projectiles weighing nearly 350 pounds into enemy walls with so much force that the stones in castle walls would actually turn to dust when the projectile hit.



They were even given special names like, The Warwolf! Trebuchets are five times stronger than regular catapults. Compared to its contemporaries the regular catapult and the ballista, the trebuchet had a far greater ability to do lots of damage to even the strongest castles. In contrast, during times of peace, it was often used to throw hundreds of roses at ladies during contests and tournaments.

A trebuchet is made up of several major parts: the arm, pivot, counterweight, projectile holder and base **(show the students each part on a pre-built trebuchet sample and/or on the diagram.)** The trebuchet is basically a long lever, with its fulcrum close to the bottom end. *(The three types of lever mechanical constructs are shown in the diagram from The Free Dictionary.com.)* The arm is winched *(pulled down by ropes being wound around a round pipe or barrel)* into place with pulleys, locked, and at the bottom (the counterweight) is loaded with



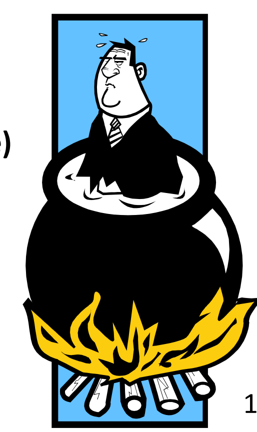


rocks. At the top end of the long arm, (which starts out by the base) the lighter projectile is loaded in the sling. This projectile can still be quite large (since the counterweight is tons of rock); common trebuchet loads included boulders, barrels of Greek fire*, and dead livestock. Dead animals and people were used to break a siege with disease, or fear of disease, which is often enough to scare people. **(Why are people so afraid of disease? Did they have medicine and doctors like we do? Did they understand as much about illnesses?)** When the arm is released, the counterweight is dropped and it forces the other end of the lever to shoot upwards into a vertical (straight up) position. The sling then flies forward, releases the projectile, launching it towards the target, and leverage changed the force of the counterweight's fall into tremendous speed for the load, which means it flies really really fast.

Greek Fire

Image credit: Felipe R. Costa. Cut the Spread. *http://www.cutthespread.com/spread-betting/parliament-approves-austerity-greek-dont-approve-parliament. Accessed 8/25/11. All Rights Reserved.*

During the Middle Ages trebuchets were used to throw an extremely dangerous weapon called Greek Fire. This very sticky liquid was dangerous to work with as it would burn *anything* and it was hard to control. The use of Greek fire required caution and skills that specially selected soldiers were carefully trained in and these special troops took several safety measures to protect themselves. **(Ask your students what they think the soldiers might have done to keep themselves safe and why they might have had to.)** Firstly, the soldiers and marines who handled Greek fire wore fireproof leather armor. Secondly, the ships and equipment used a unique mixture of vinegar, alum and talc **(Show students samples of each of these)** to remain fireproof. Thirdly, city walls and buildings also received special treatments that helped to protect them from fire.



Due to the dangers involved, the soldiers had to heat the mixture very carefully first. If they were not careful, they could also end up burning their own troops, or themselves, with the flames. Then they loaded it into ceramic pots, sealed them, put the pots into trebuchets and threw them over enemy walls like grenades, or it was sprayed onto enemy ships through firing tubes. Wherever it hit, the liquid would burst into flames when it touched anything, wood, sails, walls, houses, even people.

It would even burn on water. It is said to have been invented by a Syrian Engineer over 1,300 years ago. **(Ask your students why fire was a sailor's biggest fear, then tell them that most sailors back then didn't know how to swim. How would that add to their fear of fire?)** As anything you tried to put it out with and it burned even on water, people were terrified of it. Its introduction into warfare of its time and the amount of fear it produced is comparable in its terrifying influence to the introduction of nuclear weapons in our time. **(Why are people scared of nuclear weapons today? They can do huge amounts of destruction and we can't stop them. Why would people have been afraid of Greek Fire back then?)** Even so, Greek fire was not a super weapon that made them invincible. It had limited range that made it easy for enemies to work around once they got used to it. Other civilizations *(groups of people)* like the Arabs also created their own form of Greek fire. *(Image Credit: Neobyzantium.com Greek Fire the Byzantine Secret Weapon. http://neobyzantium.com/greek-fire-the-byzantine-secret-weapon/ Accessed 8/25/11 All Rights Reserved.)*

The secret behind Greek fire was handed down from one emperor *(ruler)* to the next for centuries and they told no one else. Now, the exact formula *(recipe)* for Greek fire has been lost. People have made guesses and scientists have tried to recreate it with no success. There have been rumors of what it might have been made of but we still don't know exactly how they made it, even today.

