CURTIS KINETIC SCIENCE COMPETITION

Resource Guide

ORLANDO SCIENCE CENTER

Curtis Kinetic Science Competition

Program Summary

The **Curtis Kinetic Science Competition** is a fun way to learn the science behind kinetic systems, as well as the skills required to plan, execute, document, reflect, and present a science project in a higher-level science competition. The Kinetic Competition will be open to any middle school, science club, and home school group in the 9 surrounding counties (Brevard, Lake, Marion, Osceola, Orange, Seminole, Polk, Sumter, and Volusia). There will be **ONE** division and students may work in teams of up to five.

This year's awards will be as follows:

- **Best in Fair**: An individual medal to each team member, $500 to the team, and $250 to the team's teacher/coach
- **Best Use of Science**: An individual medal to each team member and $250 to the team
- **Most Innovative/Creative**: An individual medal to each team member and $250 to the team

Please note that award money will be distributed evenly among all registered team members. After awards are announced, all winning team members will need to fill out a W-9 prior to leaving the Science Center.

Using this Guide:

This guide contains resources to help your students prepare for competition day. Included in this guide are explanations of the rules and requirements, examples of the project board, an explanation of the judging criteria and sample judging form, and general tips to keep in mind while working on their projects.

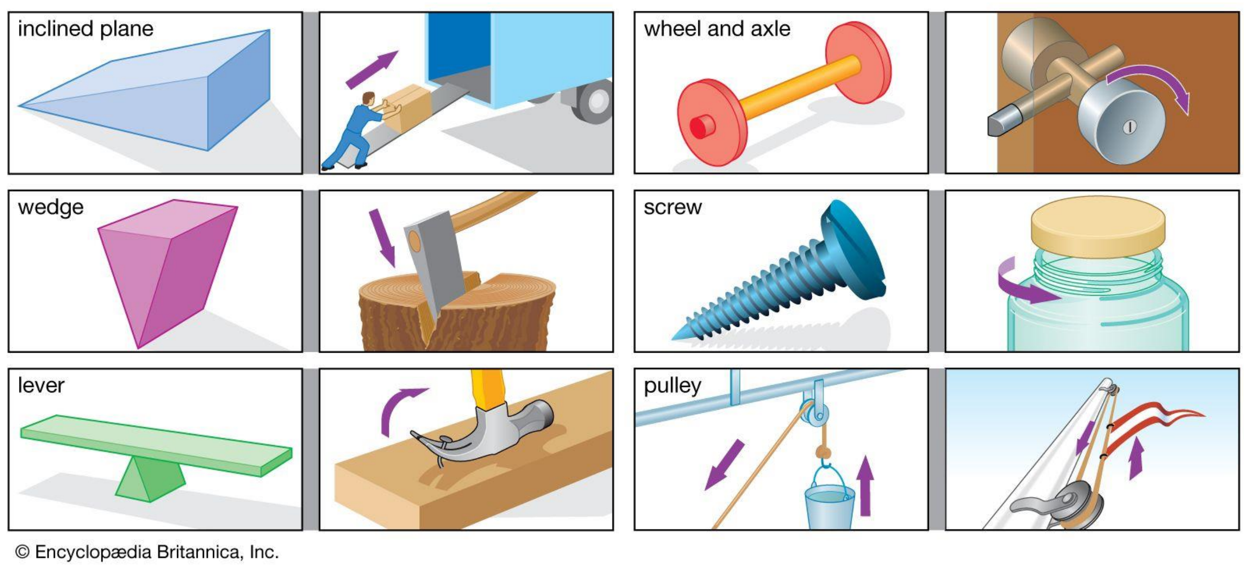
This guide contains three pre-activities which tie in 6-8 science standards. These activities are meant to prepare students to apply relevant math and science concepts while thinking critically, collaborating, communicating, and using their own creativity. These are the skills that will help students while creating their kinetic system. Activity timing and materials have been estimated but should be adjusted according to your schedule and the needs of your students.

Table of Contents

Introduction to Kinetics

Simple Machines

Throughout history, humans have developed a number of devices to make work easier. The most notable of these are known as the "**six simple machines**": the **wheel and axle**, the **lever**, the **inclined plane**, the **pulley**, the **screw** and the **wedge**.



Source: https://www.britannica.com/technology/simple-machine#/media/1/1194584/149099

1. **Wheel & Axle -** Makes work easier by moving objects across distances. The wheel (or round end) turns with the axle (or cylindrical post) causing movement. On a wagon, for example, a container rests on top of the axle.
    a. **Examples**: bicycle, car, Ferris wheel, electric fan

2. **Inclined Plane -** A flat surface (or plane) that is slanted, or inclined, so it can help move objects across distances. A common inclined plane is a ramp. The angle (the steepness of the inclined plane) determines how much effort is needed to raise the weight. The steeper the ramp, the more effort is required.
    a. **Examples**: slide, ramp, roller coaster, hill

3. **Wedge -** Instead of using the smooth side of the inclined plane to make work easier, you can also use the pointed edges to do other kinds of work. When you use the edge to push things apart, this movable inclined plane is called a wedge. An ax blade is one example of a wedge. The main function of a wedge is to change the direction of the input force. For example, if we want to split a log, we can drive a wedge downward into the end of the log with great force using an axe, and the wedge will redirect this force outward, causing the wood to split. Another example is a doorstop, where the force used to push it under the edge of the door is transferred downward, resulting in frictional force that resists sliding across the floor.
    a. **Examples**: axe, shovel, doorstop, chisel, knife, teeth

4. **Lever -** Any tool that pries something loose is a lever. Levers can also lift objects. A lever is an arm that "pivots" (or turns) against a fulcrum (the point or support on which a lever pivots). Think of the claw end of a hammer that you use to pry nails loose; it's a lever.
    a. **Examples**: see-saw, oars, wheelbarrow, arm, spoon, scissors

5. **Pulley -** Instead of an axle, a wheel could also rotate a rope, cord, or belt. This variation of the wheel and axle is the pulley. In a pulley, a cord wraps around a wheel. As the wheel rotates, the cord moves in either direction. Attach a hook to the cord, and now you can use the wheel's rotation to raise and lower objects, making work easier. On a flagpole, for example, a rope is attached to a pulley to raise and lower the flag more easily.
    a. **Examples**: sailboat, well with a bucket, elevator, window blinds, tow truck

