ERB Virtual Classroom

Build a Better Catapult Lesson Guide

Instructor: Tina Valentine
Grade Level: 3-8
Subject: STEM

Students will investigate how potential energy is transformed into kinetic energy using a simple machine.

Wonder Why:

Have you ever wondered how to make a catapult? Have you wondered how a catapult works? Have you wondered how to adjust your catapult to launch an object that goes the farthest?

Goal:

Students will build and test three models of catapults. Students will be challenged to build and advertise a "Better Catapult" by using the Engineering Design Process to design, create, and test their own creation.

Lesson Guide Agenda:

Get ready to *catapult* yourself into some STEM fun!

Lesson Guide | Vocabulary

Engineering – the branch of science and technology concerned with the design, building, and use of engines, machines, and structures.

Catapult – A catapult is a device or machine used mainly in battles of war to hurl or project heavy boulders (or explosives) a great distance to fend off enemies, protect forts, or attack enemies.

Levers – A lever is a simple machine that allows you to gain a mechanical advantage. It consists of a rigid bar or beam that is allowed to rotate or pivot about a fulcrum, along with an applied force and load.

Fulcrum – A fulcrum is the pivot or supporting point of a lever.

Potential Energy – Stored energy that depends upon the relative position of various parts of a system.

Elastic Energy – The mechanical potential energy stored in the configuration of a material or physical system as it is subjected to elastic deformation by work performed upon it.

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

Materials Needed To Complete All Models:

Lots of Popsicle sticks
Rubber bands
Plastic spoons
Cotton balls, pom poms, paper clips, etc. (soft, safe projectiles)
Tape
Paper and pencil
Tape measure

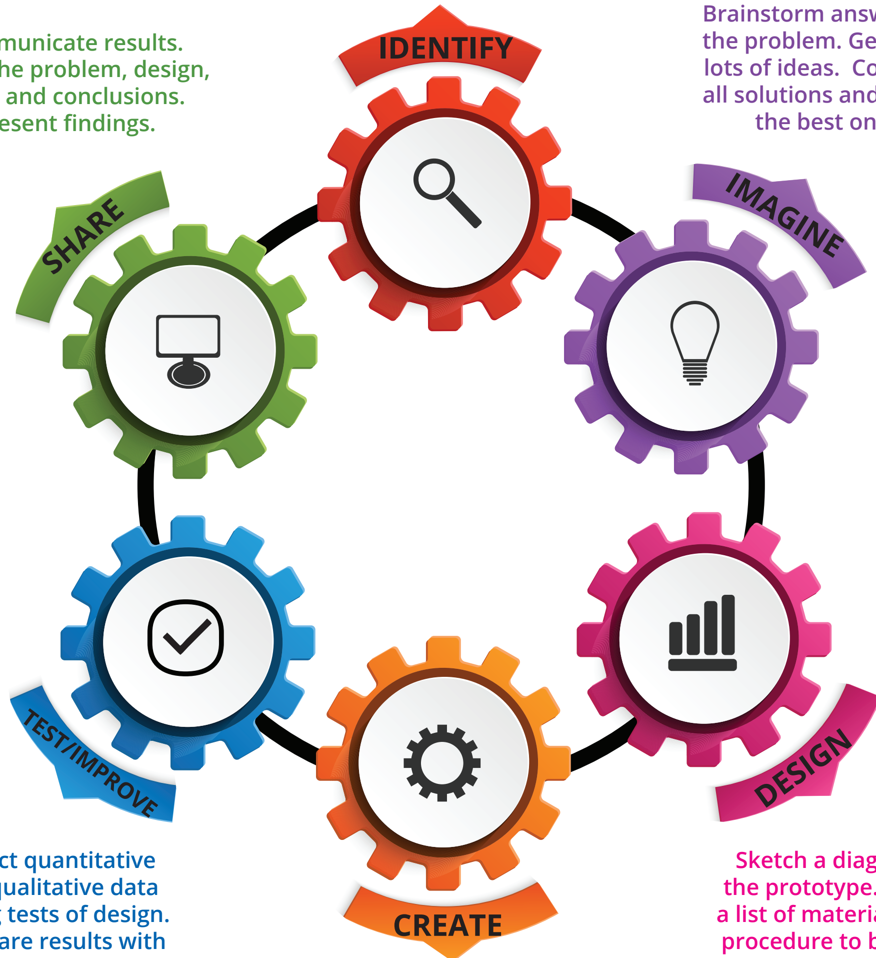
Note: A data sheet is provided on the HomeRoom website. This will help you collect the data you need to complete the lesson!