Have your students ever wanted to be able to throw something far without much effort? Here are two different styles of how to build a miniature trebuchet.

Trebuchet Plans: Little Wolf

This awesome little trebuchet was built and designed by Tom Wilson. He also put together this great tutorial. Our thanks to him for this! It's a fun and effective little project. *http://www.stormthecastle.com/trebuchet/how-to-make-a-trebuchet-out-of-popsicle-sticks.htm* *Accessed 8/23/11.*

Materials:

- 15 full popsicle sticks
- 5 Popsicle sticks cut in half
- Three pieces of string:
- 3"
- 3" with a loop tied in the end (Tie the loop first, then measure)
- 12"
- 1X3" piece of plastic grocery bag
- A 1 ½" Finishing Nail
- A paperclip
- Fishing weights
- Hot glue

How to Build It: Make the base

1. Glue together six sticks in a square, "log cabin" style.

Make the uprights

- Glue two sticks together for strength. This is your upright.

- Glue a half-stick to the side of the upright as shown below. It should stick out about 1/16 of an inch past the upright. This is your cross-beam.

- Reinforce cross-beam with another half stick as shown below.

- Repeat previous three steps to make a second upright.

Attach the uprights to the base.

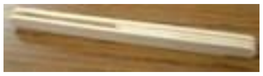
- Glue the uprights in the middle of the thick sides, with the cross-beams pointing in.
- There should be a space of at least 3/8" between the cross-beams.

- Using four half sticks (two on each side), make braces on each upright, forming an upside-down "V".

Build the Throwing Arm

To make the arm:

- Connect two full sticks with a half stick, as shown. This is the bottom of the arm.



- Glue a full stick into the space on the top side of the arm.

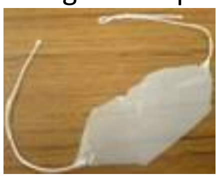
Ask your students: How could changing the arm length affect the performance of the trebuchet?

- Help drill or hammer two holes in the bottom of the arm, about ¼" and ¾" up from the bottom.

Attach the sling and the pin

• PIN: Using pliers, bend a piece of stiff but thin wire (a paperclip works perfectly) into a sharp "J" shape.

• SLING: Cut the ends of your plastic into "V" points. Using a small dot of glue, attach a 3-3 ½ " string to one point. Attach a 3" string with a loop on the end to the other point.



• Glue the pin to the top of the arm so the top of the "J" sticks out about 1/8". Use plenty of glue for this: It has to be on very solidly.

• While the glue on the pin is still warm, attach the end of the straight string. The sling and the looped string should hang down freely.

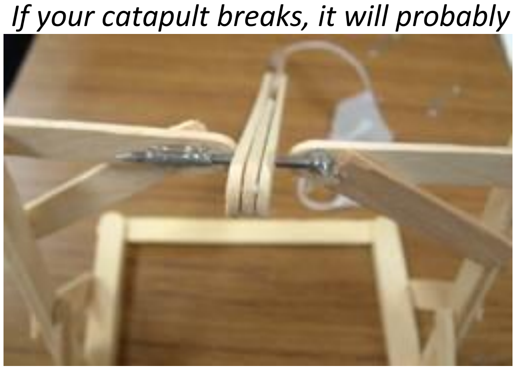
Attach the throwing arm to the base.

• Insert the nail through the upper hole in the arm.

!! You might have to work a little hard to get it through. BE CAREFUL NOT TO STAB YOURSELF!

• Using plenty of glue, attach the ends of the nail to the cross-beams.

If your catapult breaks, it will probably be at this joint, so use plenty of glue and make it secure!



Attach the Weights.

• Tip your trebuchet forward so the bottom of the throwing arm is touching the table.

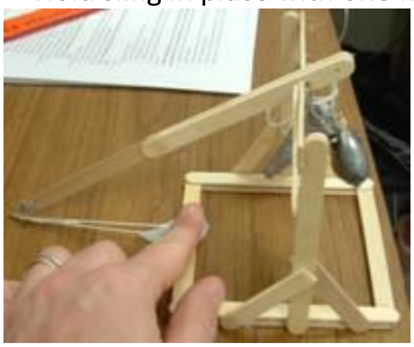
• Insert your 1' string through the bottom hole on the arm.