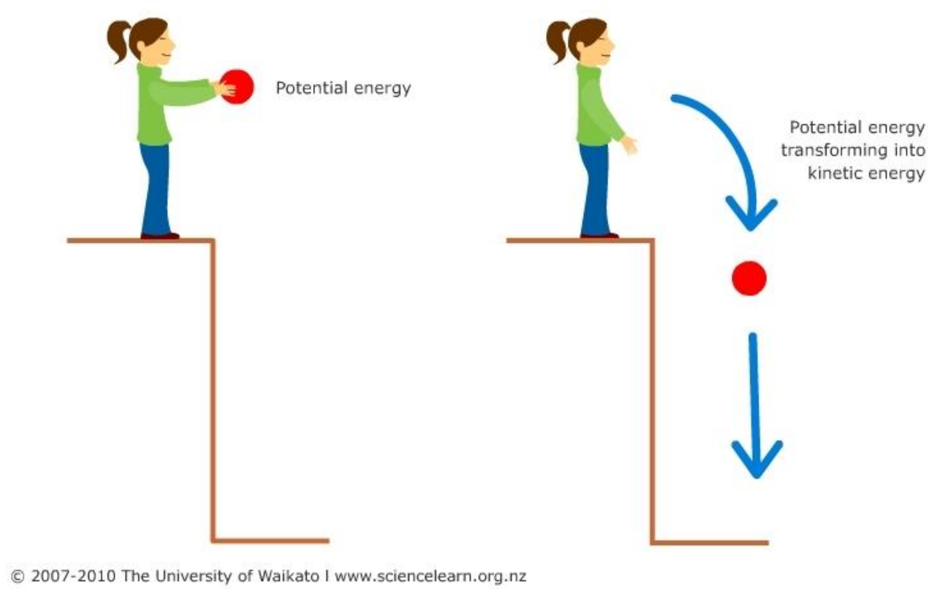
6. **Screw -** When you wrap an inclined plane around a cylinder, its sharp edge becomes another simple tool: a screw. If you put a metal screw beside a ramp, it may be hard to see similarities, but a screw is just another kind of inclined plane. One example of how a screw helps you do work is that it can be easily turned to move itself through a solid space like a block of wood.
    a. **Examples**: bolt, drill, jar lid, bottle cap, light bulb

Because **work** is defined as **force** acting on an object in the direction of motion, a machine makes work easier to perform by accomplishing one or more forms of work. Pushing, pulling, and lifting are common forms of work. A force is any push or pull that causes an object to change its position (movement), direction, or shape.

Many machines combine more than one of these devices to make work easier. For instance, we might attach a long handle to a shaft to make a windlass or use a block and tackle to pull a load up a ramp. While these machines may seem simple, they continue to provide us with the means to do many things that we could never do without them.

Energy Transformations

Energy is the ability to do work and comes in many forms. All matter contains potential or kinetic energy. In simple terms, **potential energy** is stored in an object, waiting to be transformed into **kinetic energy** when the object moves. For example, a ball sitting at the top of hill has potential energy, which is transformed into kinetic energy as the ball rolls down the hill.

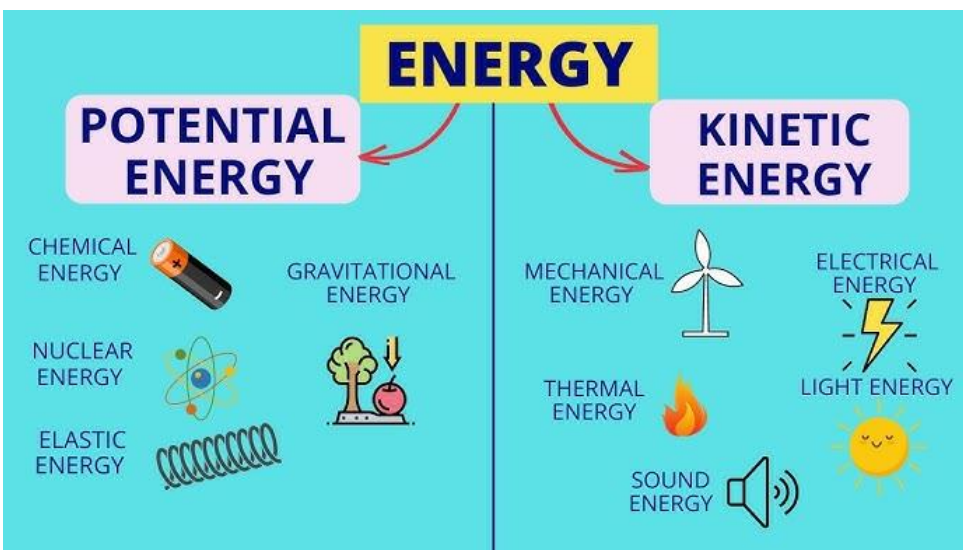


Source: https://www.sciencelearn.org.nz/images/2184-potential-and-kinetic-energy

Potential energy can be classified as chemical energy, nuclear energy, elastic energy, or gravitational potential energy. **Chemical energy** is the energy stored in atomic bonds, like in food, batteries, and coal. **Nuclear energy** is the energy stored in the nucleus of an atom; when an atom is split, all this energy is released and can be used to generate electricity. **Elastic**

energy is the energy stored in the compression or stretching of elastic materials. When a rubber band is stretched out, it contains elastic energy. **Gravitational potential energy** is the energy related to an object's height above the ground. Objects that are at a higher position have more gravitational potential energy. Hydropower plants use gravitational potential energy to rotate hydroelectric turbines, generating electricity.

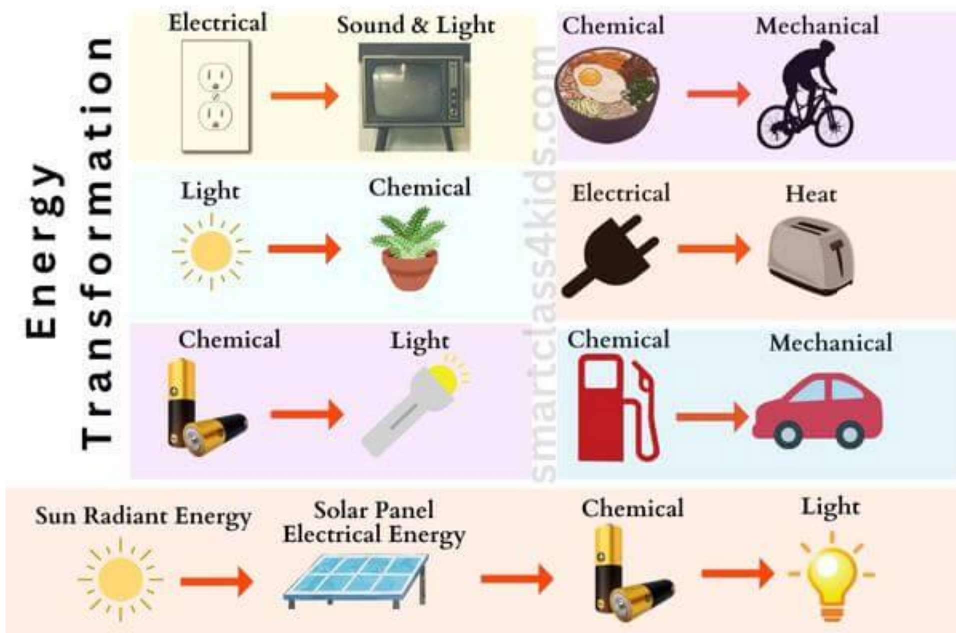
Kinetic energy can be classified as either radiant, thermal, electrical, sound, or motion energy. **Radiant energy** (or light) is electromagnetic energy that travels in waves. The Sun is our major source of radiant energy. **Thermal energy** (or heat) comes from the movement of atoms within matter. Atoms move quickly within objects that have higher temperatures, while the atoms within colder objects move more slowly. **Electrical energy** is the energy in electrons as they move between areas of different charge. Lightning is a familiar example of electrical energy at work. **Sound** is energy that moves through the vibration of particles in an object. **Mechanical kinetic energy** (or **motion energy)** is probably the most recognizable type of kinetic energy as it is easily visible. Any object that is moving (e.g., people, cars, animals, windmills) displays motion energy.



Source: Hungry SciANNtist on YouTube (https://www.youtube.com/watch?v=6KUP__MR4u8)

Mechanical energy is found when an object contains both potential and kinetic energy. The amount of mechanical energy is equal to the sum of its potential and kinetic energy.