Engineering Process

Identify the problem and how it affects people. Think locally, nationally, and globally.

Brainstorm answers to the problem. Generate lots of ideas. Consider all solutions and select the best one.

Communicate results. Share the problem, design, data, and conclusions. Present findings.



Collect quantitative and qualitative data during tests of design. Compare results with expectations. Make needed changes for improvement.

Sketch a diagram of the prototype. Create a list of materials and a procedure to build the prototype. Discuss the desired results.

Build the prototype according to design plan and procedures.

Ag in the Classroom

Watch the "Build a Better Catapult" video before continuing to the challenge!

Be sure to print and complete your data sheet while completing this lesson!

If you have any questions throughout this lesson, please email teachers@oerb.com. We would love to hear from you!

Catapult Model #1 – Spoon with a Popsicle base

Materials Needed:

9 Popsicle sticks
3 Rubber bands
1 Spoon

Catapult Model #1 Instructions:

1. Take 8 Popsicle sticks and stack them on top of each other. Use a rubber band and wrap it around one end of the stack.
2. Insert a single Popsicle stick above the bottom Popsicle so that it is perpendicular. Wrap a rubber band on the other end of the stack of 8.
3. Attach the end of the spoon with a rubber band to the single Popsicle stick so that the spoon rests on top of the stack of 8.

Continue to the next page for a visual example

Catapult Model #2 – Base with a spoon

Materials Needed:

7 Popsicle sticks
7 Rubber bands
1 Spoon
Tape

Catapult Model #2 Instructions:

1. Take 3 Popsicle sticks to form a triangle with the sticks crossing over each other at the endpoints forming an X. Attach a rubber band at each endpoint X. You need two triangles.
2. Overlay the triangles and attach them together at two points with rubber bands.
3. Where the third points are left open, stretch it apart. You will take a single Popsicle stick and attach one end of the stick to the lower open triangle with a rubber band.
4. Stretch apart the other end of the open triangle and attach it along the lengths of the single Popsicle stick with a rubber band.
5. Now tape the spoon on the single Popsicle stick.

Continue to the next page for a visual example

Catapult Model #3 – Square Base with a Spoon

Materials Needed:

10 Popsicle sticks
7 Rubber bands
1 Spoon
Tape

Catapult Model #3 Instructions:

1. Stack 6 Popsicle sticks and use rubber bands to secure both ends.
2. Take a single Popsicle stick and attach it perpendicular to the stack and in the middle of the stack. Secure with a rubber band. Wrap the rubber band around the Popsicle stick by crossing the rubber band around making X's as your wrap around.
3. Now to make the square base. Take single Popsicle sticks and attach one at each end of your stack of 6 with rubber bands.
4. Take a single stick and attach to the arm ends to form the square.
5. Tape the end of the spoon to your single stick perpendicular to the stack.

Continue to the next page for a visual example

Testing Your Catapult

1. Put your catapult in an open area with a sturdy, flat surface such as a table or an open space on a hard floor.
2. Use a tape measure. Tape it down to the floor.
3. Place catapult at the starting line.
4. Place a cotton ball (or other item – use same items for all models in tests) in the launching spoon, push the spoon down and let go.
5. Record how far the launched item travels. Find where it lands first. (Not bounced or rolled)
6. Repeat the test 10 times to make your observations.
7. Record results on a data table.
8. Repeat for all models.
9. Take measurements on a data table (provided) and calculate the total, mean, and furthest distance launched item traveled.
10. Make notes on your results.