Use the string to tie on the desired weights.

How will changing the amount of weight affect your catapult's performance? Are there any risks?

Firing: Loading and releasing

- Fold the sling in half over your projectile.
- Place sling loop over pin.
- Pull throwing arm down to the ground, with sling lying flat on ground pointed toward base.
- Hold sling in place with one finger. Quickly remove finger to release.



Tuning

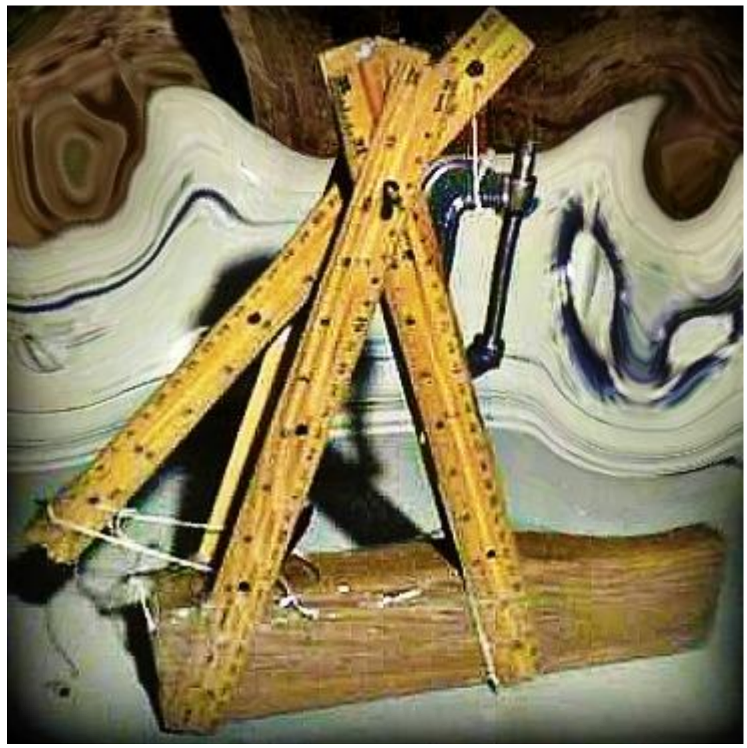
*Remember: Make small adjustments, one at a time, until you achieve the desired performance. Making huge adjustments, or several adjustments at a time, can have unpredictable results***!**

- If sling doesn't fly over the top of the throwing arm, you need either more weight or a lighter projectile.
- If loop doesn't release, you might have twisted sling strings, or your pin might be too long, nicked, or gunked up with glue.
- If trajectory is too high (the projectile flies straight up or backwards), use pliers to bend pin slightly forward. This will delay the release of the sling, making for a flatter trajectory.
- If trajectory is too low (the projectile flies downward into the ground), use pliers to bend the pin slightly backward. This will release the loop sooner, causing a higher trajectory.

Trebuchet! Version 2

Instructions and Image Credits: Aztennenbaum. Instructables.com http://www.instructables.com/id/Build-a-trebuchet-in-five-minutes/ Accessed 8/25/11.

Materials:

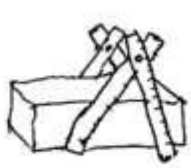


- 5 rulers with multiple holes in both ends (plastic or wood)
- A large nail or bolt (must stretch across the width of your board/brick and fit through holes in rulers)
- Two very small nails
- Tape (duct tape works well)
- String
- A heavy keychain or other object which can work as a counterweight

A brick or block of wood, for a base

All right, lets get started!

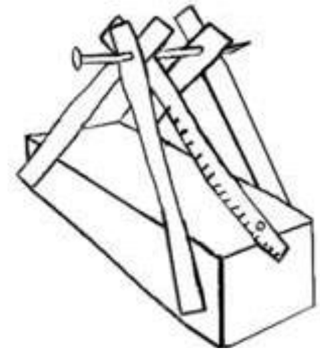
1. Attach rulers to brick



Putting the brick or block of wood on its side (drawings do not show this), tape the four rulers to the brick as shown, so that the holes line up, in order to build the support structure. Triangles make the most stable shape and provide the best support. Some adjustments may have to be made as you figure out what angle the rulers should be, calibrating them so that the holes on the rulers overlap, and you can line the third hole of your last remaining ruler up with these holes. The 5th ruler's bottom hole should end up slightly above the brick. Once it's lined up right, tape the four rulers in place. It may be easier to mark with a permanent marker on your brick/board, showing you where to tape them.