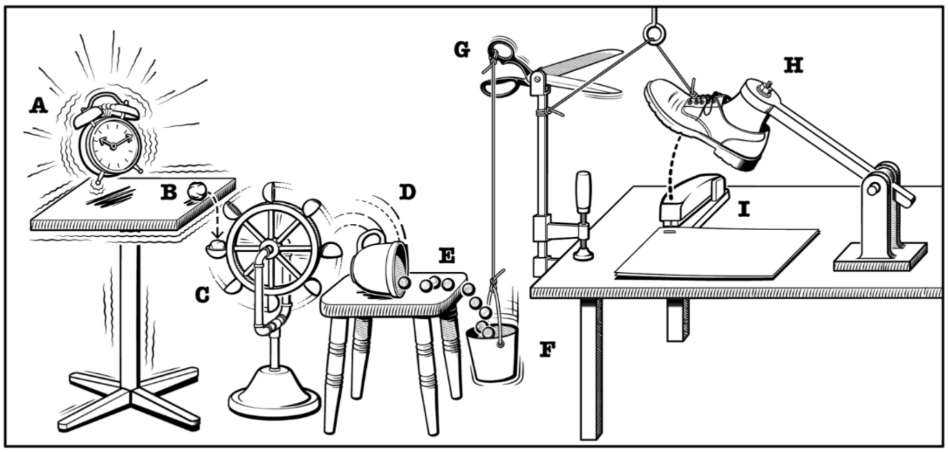
One of the key concepts of energy is the **Law of Conservation of Energy**: Energy cannot be created or destroyed, only transformed. Energy is constantly being transformed from one type to another. Chemical reactions within the Sun cause chemical energy to be transformed into radiant and thermal energy needed for all life on Earth to exist. Our digestive systems break down the food we eat, transforming its chemical energy into thermal and motion energy.



Source: https://smartclass4kids.com/science/physics/types-of-energy/

Rube Goldberg Machines

Some of the most recognizable kinetic systems are Rube Goldberg Machines. These machines are named after Rube Goldberg, best known for his cartoons showing complicated machines performing simple tasks. Rube Goldberg Machines and other kinetic systems are made of a combination of different simple machines, which can be built using a variety of materials, including found or recycled objects.



© Vernier Software & Technology

Source: https://www.vernier.com/experiment/pep-16_rube-goldberg-machine/

There are many tasks that can be accomplished with a kinetic system like a Rube Goldberg Machine. We've created a playlist of some examples of Rube Goldberg Machines achieving different tasks:

https://bit.ly/CurtisKinetic

Some other tasks that can be achieved with a kinetic system include:

• Turn on/off a light	• Apply a band-aid	• Crack an egg
• Water a plant	• Sharpen a pencil	• Open/close a door
• Ring a bell	• Toast a piece of bread	• Build a hamburger
• Pop a balloon	• Open a book	• Replace a light bulb
• Fill a glass of water	• Hammer a nail	• Zip a zipper
• Turn off an alarm clock	• Drop trash in a trash can	• Erase a chalkboard
• Put toothpaste on a toothbrush	• Plant seeds in a pot of soil	• Open/close an umbrella

Project Requirements

Requirements

- The kinetic system must include at least 3 energy transformations that perform a selected task or goal.
- The system must run successfully within the first 3 tries.
- The system must run for a minimum of 30 seconds.
- Teams must be able to reset the system within 5 minutes.
- The system must be able to run at least 3 times.
- Teams will create a project board and laboratory notebook detailing their project.
- Each member of the team will participate in a presentation of their project to the judges.

Rules & Forms

Design:

- System may be free-standing or designed for a tabletop.
- Total size must not be larger than 30" x 72" x 108" (as measured from the floor)

Building Materials:

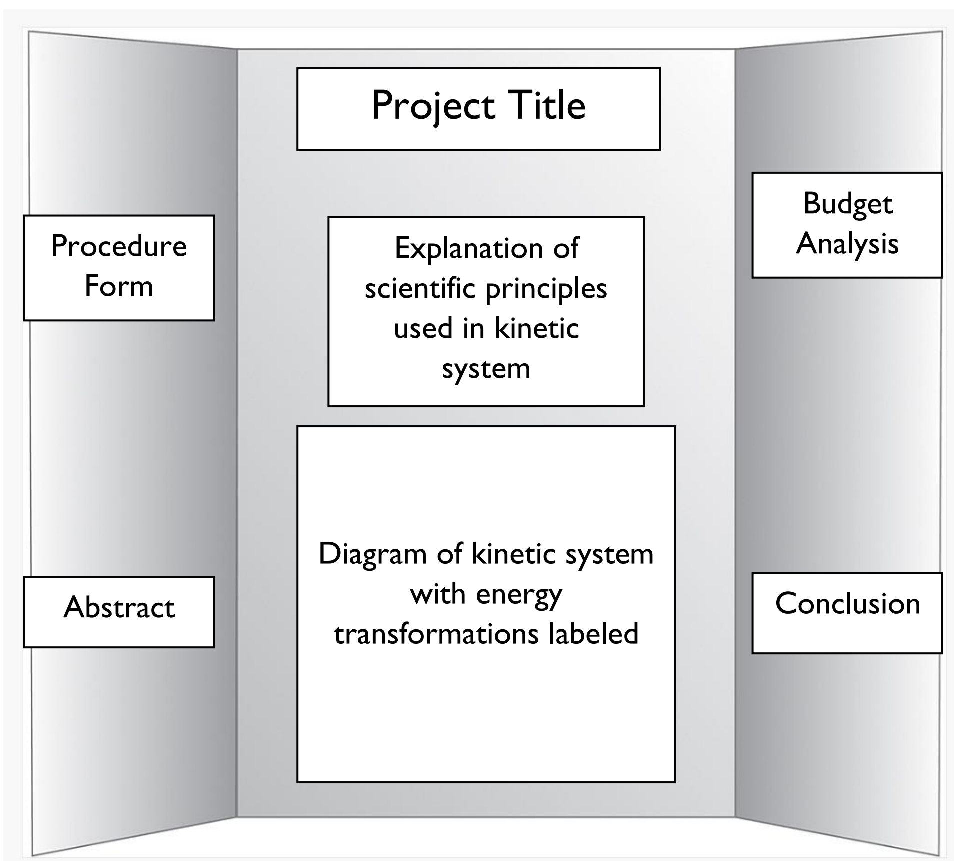
- Purchased parts must not exceed a total of $100.
- Found objects may not exceed $20 each.
    - This means that if you were to purchase a found item in the store, it would cost no more than $20.
- The following items are prohibited:
    - Explosive or effervescent chemicals (including soda and Mentos)
    - Balloons
    - Live Animals

Project Board

Each kinetic system must also have an accompanying project board. The project board must contain:

- Procedure Form, on the upper left side.
- The abstract, in the lower left corner.
- Project title, in the upper center of the board.
- An explanation of the Scientific Principles used, below the title.
- A drawing of the system explaining energy transformations (this should take up most of the center of the board).
- Budget Analysis Form, upper right side.
- Conclusions (data collected, expected results and how you reached them), lower right corner below the Budget Analysis.