Note: A data sheet is provided on the HomeRoom website. This will help you collect the data you need to complete the lesson!

Catapult Testing Data Table Example:

Use the Catapult Testing Data Table provided on HomeRoom to record your data for each Catapult Model!

Find the Mean by taking the sum and dividing it by the number of trials:

$$\text{Mean} = \frac{\textit{Total Sum of Distance Travelled}}{\textit{Total Number of Trials Completed}}$$

This will allow you to see which catapult launched the furthest!

Catapult Data Sheet

Catapult Testing Data Table

Circle One: Distance is measured in: Centimeters or Inches

Item being launched: cottonball

Trial #	Model #1 Name:	Model #2 Name:	Model #3 Name:
1	33		
2	29		
3	47		
4	41		
5	30		
6	34		
7	34		
8	40		
9	41		
10	42		
Total: Add the distance from each trial	371		
Mean: *Divide total by trial #'s. If you do 10 trials, divide by 10.	37.1		
Farthest Distance:	47		

How it Works!

Before we challenge ourselves to build our catapults, let's check out some of the science behind how this works!

We want to better understand how catapults work before we *launch* ourselves into building a "better" catapult!

The Science Behind Your Catapult

- Notice that this is a model of a simple machine, or a lever. We have a Popsicle stick propped up by a fulcrum (a pivoting point). A lever will magnify the force you put on it if the fulcrum (the pivoting point) is closer to your force than it is to the load. The catapult magnifies your force to throw an item. Catapults are levers!

- The energy is added and stored in the Popsicle stick when the tiny projectiles are added to the spoon. When you let go of the Popsicle stick, the stored energy is transferred to the object launched by the spoon which then flies through the air. Catapults also use the **elastic energy** which is transformed into **kinetic energy** under tension stored in the rubber bands. <u>**The amount of force is directly related to the amount of mass.**</u>

- If the mass of the projectile is increased, then it requires more force to convert the stored energy into kinetic energy. The extra force is created by using more elastic bands. The transferred kinetic energy is the reason the projectile is thrown out of the spoon.

Thinking and Discussion Questions

1. What happens to the cotton ball? Did it fly? Did it go high or low? Where did it land?
2. What do you expect will happen when you push the spoon farther down? Will this make it fly higher, farther, both higher and farther, or take the same path but maybe faster?
3. Perform a test: Put your cotton ball in the spoon, push the spoon down farther, release and observe. You might need to repeat the test a few times to make your observations. It all happens fast! Does your ball fly higher or lower? Does it land farther or nearer when you push down a lot compared with when you push down a little?
4. Did you notice in which case you needed to do the most work? Is it when you pushed down a little or when you pushed down farther?
5. Try more launches. Do you get similar results each time? Is what you observe what you expected? Can you explain why?
6. **Extra**: Tell what happens if you move the stack of 6 sticks closer to the launching cup or in the other direction. This will change the position of the launching stick when the missile becomes airborne. How do you think your change will affect the ball's flight path?

Observations and Results

1. Did you see your cotton ball fly higher and farther when you pushed your launching spoon farther down?

2. When you bend your spoon, you load your launching spoon up with energy. When you let go, this energy is released and converted to energy of motion. Most of this energy transfers to the missile, which shoots through the air.

3. Pushing the spoon down farther takes more effort from you. Maybe you felt you needed to exert more force or work harder to bend the stick farther. Bending farther means more elastic potential energy gets stored in the spoon, and when you let go, all this potential energy is converted into energy of motion, so the missile flies through the air at a higher speed. In the case of your catapult, the missile probably flew higher and farther.

Challenge: Use what you have learned to create your own catapult!