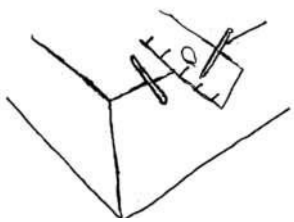
2. Create the arm

Put a long nail through the hole in the five rulers as shown, making sure the hole should be just above the brick. Note: You may want to have some clay or other blunting material available for the end of the nail.



Create the Arm

3. Create release mechanisms

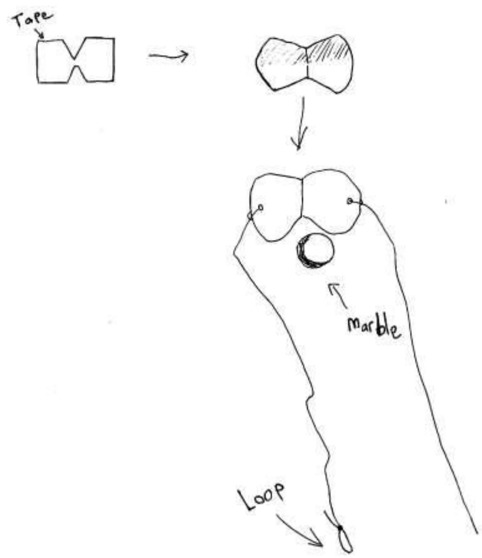


Release Mechanisms

Tape the two little nails, one to the brick and one to the ruler as shown.

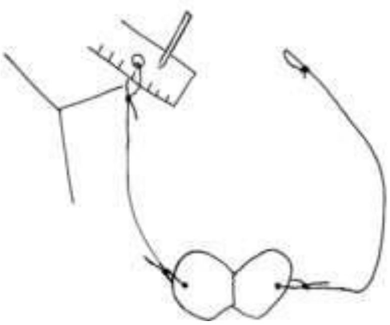
4. Make a Sling

Make sling out of tape and string as shown. Test it out by seeing if you can throw a ball of tape with it.



Make a Sling

5. Tie sling to ruler

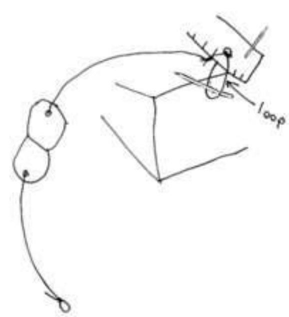


Tie Sling to Ruler

Tie the loose end (the one without the loop) of the sling to the ruler as shown.

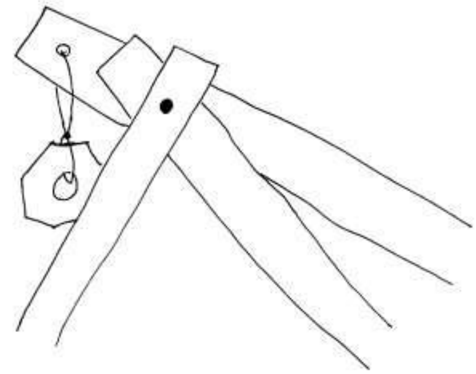
6. Create your hook/loop Catch

Create a loop of string going through the hole in the ruler. This loop should be able to work as a catch and reach down to the nail and be able to hold the ruler in place, keeping your counterweight up high until you're ready to fire.



Make a loop/catch

7. Add counter weight



Attach the counterweight to the hole on the arm. The counterweight should be as heavy as possible, without messing up your trebuchet.

8. Cock and fire!

Hook the loose string of your sling to nail on ruler by the loop. Stuff sling under the arm of the trebuchet, and release string from the nail to all the counterweight to drop and the sling to rise and fire.

This is the point where students can make adjustments and refine the design just as real siege engine engineers had to.

Building a Better Siege Engine

Now that students are siege engineer extraordinaires have students figure out their own designs or improve on the basic variations you build together.