An example board set up can found below:



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Laboratory Notebook

The laboratory notebook must contain the following sections:

- Abstract or Abstract Form
    - A project abstract is a brief paragraph or two, limited to a maximum of 250 words, highlighting and/or summarizing the major points or most important ideas about your project. An abstract allows judges to quickly determine the nature and scope of a project. Abstracts must include a brief overview of the following:
        - Purpose of the experiment
        - Procedure
        - Data gathered
        - Conclusions

- Scientific Principles in Kinetic System
    - Research on the scientific principles used in your kinetic system goes in this section. This should include information on the types of energy and transformations. Please also include a bibliography citing your sources.
- Materials
    - A list of materials that were used in the creation of your kinetic system should be included in this section. This can be filled out on a Budget Analysis Form and glued in or handwritten. Receipts for purchased materials should also be included in this section. For found objects, estimate the cost if you were to buy that same object from a store.
- Procedure or Procedure Form
    - The Procedure Form or a handwritten version of it should be included. This should state each step of your kinetic system from beginning to end (e.g., the ball rolls down the ramp, knocking over the block).
- Conclusion
    - The conclusion should include information on the experimental procedure for testing the scientific principles used in the kinetic system. Expected results of the kinetic system and how it was reached should be included. You should also include information about the test runs that were made and a discussion about any problems that were encountered and solved by running the system. An explanation of your original approach or technique should be included as well.

An example of the notebook is included in the resources folder on the competition webpage. There is a digital and word document version. The digital version may be filled out in lieu of a physical notebook but must be presented on a laptop or tablet (supplied by the team) for the judges to view. The Procedure Form, Abstract Form, and Budget Analysis Form can also be found in the same folder.

Budget Analysis Form

The Budget Analysis form below should be filled out and placed on the right side of your board above your conclusion. This form can be found in the resources folder on the competition website. There are two sections of the form, one for purchased items and one for household/found items.

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Budget Analysis: Purchased Items

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Date of Purchase	Supplier	Item Type	Unit Cost	Quantity	Total Cost

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Budget Analysis: Found Items

Item Type	Potential Supplier	Estimated Cost (up to $20)

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Judging & Scoring Process

Teams will demonstrate their kinetic system to judges and present the science behind their system. Judging will be based on the following criteria:

- Interactions during judging
- Innovation: creating a new system or changing an existing system in a creative and innovative way
- Presentation skill and explanation of the science behind their creation
- Project boards
- Laboratory notebook

Sample Judging Questions:

1. What math/science/engineering principles did you learn about and apply while building your kinetic system?
2. What is the task your system is meant to accomplish? Why did you choose this task?
3. What types of energy transfers are in your system and where are they located?
4. What parts of your system were difficult to create? How did you overcome the challenges?
5. What materials did you use to build your system? Why did you choose those specific materials?
6. Is there anything about your kinetic system that you would like to improve if given the chance and why?
7. How did you work as a team to contribute to the creation of the system, project board, and notebook?

Tips for Judging:

- Look over the example judging questions and judging criteria sheet to prepare yourself for what you may be asked.
- Be familiar with how to talk about the energy transfers in your system; have an outline and decide who will talk about which parts.
- Be prepared for the judges to stop you and ask questions during the presentation.
- Be respectful with judges, teachers, and peers. Listen and use appropriate language.

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Judging Criteria – Curtis Kinetic Science Competition

Judge: ____________________ Team #/Name: ____________________________

Kinetic System Design Criteria:	Comments:	Score
Theme/Presentation: How well is the theme incorporated into the system?		__/10
Balance of new vs recycled/found materials		__/10
Construction		__/10
Innovation & Creative Expression		__/10
Diverse types of energy and steps in system		__/10
	Total Kinetic System Design Score (out of 50)	_____

Kinetic System Operation	Yes = 5 points, No = 0 points	Score
Run # 1 Task Completed	Yes or No	_____
-Run Time – Did the machine meet the minimum of 30 seconds?	Yes or No	_____
-Reset Time – Did the team reset their system in 5 minutes or less?	Yes or No	_____
Run # 2 Task Completed	Yes or No	_____
-Run Time – Did the machine meet the minimum of 30 seconds?	Yes or No	_____
Run # 3 Task Completed	Yes or No	_____
-Run Time – Did the machine meet the minimum of 30 seconds?	Yes or No	_____
Did the system have at least 3 energy transformations?	Yes or No	_____
Did the system run successfully within the first three tries?	Yes or No	_____
System Size – Was it within the set dimensions?	Yes or No	_____
Total Kinetic System Operation Score (out of 50)		_____

Project Board and Laboratory Notebook	Yes = 5 points, No = 0 points	Score
Abstract	Yes or No	_____
Materials (Budget Analysis Form & Proof of Purchase)	Yes or No	_____
Drawing/Sketch of System with Labels	Yes or No	_____
Procedure	Yes or No	_____
Scientific Principles Used	Yes or No	_____
Conclusion	Yes or No	_____
Total Project Board/Notebook Score (out of 30)		_____

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Oral Presentation Criteria:	Comments:	Score
How well did the team explain the energy transformations in their system and demonstrate their understanding of the scientific principles?		__/10
How well did the team explain the task that their kinetic system was created to complete?		__/10
How well did the team explain how they created their system and how they improved it during testing?		__/10
Overall, how well did the students present their system to the judges?		__/10
Overall, how well did the students work as a team?		__/10
	Total Presentation Score (out of 50)	______
	Overall Score (out of 180):	______

Judges' Comments – Used in Judges Discussion

How well does the system complete the chosen task? How creative and innovative is the approach to achieving the task?

What did this team do well? What are areas for improvement?

General Comments:

General Tips and Suggestions

Designing and creating a kinetic system for single use can be tricky! It's an added challenge to create a system that can be moved to a new location and still run as designed. Here are a few tips and tricks for creating your systems.

Creating your System:

- Consider all the competition criteria.
- Make a blueprint to follow as you create your structure.
- Mark the energy transfers.
- Use sturdy materials for the base of your system and consider the material properties of each component.
- Decide on an orientation, vertical or horizontal.
- Use a level! Levels will help you set up your base the same way each time and help set each component.
- Consider how each component will be fixed to the board. Try to create strong, secure fixture points. Pay special attention to the energy transfer points!

Testing and Improving your System

- As you build your system, test, test, and retest!
- Use a level to mark angles and to ensure the base is still level.
- If there are items that need to be permanently adhered to the board, create a strong bond.
- As you test the system, pay attention to those energy transfers, keep improving until you are satisfied with the results again and again.
- Practice moving and rebuilding your design.
- Create a final blueprint to reference on competition day.

Competition Day

- Pack your design safely so nothing is bent, broken, or shifts during the ride.
- Use a level and the blueprint to rebuild your design at the Orlando Science Center.
- Test and make adjustments to your system before the judges come around.