1. Identify your problem: “Build a Better Catapult”
2. Imagine ideas by brainstorming catapult designs: There is limitless information on the internet. We have listed a few resources for you if you need ideas. With your parent’s permission, go online and see what you can find.
3. Design your prototype with a sketch or diagram.
4. Create your prototype.
5. Test it and evaluate the solutions.
6. Share your solutions.
7. Redesign if needed.
8. Write an advertisement for your new Prototype Catapult.
    a. Name your design
    b. Make a slogan for it
    c. Include information about your catapult. Give the Who: What: When: Where: Why: and How. Provide other details to “sell” your catapult.

Important Challenge Note

Use the “Design and Advertisement Worksheet” provided on HomeRoom to complete this challenge!

If you have any questions about this challenge, please email teachers@oerb.com.
We would love to hear from you!

WANT TO WIN A PRIZE?

Submit your advertisement with a picture of your design and prototype! Share your pictures and advertisement with us by emailing teachers@oerb.com and on Facebook/Instagram by tagging us @oerbok.

Be sure to include your name, grade, school, and teachers!

The teacher with the most student submissions will win a $100 Amazon Gift Card!

Check out these additional resources!

1. Engineering Process
https://www.agclassroom.org/ok/resources_classroom/engineering.php

2. Leonardo Da Vinci's Design
https://www.gizmodo.com.au/2016/03/how-to-build-a-mini-catapult-straight-from-the-mind-of-leonardo-da-vinci/

Lesson Guide | Oklahoma Academic Standards

3.1.R.1 Students will actively listen and speak clearly using appropriate discussion rules.
3.R.2 Students will ask and answer questions to seek help, get information, or clarify about information presented orally though text or other media to confirm understanding.
3.3.W.3 Students will express an opinion about a topic and provide reasons as support.
3.7.W.1 Students will create multimodal content that communicates an idea using technology or appropriate media.
3.7.W.2 Students will create presentations using video, photos, and other multimedia elements to support communication and clarify ideas, thoughs, and feelings.
3.N.2 Add and subtract multi-digit whole numbers, multiple with factors up to 10, represent multiplication and division in various ways; Solve real-world and mathematical problems through the representation of relation operations.
3.GM.2.3 Choose an appropriate measurement instrument and measure the length of objects to the nearest whole centimeter or meter.
3.GM.2.4 Choose an appropriate measurement instrument and measure the length of objects to the nearest whole yard, whole foot, or a half inch.
3.S.1.1 Summarize and construct a data set with multiple categories using a frequency table, line plot, pictograph, and/or bar graph with scaled intervals.

3-PS2-1 Students who demonstrate understanding can: Plan and conduct investigations on the effects of balanced and unbalanced forces on the motion of an object.

- Science & Engineering Practices: Planning and carrying out investigations:
    - Planning and carrying out investigations to answer questions or test solutions to problems in 3-5 builds on K-2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.
    - Plan and conduct an investigation collaboratively to produce data to serve as the basis for evidence, using fair tests in which variables are controlled and the number of trials considered.
- Crosscutting Concepts: Cause and Effect:
    - Cause and effect relationships are routinely identified.

3-PS2-2 Students who demonstrate understanding can: Make observations and/or measurements of the object's motion to provide evidence that a pattern can be used to predict future motion.

- Science & Engineering Practices: Planning and carrying out investigations:
    - Planning and carrying out investigations to answer questions or test solutions to problems in 3-5 builds on K-2 experiences and progresses to include investigations that control variables and provide evidence to support explanations or design solutions.
    - Make observations and/or measurements to produce data to serve as the basis for evidence for an explanation of a phenomenon or test a design solution.
- Crosscutting Concepts: Patterns:
    - Patterns of change can be used to make predictions.