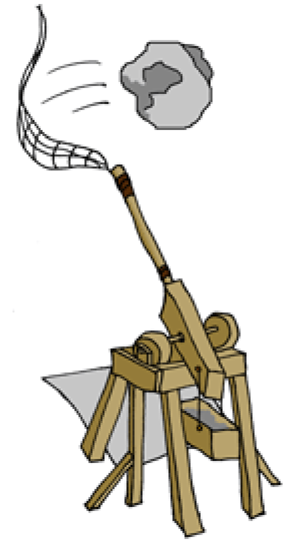
Tell them they can build their catapults how they please, but they can only use the materials you have provided them. Give students time to draw and design, build and test their own kinds of catapults as well as name their team, ex. The Warwolves. Tell students that after building their catapults, they will compete to see whose catapult can fling cotton balls or ping pong balls the farthest and whose catapult can fling an object closest to a target. There can be many different designs. Cotton balls will be flying all over!

Competition Ideas:

1. Place a bowl 6 to 12 inches away from the catapult. See how many cotton balls in a row you can shoot into the bowl.

2. Same as game one, except this time give each person ten cotton balls (different colors helps). Person who shoots the most into the bowl wins.

3. Make a tower using three rigatoni (log-style) noodles. See how many times it takes to knock down the tower.



(Variation: Launch half a dozen Q-tips at once.)

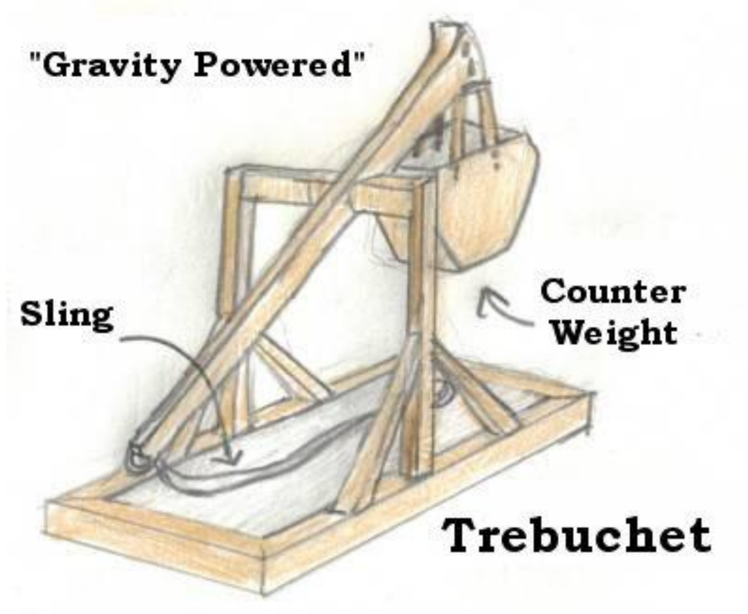
4. Lay a roll of masking tape its side. That's your target. Now each person flings a cotton ball toward the target. Closest wins a point. (If you make it in the center of the roll you win three points.) First person to ten points wins.

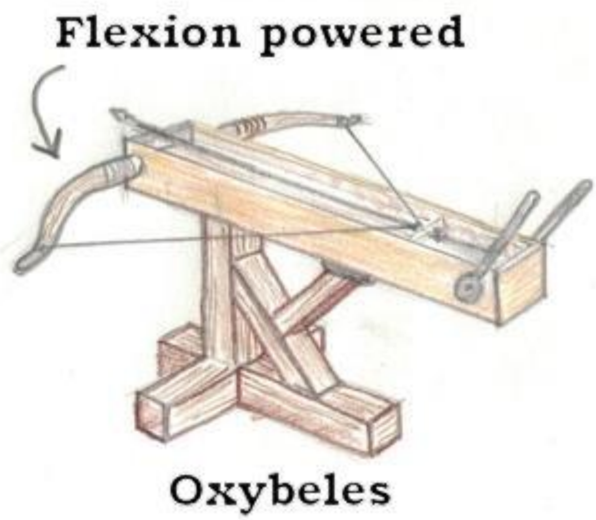
5. Use a marker to make red freckles on three cotton balls, and blue freckles on three others. Again lay the roll of masking tape its side. Your students shoots their three, and you shoot yours. Give a point to the three closest. For example–2 for red and 1 for blue. First person to reach ten points wins.