Practice Activities Standards Correlation

Florida Next Generation Sunshine State (NGSS) Standard	Design a Roller Coaster	Catapult Challenge	Energy Transformations
Nature of Science			
SC.6.N.1.1: *Define a problem from the sixth grade curriculum, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigation of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions.*	X	X	X
SC.6.N.1.2: *Explain why scientific investigations should be replicable.*	X	X	X
SC.6.N.1.4: *Discuss, compare, and negotiate methods used, results obtained, and explanations among groups of students conducting the same investigation.*	X	X	X
SC.6.N.1.5: *Recognize that science involves creativity, not just in designing experiments, but also in creating explanations that fit evidence.*	X	X	X
SC.7.N.1.1: *Define a problem from the seventh grade curriculum, use appropriate reference materials to support scientific understanding, plan and carry out scientific investigation of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions.*	X	X	X
SC.7.N.1.3: *Distinguish between an experiment (which must involve the identification and control of variables) and other forms of scientific investigation and explain that not all scientific knowledge is derived from experimentation.*	X	X	X
SC.7.N.1.6: *Explain that empirical evidence is the cumulative body of observations of a natural phenomenon on which scientific explanations are based.*	X	X	X
SC.8.N.1.1: *Define a problem from the eighth grade curriculum using appropriate reference materials to support scientific understanding, plan and carry out scientific investigations of various types, such as systematic observations or experiments, identify variables, collect and organize data, interpret data in charts, tables, and graphics, analyze information, make predictions, and defend conclusions.*	X	X	X

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Florida Next Generation Sunshine State (NGSS) Standard	Design a Roller Coaster	Catapult Challenge	Energy Transformations
Nature of Science, cont.			
SC.8.N.1.2: *Design and conduct a study using repeated trials and replication.*	X	X	
SC.8.N.1.6: *Understand that scientific investigations involve the collection of relevant empirical evidence, the use of logical reasoning, and the application of imagination in devising hypotheses, predictions, explanations and models to make sense of the collected evidence.*	X	X	
Physical Science			
SC.6.P.11.1: *Explore the Law of Conservation of Energy by differentiating between potential and kinetic energy. Identify situations where kinetic energy is transformed into potential energy and vice versa.*	X	X	X
SC.6.P.13.1: *Investigate and describe types of forces including contact forces and forces acting at a distance, such as electrical, magnetic, and gravitational.*	X	X	X
SC.6.P.13.2: *Explore the Law of Gravity by recognizing that every object exerts gravitational force on every other object and that the force depends on how much mass the objects have and how far apart they are.*	X		X
SC.6.P.13.3: *Investigate and describe that an unbalanced force acting on an object changes its speed, or direction of motion, or both.*	X	X	X
SC.7.P.11.2: *Investigate and describe the transformation of energy from one form to another.*		X	X
SC.7.P.11.3: *Cite evidence to explain that energy cannot be created nor destroyed, only changed from one form to another.*		X	X
SC.8.P.8.2: *Differentiate between weight and mass recognizing that weight is the amount of gravitational pull on an object and is distinct from, though proportional to, mass.*	X		

Practice Activity 1: Design a Roller Coaster

Prep: 5 – 10 min.

Activity: 65 min.

Science Topic: Motion of Objects

Learning Objectives: Students will...

- Explore different ways objects move.
- Investigate the effect of applying various pushes and pulls on different objects.
- Use empirical evidence to explain the relationship between force, energy, and motion.
- Explore how energy transforms from potential to kinetic and vice versa.

Vocabulary

- force
- gravity
- energy
- potential energy
- kinetic energy
- friction
- motion
- accelerate
- momentum

Overview

In this activity, students explore the effects of various forces on the motion of an object. Students use the engineering design process to find a possible solution to the problem: Create a roller coaster which is safe and fun.

Students must collaborate with their peer(s) to design a model roller coaster which will meet the engineering design goal. Students will determine whether their structure has met the criteria, and whether their second prototype has improved in meeting these criteria.

Students work within materials and time constraints as they attempt to solve the problem. Students receive a set number of building materials and create, test, and improve their designs. Students evaluate their designs to determine whether they have met the goal criteria.

Students share their designs with their classmates and compare different designs to appreciate the creativity that goes into engineering.

Background

A **force** is a push or pull on an object. When a force increases or decreases in its push or pull on an object, it causes a change in motion in that object. Objects may accelerate, slow down, or change shape. The greater the amount of force applied, the greater the effect will be on an object's motion.

Mass is how much matter is contained is contained in an object. **Gravity** is a force of attraction between objects which have mass. All objects that have mass exert a gravitational pull. Objects with greater mass have greater gravitational force than objects with less mass. Since the Earth is so much larger than the objects on it (i.e., you and me, plants, animals, buildings), all objects on Earth are pulled toward the center of the Earth.

Energy is the capacity for doing work. It cannot be created or destroyed, but instead converts from one form of energy to another. These conversions can be caused by an imbalance of forces acting on an object and can cause a change in **motion**, or how an object moves.

- **Potential energy** is stored energy. For example, a roller coaster car resting at the base of the first hill has balanced forces acting on it between gravity pulling it toward the center of the earth and the rails pushing back against the car. However, when the car is at the top of the first hill it gains potential energy to be pulled toward the ground due to gravity. The potential energy of an object will only change if the energy converts, decreasing the potential energy, or if additional work is applied to the object, creating additional potential energy.
- **Kinetic energy** is the energy an object possesses due to its motion. For example, when the roller coaster car goes down the first hill, gravity is acting on the car more than any other force. As a result, some of the potential energy converts into kinetic energy as gravity pulls it toward the center of the earth.

A force can cause an object in motion to **accelerate** or speed up. Other forces can cause an object to slow down or even cease moving. Speed (or velocity) = distance/time.

Friction is a force which slows the motion of an object. Friction converts kinetic energy to thermal energy (heat) when surfaces move against one another in opposite directions. For example, friction is created between a roller coaster car and the track. This is why each successive hill must be shorter than the hill before it: energy is gradually converted into heat due to friction, leaving less kinetic energy to push the car to the top of each hill.

Momentum is the relationship between the mass of an object and its speed of motion, or velocity. Momentum = mass x velocity. The greater the mass and/or speed of an object, the more momentum it has. Greater force is required to alter the motion of an object with greater momentum. For example, a heavy roller coaster car will need more force applied to accelerate than a lighter car, and once it has accelerated it will need more force applied to it to slow down or stop.

Additional Resources

- "Kids Discover: Force and Motion": http://www.kidsdiscover.com/spotlight/force-motion-kids/
- "Physics 4 Kids": http://www.physics4kids.com/

Pre-Requisite Knowledge

Students should have grade-appropriate comprehension of the following concepts:

- An understanding of what gravity is and how it affects objects' motion
- An understanding of potential and kinetic energy
- How to measure with measuring tape to the nearest ¼ inch
- How to measure time in seconds
- Addition, subtraction, and division

Pre-Requisite Resources: The following resources provide activities for educators who have not yet covered the pre-requisite science concepts in the classroom:

- Types of Forces: https://www.cpalms.org/PreviewResourceStudentTutorial/Preview/165128
- Gravity: https://www.cpalms.org/PreviewResourceStudentTutorial/Preview/165166
- Conservation of Energy: https://www.cpalms.org/PreviewResourceStudentTutorial/Preview/118860
- "Let's Build a Contraption" (transformation of energy): https://www.cpalms.org/PreviewResourceStudentTutorial/Preview/181472

Materials

For the Class:

- Engineering Design Process (on the board or on chart paper)
- Images of examples of roller coasters
- 3 Rolls of masking tape

For Each Group of Students

- 1 Timer
- 1 Glass marble
- 12 Paper plates with deep lip (a marble should be able to roll against the edge of the plate without rolling off)
- 22 Sheets of paper, 8 ½" x 11" (**tip: use recycled paper**)
- 1 Measuring tape
- Scissors
- Calculator

For Each Student

- Pencil
- "Design a Roller Coaster" worksheet

Introduction (15 min.)