4.1.R.1 Students will actively listen and speak clearly using appropriate discussion rules.
4.1.R.2 Students will ask and answer questions to seek help, get information, or clarify information presented orally through text or other media to confirm understanding.
4.3.W.3 Students will express an opinion about a topic and provide fact-based reasons as support.
4.7.W.1 Students will create multimodal content that effectively communicates an idea using technology or appropriate media.
4.7.W.2 Students will create presentations using videos, photos, and other multimedia elements to support communication and clarify ideas, thoughts, and feelings.
4.N.1 Solve real-world and mathematical problems using multiplication and division
4.GM.2.4 Choose an appropriate instrument and measure the length of an object to the nearest whole centimeter or quarter-inch.
4.GM.2.5 Solve problems that dela with measurements of length, when to use liquid volumes, when to use mass, temperatures above zero and money using addition, subtraction, multiplication, or division as appropriate (customary and metric).
4.D.1.2 Use tables, bar graphs, timelines, and Venn diagrams to display data sets. The data may include benchmark or decimals.

5.1.R.2 Students will ask and answer questions to seek help, get information, or clarify about information presented orally through text or other media to confirm understanding.
5.1.W.1 Students will give formal and informal presentations in a group or individually, organizing information and determining appropriate content for audience.
5.2.W.1 Students will create multimodal content that effectively communicates an idea using technology and appropriate media.
5.7.W.2 Students will create presentations that integrate visual displays and other multimedia to enrich the presentation.
5.N.1 Divide multi-digit numbers and solve real-world and mathematical problems using arithmetic.
5.GM.3.2 Choose an appropriate instrument and measure the length of an object to the nearest whole centimeter or 1/16-inch.
5.GM.3.3 Recognize and use the relationship between inches, feet, and yards to measure and compare objects.
5.GM.3.4 Recognize and use the relationship between millimeters, centimeters, and meters to measure and compare objects.
5.D.1.1 Find the measures of central tendency (mean, median, or mode) and range of a set of data. Understand that the mean is a “leveling out” or central balance point of the data.

6.1.R.2 Students will actively listen and interpret a speaker's messages (both verbal and nonverbal) and ask questions to clarify the speaker's purpose and perspective.
6.1.W.1 Students will give formal and informal presentations in a group or individually, organizing information and determining appropriate content and purpose for audience.
6.2.W.1 Students will apply components of a recursive writing process for multiple purposes to create a focused, organized, and coherent piece of writing.
6.3.W.3 Students will clearly state an opinion supported with facts and details.
6.7.W.1 Students will create multimodal content that effectively communicates ideas using technologies and appropriate media.
6.7.W.2 Students will create presentations that integrate visual displays and other multimedia to enrich the presentation.
6.N.2 Add and subtract integers in order to solve real-world and mathematical problems.
6.N.4 Multiply and divide decimals, fractions, and mixed numbers; solve realworld and mathematical problems with rational numbers.
6.GM.3 Choose appropriate units of measurement and use ratios to convert within measurement systems to solve real-world and mathematical problems.
6.D.1 Display and analyze data.
6.D.1.1 Calculate the mean, median, and mode for a set of real-world data.

MS-PS3-1 Students who demonstrate understanding can: Construct and interpret graphical displays of data to describe the relationships of kinetic energy to the mass of an object and to the speed of an object.

- Science and Engineering: Analyzing and interpreting data
    - Analyzing data in 6–8 builds on K–5 and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis.
    - Construct and interpret graphical displays of data to identify linear and nonlinear relationships.
- Crosscutting Concepts: Scale, Proportion, and Quantity • Proportional relationships (e.g. speed as the ratio of distance traveled to time taken) among different types of quantities provide information about the magnitude of properties and processes.

MS-PS3-2 Students who demonstrate understanding can: Develop a model to describe that when the arrangement of objects interacting at a distance changes, different amounts of potential energy are stored in the system.