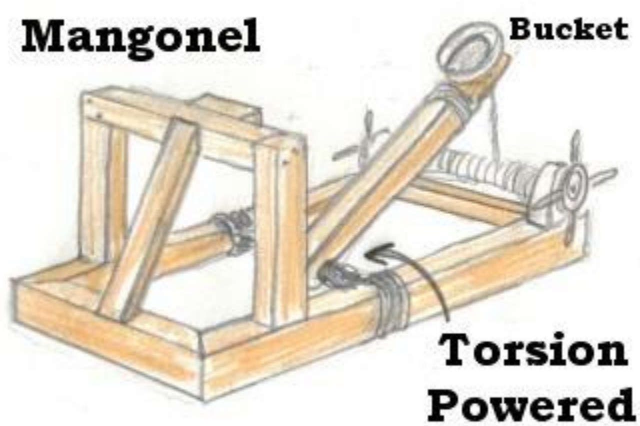
The Greek Fire Daily Paper: Siege Engine Ads

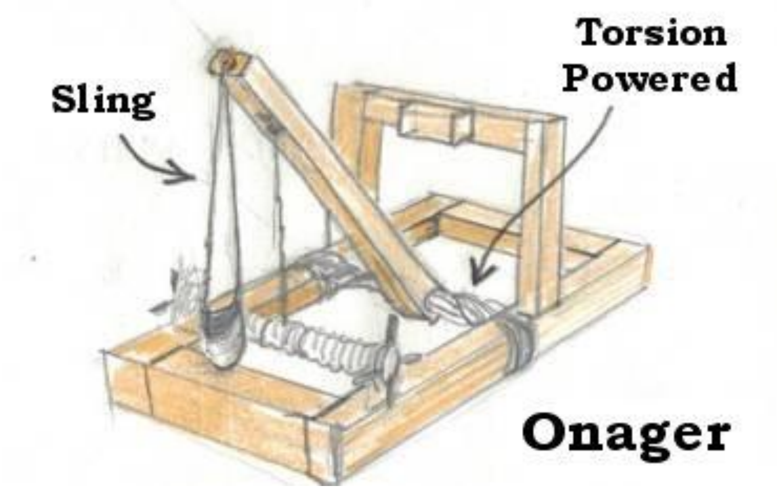
Come one, come all! Fire in the Hole!

Have students decide on their favorite kind of catapult (their own design, regular catapult, trebuchet, onager, or oxybeles) and design a poster advertising it. Have them think about why they believe that design (or their own design) is better, what it can do/throw, how far, etc. Their goal will be to convince an investor to invest in their invention **and diagram how their siege engine uses force and kinetic and potential energy.** Why is their design superior? What features in their design will lead to a successful siege? Students can use the included directions and guides by Will Kalif of Storm the Castle to help draw their siege engine ads.

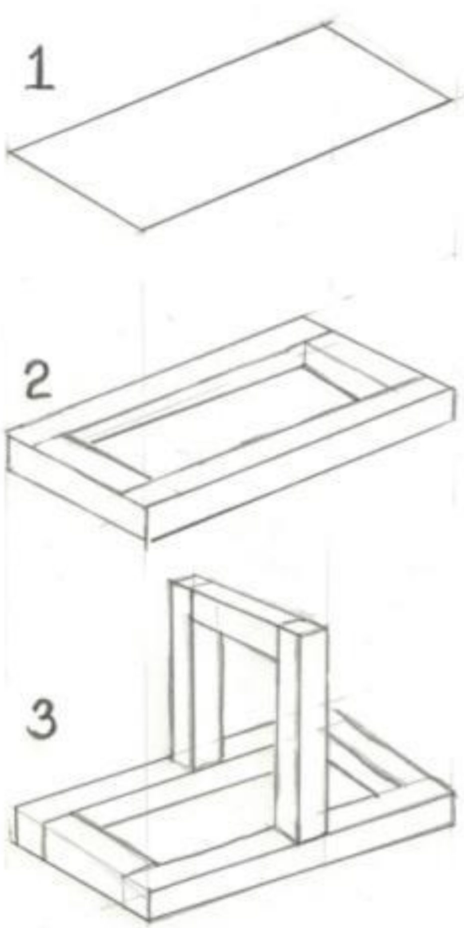

"Gravity Powered"
Sling
Counter Weight
Trebuchet


Flexion powered
Oxybeles


Mangonel
Bucket
Torsion Powered


Sling
Torsion Powered
Onager

How to Draw a Catapult



Catapults are typically very rectangular machines.

This group of drawings will show you how to make a drawing of a catapult. You start out (1) with a parallelogram. This will be the base, the bottom, of your catapult.