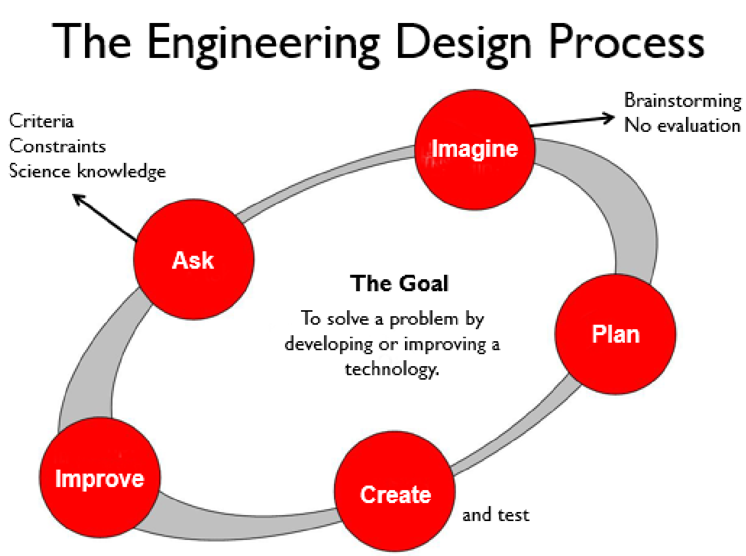
1. Review with students what they have learned about force and motion. Ask:
    - **What is a force?** *(A force is a push or pull that may change the motion of an object.)*
    - **What is the force that pulls objects toward the surface of the earth?** *(gravity)*
        - Expand the definition of gravity to include the relationship between mass and gravitational pull.
2. Lead students in a discussion about energy. Ask:
    - **What is energy?** *(The capacity of an object to move)*

- **What are some different forms of energy?** *(Answers will vary and could include sound vibrations, solar, potential, kinetic)*
- **When have you seen a force act on an object, giving it energy to move?** *(Answers will vary. Examples: gravity causing structures to fall, throwing or kicking a ball, wind moving tree branches)*
- **What is potential energy?** *(stored energy)*
- **What is kinetic energy?** *(energy of motion)*

3. Explain to students that energy is never created or lost, it is simply converted into other forms of energy (Law of Conservation of Energy).

4. Explain to students that while some forces cause objects' motion to increase, other forces slow objects down. Ask:
    - **What do you know about friction?** *(Pause and take answers.)* Clarify: Friction is a force which converts energy to heat when objects rub together. This means that objects have less kinetic energy and slow down.

5. Introduce students to the Engineering Design Process (skip if your students are already familiar with this). The Engineering Design Process is a tool engineers use when developing new technology or improving existing technology.



** Source: Engineering is Elementary (www.eie.org)*

ASK questions that will help you achieve your goal.

- What are the criteria my design needs to meet?
- What are the constraints which limit me?
- What science and math content will I need to consider as I design my technology?

IMAGINE at least two possibilities for design.

- What could be some solutions?
- Brainstorm ideas.

PLAN the design before building.

- Collaborate with my team to make a plan for our design.
- Make a list of the materials needed.

CREATE at least one design solution.

- Follow the plan and create it.
- Test design and evaluate results.

IMPROVE the design based on evidence around the original design criteria.

- Make the design better.
- Re-test and evaluate results.

6. Explain to the students that they are going to be engineers.
   - **Problem:** An older theme park is not getting as many guests anymore. They need a new, exciting roller coaster to draw crowds in again.
   - **Goal:** Design a roller coaster which is safe and fun.

7. Ask the students: **"Now that we have our goal, where should we start in the engineering design process?"** *(We should ask questions to identify criteria and constraints as well as to explore any science and math content we will need to know to solve the problem.)*

8. Record students' questions on the board. Guide them toward the following questions:
   - How do we know if a roller coaster is "fun?"
   - How do we know if a roller coaster is "safe?"
   - Does the roller coaster need to be a certain length?
   - How fast does the roller coaster need to go?
   - How long will we have to create our designs?
   - What materials can we use?
   - What examples of real roller coasters are there?

9. After students have finished brainstorming questions, answer each of them. Record criteria and constraints on the board or on chart paper.
   - **Fun:**
     - The roller coaster is fun if it has at least two turns or hills in it.
     - The roller coaster is fun if it is fast (see speed criteria).
   - **Safety:**
     - The roller coaster car (marble) must remain on the track the entire length of the roller coaster to be considered safe.
   - **Length:** The roller coaster must extend from the seat of a chair to the floor.
   - **Speed:**
     - The faster the roller coaster is, the more fun people will think it is. The theme park will want the fastest design that is still safe, so students will try to create the fastest design in the class.
     - Calculate speed by dividing the length of the roller coaster track by the amount of time the ride lasts. Students will measure the length to the nearest ¼" with a measuring tape and will measure time with a stopwatch or timer.
   - **Time:**
     - Each student will have 5 minutes to imagine ideas on their worksheets.
     - Teams will then collaborate for 5 minutes to develop a plan.
     - Once the plan has been approved by the teacher, teams will have 15 minutes to create their designs. Any changes to the designs should be reflected in the plan.
     - We will test the fun and safety of our designs.
     - Teams will then have 10 minutes to improve their designs.
     - We will test the fun and safety of our improved designs.
   - **Materials:**
     - Students will receive 1 foot of masking tape at a time but will not be limited to how much total tape they can use.
     - Each group will receive 20 sheets of paper, 10 paper plates, scissors, a stopwatch, and measuring tape. A marble will represent the roller coaster car.
     - To make it more challenging, students cannot tape their coaster track to tables or chairs; they must create support structures themselves.
   - **Examples of roller coasters:**
     - Ask: **Have you ever been on or seen a roller coaster before? What was it like? What kinds of materials were they made of?**

- Show the students example images of real roller coasters. Ask:
  - **How are the designs similar and different?** *(materials, loops, hill size, curves)*
  - **What different main features do you see?** *(Support beams, tracks, roller coaster car)*
  - **What are some different ways that these designs have been supported for stability?** *(Straight beams, diagonal beams, cross beams)*
- Make sure students understand that their designs do not have to look like any of these images, but they can take inspiration from them if they like.

10. Show students an example of each type of material they will receive. Call on a few students to share ideas about each question.
    - How could we use these materials to create hills?
    - How could we use these materials to create turns?
    - How could we use these materials to create support beams to hold up our roller coaster?

Activity (45 min.)

1. Have students remind you of the next step in the engineering design process. *(Imagine)* Explain that students should be imagining individually and not talking yet. Students will get to share their ideas when it is time to plan.

2. Show students the "Imagine" section at the top of their worksheet. Give each group a sample of their materials. Clarify that these are not part of their building materials, so they don't have to worry about damaging them. Encourage students to experiment with the materials as they imagine ideas.

Sample materials (per group)

- 2 sheets of 8 ½" x 11" paper
- 2 paper plates
- 6 inches masking tape
- scissors

3. Give students 5 minutes to imagine ideas. Circulate among the students. If students are having trouble imagining ideas, ask them to think about the images of roller coasters they saw in class, or structures they've seen in real life. Ask:

    - What kinds of shapes did you see in those examples?
    - Were the roller coasters wide? Short? Tall? Narrow?
    - How could you use your materials to create the track?
    - What kind of supports were added to the roller coasters? How could you use your materials to create these supports?

4. After 5 minutes, ask the students which step is next in the engineering design process. *(Plan)* Set expectations for how students will interact: taking turns, speaking kindly, voting on ideas, etc. Emphasize that groups can combine ideas; they don't just have to choose just one. Tell the groups to draw their ideas in the Plan section on their worksheets.