- Science & Engineering Practices
  - Developing and using models Modeling in 6–8 builds on K–5 and progresses to developing, using and revising models to describe, test, and predict more abstract phenomena and design systems.
  - Develop a model to predict and/or describe phenomena.
- Crosscutting Concepts: Systems and System Models
  - Models can be used to represent systems and their interactions – such as inputs, processes, and outputs – and energy and matter flows within systems.

7.1.R.2 Students will actively listen and interpret a speaker's messages (both verbal and nonverbal) and ask questions to clarify the speaker's purpose and perspective.
7.1.W.1 Students will give formal and informal presentations in a group or individually, providing evidence to support a main idea.
7.2.W.1 Students will apply components of a recursive writing process for multiple purposes to create a focused, organized, and coherent piece of writing.
7.3.W.3 Students will introduce a claim and organize reasons and evidence, using credible sources.
7.7.W.1 Students will select, organize, or create multimodal content to complement and extend meaning for a selected topic.
7.7.W.2 Students will utilize multimedia to clarify information and strengthen claims or evidence.
7.N.2.3 Solve real-world and mathematical problems involving addition, subtraction, multiplication and division of rational numbers; use efficient and generalizable procedures including but not limited to standard algorithms.
7.D.1.1 Design simple experiments, collect data and calculate measures of central tendency (mean, median, and mode) and spread (range). Use these quantities to draw conclusions about the data collected and make predictions.

Lesson Guide | Oklahoma Academic Standards

PA.N.1 Read, write, compare, classify, and represent real numbers and use them to solve problems in various contexts.
PA.D.1 Display and interpret data in a variety of ways, including using scatterplots and approximate lines of best fit. Use line of best fit and average rate of change to make predictions and draw conclusions about data.
A1.A.1.1 Use knowledge of solving equations with rational values to represent and solve mathematical and real-world problems (e.g., angle measures, geometric formulas, science, or statistics) and interpret the solutions in the original context.
A1.D.1 Display, describe, and compare data. For linear relationships, make predictions and assess the reliability of those predictions

8.1.R.2 Students will actively listen and interpret a speaker's messages (both verbal and nonverbal) and ask questions to clarify the speaker's purpose and perspective.
8.1.W.1 Students will give formal and informal presentations in a group or individually, providing textual and visual evidence to support a main idea.
8.2.W.1 Students will apply components of a recursive writing process for multiple purposes to create a focused, organized, and coherent piece of writing.
8.3.W.3 Students will introduce a claim, recognize at least one claim from an opposing viewpoint, and organize reasons and evidences, using credible sources.
8.7.W.1 Students will select, organize, or create multimodal content that encompasses different points of view.
8.7.W.2 Students will utilize multimedia to clarify information and emphasize salient points.

PA.N.1 Read, write, compare, classify, and represent real numbers and use them to solve problems in various contexts.

PA.D.1 Display and interpret data in a variety of ways, including using scatterplots and approximate lines of best fit. Use line of best fit and average rate of change to make predictions and draw conclusions about data.

A1.A.1.1 Use knowledge of solving equations with rational values to represent and solve mathematical and real-world problems (e.g., angle measures, geometric formulas, science, or statistics) and interpret the solutions in the original context.

A1.D.1 Display, describe, and compare data. For linear relationships, make predictions and assess the reliability of those predictions.

MS-PS2-2 Students who demonstrate understanding can: 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.

- Science & Engineering Practices: Planning and carrying out investigations
    - Planning and carrying out investigations to answer questions or test solutions to problems in 6–8 builds on K–5 experiences and progresses to include investigations that use multiple variables and provide evidence to support explanations or design solutions.
    - Plan an investigation individually and collaboratively, and in the design: identify independent and dependent variables and controls, what tools are needed to do the gathering, how measurements will be recorded, and how many data are needed to support a claim.
- Crosscutting Concepts: Stability and Change
    - Explanations of stability and change in natural or designed systems can be constructed by examining the changes over time and forces at different scales.

If you would like to explore more Oklahoma Academic Standards for Science click here.