Then, start drawing the timbers/boards of the catapult (2) It starts to take on a three dimensional shape, meaning it looks like it sticks up off of the paper.

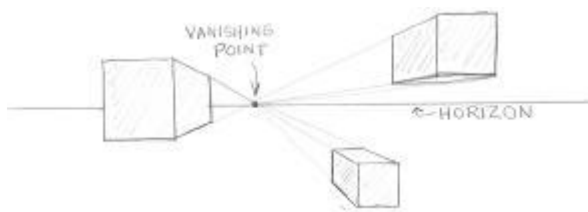
Now continue to build the structure of your catapult as shown in (3).

An important thing to think about is that the catapult is made up of a lot of parallel lines (lines that are the same distance apart and never touch, like the sides of a ladder.) These lines tend to get just a little bit narrower/thinner the farther away from the viewer they are. So you draw the board that's farther away just a little bit thinner than the board that's close to you. And the structure gets a little bit smaller the farther away from the viewer it is. This is called using perspective and vanishing point.

Practice drawing some different siege engines using the different ones on the other page for inspiration. If you really want to get some good practice you can take a good look at one of the catapults for a couple of minutes then looking away and trying to draw it from memory.

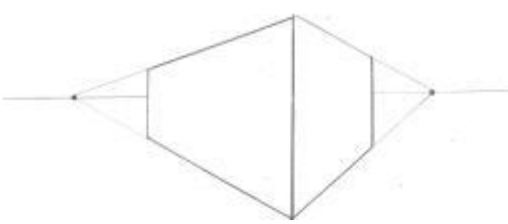
Vanishing Point

The first and most important thing about perspective is understanding what is the vanishing point of a drawing. The vanishing point is the point on the horizon (eye-level) where everything disappears into. Below here is an example of a vanishing point. The cubes, one on the horizon, one below the horizon and one above the horizon all point toward and fall in line with the vanishing point.

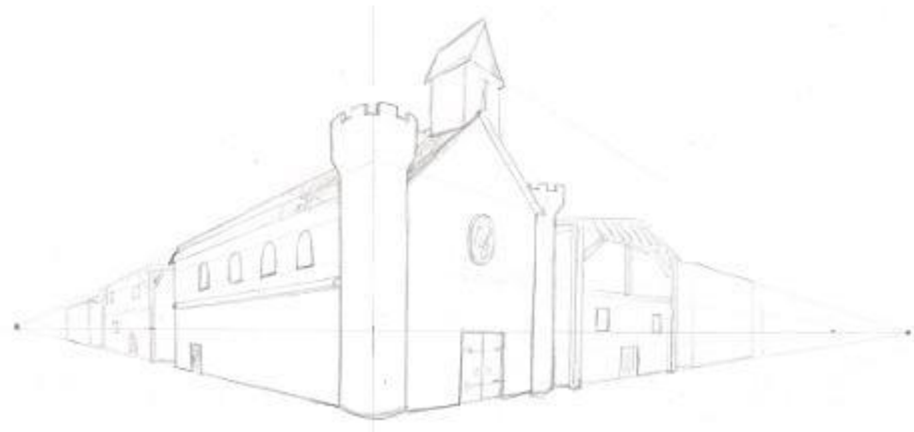


This usage of the vanishing point sets the object firmly in place and makes them three dimensional in a way that looks good to your eye. It is always a good idea look at your drawings and decide where the vanishing point is and draw light lines to it in order to guide you into drawing the objects with a correct looking perspective.

Multiple Vanishing Points - Not all drawings have just one vanishing point. They can have two or even many more vanishing points. It depends on what you are drawing, how complicated it is and where you, the artist, are looking at things from. Here is an example of a simple drawing with two vanishing points.



Using two vanishing points sets this rectangle firmly on the ground. It looks very solid and it looks correct to your eye. Let's take a look at an actual drawing that uses two vanishing points. This is a sketch of a block in a



medieval renaissance type of town.

See how everything fades off directly to the two vanishing points? This gives a proper sense of depth. You almost feel like you could walk along the buildings off into the distance.

Perspective may seem to be a challenge at first, but all it takes is a ruler and some practice doing some perspective drawings with one, two or more vanishing points. Do some common objects in all shapes and sizes. Try small objects like a laptop computer or a stapler then do some larger objects like cars and a refrigerator. Then finally draw some large objects and some scenes like the buildings in the medieval picture shown here.