5. Give students 5 minutes to collaborate and form a plan. Circulate during this time, asking students questions:

    - What do you think about _____'s idea?
    - Has everyone had a turn to share?
    - What have you seen in real life that makes you think your design will be successful?

6. After 5 minutes, check each group's design for approval. Retrieve the sample materials (leave the scissors).

7. Ask students which step is next in the engineering design process. *(create)* Tell students that they will have 15 minutes to create their roller coasters. Remind students that they can make changes to their design as they build, but that these changes should also be changed in their plan.

8. Give each group their building materials and set a timer for 15 minutes. During this time, students should build their coasters and add any changes they've made to their designs on their worksheets. Circulate during this time, asking students questions:

Teacher Tip:

Have extra paper and paper plates on hand to replace any damaged materials.

- How did you come up with this idea?
- Does your design look like anything you've seen in real life?
- What sort of changes have you made to your design so far? Why?
- Why do you think your design will be successful

9. After 15 minutes, have groups measure the length of their coaster track and record it on their worksheets. Have each group share their idea with the class and briefly explain how they came up with the design.

10. Then, test each group's design one at a time while the rest of the class watches. Students will measure the time it takes the marble to travel along their roller coaster and record it on their worksheets.

Teacher Tip:

To save time, multiple groups can test at once.

Give students time to walk around and look at other groups' designs before beginning the test.

11. After all groups have tested, have them calculate the speed of their coaster and determine whose coaster was the fastest. Students will check off the design criteria they achieved on their worksheet.

12. Ask students which step is next in the engineering design process. *(improve)* Tell students that they will have 10 minutes to improve their roller coasters. If their coaster was not the fastest, they will need to try and increase their speed. Remind students that they can make changes to their design as they build, but that these changes should also be changed in their plan. Students should answer the Improve question on their worksheet.

13. Set a timer for 10 minutes. Circulate during this time, asking students questions:
    - What was successful about your design in the first test? What failed in your design in the first test?
    - How are you planning to improve your design based on test results?
    - What sort of changes have you made to your design so far? Why?
    - Have you changed these in your plan as well?
    - Why do you think your improved design will be more successful than your first design?

14. After 10 minutes, have groups measure the length of their coaster track and record it on their worksheets. Have each group share their improved idea with the class and briefly explain what part of the design they changed.

15. Then, test each group's design one at a time while the rest of the class watches. Students will measure the time it takes the marble to travel along their roller coaster and record it on their worksheets.

16. After all groups have tested, have them calculate the speed of their coaster and determine whose coaster was the fastest. Students will check off the design criteria they achieved on their worksheet.

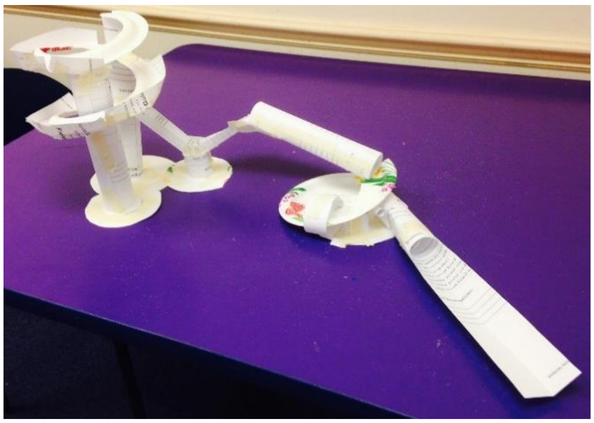
Reflection (5 min.)

1. Ask the students:
   - Where on your roller coaster did the car (marble) have the most potential energy? (*at the highest point; right before it is released)*
   - Where did it have the most kinetic energy? (*at the bottom of the highest hill, when it has the most speed)*
   - Was your second design more successful than your first design? Why or why not?
   - What did different groups' designs have in common? Did any of these commonalities seem to contribute to the success of the designs?
   - How were different groups' designs unique? Did any of these differences seem to contribute to the success of the design?
   - How would you improve your team's design if you had more time?

2. Have students record their thoughts in the Reflect portion of their worksheets.

Teacher Notes

The pictures below are example structures made from each set of materials. These are examples for the teacher only and should NOT be shown to students.



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Name ________________________

Design a Roller Coaster Student Worksheet

Imagine at least two solutions to the problem.

Plan: Draw the plan for your design below.

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Test 1

The length of our roller coaster track is: ________________ .

The length of time the car was on the track is ______________.

________________ = ________________ ÷ __________________

Speed Distance Time

Our roller coaster is: ☐ Safe ☐ The fastest

Improve: What will your team improve about your design? Why?

____

____

Test 2

The length of our roller coaster track is: ________________ .

The length of time the car was on the track is ______________.

________________ = ________________ ÷ __________________

Speed Distance Time

Our roller coaster is: ☐ Safe ☐ The fastest

Reflect: Was your improved design more successful? How do you know?

____

____

Where did your roller coaster have the most potential energy? The most kinetic?

____

____

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Practice Activity 2: Catapult Challenge

Prep: 5-10 min.

Activity: 65 min.

Science Topic: Simple Machines

Learning Objectives: Students will...

- Explore how levers can be used to move objects over long distances.
- Use simple machines to demonstrate the Law of Conservation of Energy.
- Describe and observe the precision and accuracy of an object's motion.
- Observe the effects of unbalanced forces on the motion of objects.

Vocabulary

- force
- energy
- potential energy
- kinetic energy
- lever
- simple machine
- precision
- accuracy
- Law of Conservation of Energy

Overview

In this pre-activity, students will use everyday objects to create catapults that will launch an object onto a target.

Background

One of the most successful weapons in the Middle Ages was the catapult. Using catapults as siege weapons, enemy forces were able to successfully surround and infiltrate fortresses. Catapults are made using basic simple machinery (levers). The basic premise behind a simple machine is to decrease the amount of effort it takes to do a job.

Some other simple machines are:

- **Wheel and axle:** These two components are attached and turn in the same direction. A rope is wrapped around the smaller axle and when a small force is applied to the large wheel, the force is amplified.
- **Inclined Plane:** Large, flat ramp-like structure. Inclined planes are mostly used as an aid in raising or lowering a heavy load. The downfall of this is that the distance traveled is made greater. More "work" is required to lift a heavy object vertically.
- **Wedge:** Versatile and portable inclined plane. Wedges can be used to separate objects from one another (splitting wood), lift an object, or keep objects in place.
- **Pulley:** Pulleys are used to change the direction of a force and to increase lifting power. The mechanical advantage in pulleys is directly related to the number of loops of rope. The more loops, the easier it is to lift a load.
- **Screw:** Screws convert rotational motion into linear motion. The distance between the threads of a screw is called the pitch. The smaller the pitch (the closer the threads are to each other) the greater the mechanical advantage.

Additional Resources

- Teach Engineering Simple Machines: https://www.teachengineering.org/populartopics/simplemachines

Pre-Requisite Knowledge

Students should have grade-appropriate comprehension of the following concepts:

- How to measure with a ruler to the nearest inch
- An understanding of forces and how they act on an object's movement
- An understanding of the difference between kinetic and potential energy
- An understanding that energy is needed to perform work

Pre-Requisite Resources: The following resources provide activities for educators who have not yet covered pre-requisite concepts in the classroom:

- Types of Forces: https://www.cpalms.org/PreviewResourceStudentTutorial/Preview/165128
- Gravity: https://www.cpalms.org/PreviewResourceStudentTutorial/Preview/165166
- Kinetic & Potential Energy: https://www.cpalms.org/PreviewResourceStudentTutorial/Preview/182278

Materials

For the Class

- Engineering Design Process (on the board or on chart paper)
- Meterstick
- 1 Roll of masking tape
- 1 Sheet of butcher paper (approximately 2 feet x 2 feet)

For Each Group

- 1 Ziploc bag
- 1 Plastic spoon
- 2 Dixie cups (3 oz. size)
- 2 Cotton balls
- 5 Pencils (unsharpened)
- 2 Clothespins
- 10 Popsicle sticks
- 5 Rubber bands
- 2 Binder clips

For Each Student

- "Catapult Challenge" worksheet
- Pencil

Preparation

1. Create a materials kit for each group by placing the materials listed above in a Ziploc bag.
2. Create an "Emergency Materials Kit" with extras of each material (especially plastic spoons and rubber bands).
3. Use a large piece of butcher paper and markers to create a target. Tape the target on the floor in an area with at least 10 feet of open space for a testing area.
    a. If butcher paper is not available, tape 4-8 pieces of copy paper together to create a large target.
4. Use a piece of masking tape to mark the starting point 10 feet away from the target.
    a. Tip: Use smaller pieces of masking tape to mark 1-foot intervals between the starting point and the target. This will speed up measurement for any groups that need to move their catapults closer to the target.

Introduction (15 min.)

1. Review with students what they have learned about forces and energy. Ask:
    - **What is a force?** *(A force is a push or pull that may change the motion of an object.)*
    - **What is energy?** *(The capacity of an object to move)*
    - **What are some different forms of energy?** *(Answers will vary and could include sound vibrations, solar, potential, kinetic)*
    - **When have you seen a force act on an object, giving it energy to move?** *(Answers will vary. Examples: gravity causing structures to fall, throwing or kicking a ball, wind moving tree branches)*
    - **What is potential energy?** *(stored energy)*
    - **What is kinetic energy?** *(energy of motion)*

2. Explain to students that energy is never created or lost, it is simply converted into other forms of energy (Law of Conservation of Energy).

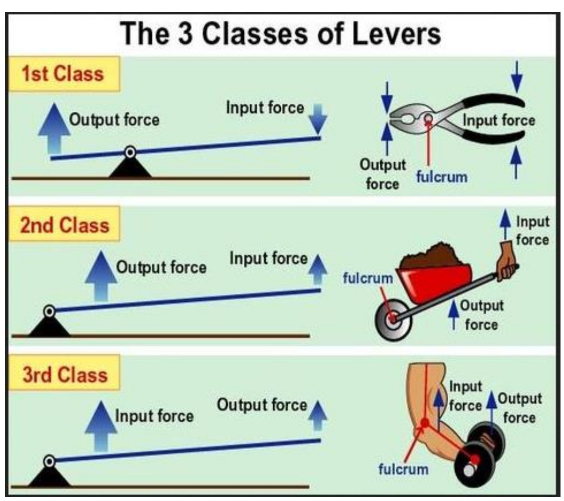
3. Review with students what they know about simple machines. **Simple machines help to make work easier. In science, we define work as the force acting on an**

object in the direction of motion. Pushing, pulling, and lifting are all common forms of work.

- **What are the 6 types of simple machines?** *(wheel and axle, inclined plane, wedge, lever, pulley, screw)*
  - Show examples or pictures of each
- **Where may you have seen some of these simple machines in your everyday lives?** *(Door stopper, screw, jar with lid, doorknob, hammer, seesaw, shovel, ax, wheelbarrow, wrench, tweezers, ramps, etc.)*

4. During this activity, we will be concentrating mostly on the lever. Ask:
   - **What is a lever?** *(A lever is any rigid bar that rests on a pivot point, or fulcrum, that is used to move a heavy or fixed load with one end by putting pressure on the opposite end.)*

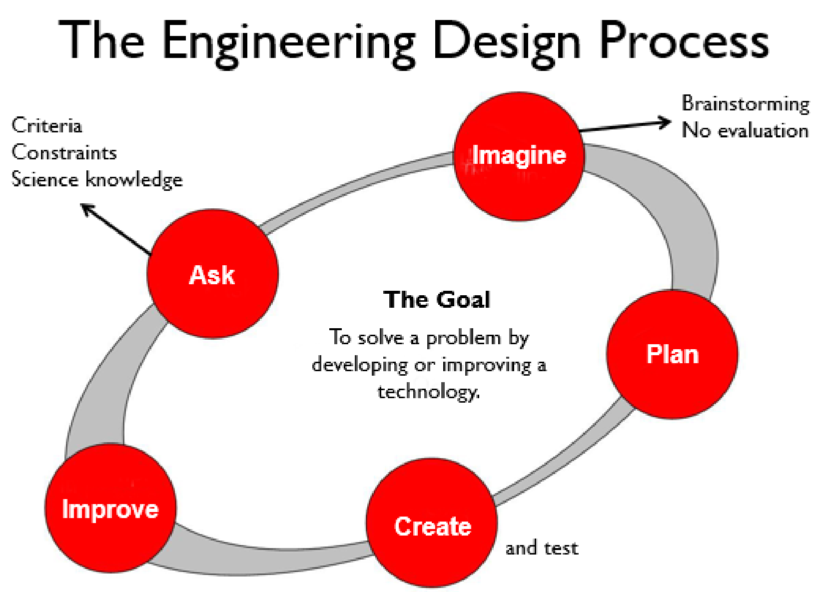
5. There are three different classes of levers.
   - Class I levers have the fulcrum, or pivot point, between the effort and the load.
     - Ex: A claw hammer pulling out a nail, catapults, see saw.
   - Class 2 levers have the load between the effort and the fulcrum (always closer to the fulcrum).
     - Ex: Wheelbarrow
   - Class 3 levers have the effort between the fulcrum and the load.
     - Ex: Sweeping a broom, tweezers



**Source: https://www.toppr.com/ask/content/concept/kinds-of-levers-208470/*

6. In this activity we will be concentrating on class 1 levers as we build catapults.

7. Introduce students to the Engineering Design Process. The Engineering Design Process is a tool engineers use when developing new technology or improving existing technology.



* *Source: Engineering is Elementary (www.eie.org)*

ASK questions that will help you achieve your goal.

- What are the criteria my design needs to meet?
- What are the constraints which limit me?
- What science and math content will I need to consider as I design my technology?

IMAGINE at least two possibilities for design.

- What could be some solutions?
- Brainstorm ideas.

PLAN the design before building.

- Collaborate with my team to make a plan for our design.
- Make a list of the materials needed.

CREATE at least one design solution.

- Follow the plan and create it.
- Test design and evaluate results.

IMPROVE the design based on evidence around the original design criteria.

- Make the design better.
- Re-test and evaluate results.

8. Explain to the students that they are going to be engineers.
    - **Problem:** The zoo is short on staff and is looking for a way to quickly bring food to the different animals without entering each of their enclosures.
    - **Goal:** Design a catapult that can accurately send food over the walls of an animal's enclosure and into its feeding area.

9. Ask the students: **"Now that we have our goal, where should we start in the engineering design process?"** *(We should ask questions to identify criteria and constraints as well as to explore any science and math content we will need to know to solve the problem.)*

10. Record students' questions on the board. Guide them toward the following questions:
    - How will we test the accuracy of our catapult?
    - How far away will the catapult be from the target?
    - How long will we have to create our designs?
    - What materials can we use?
    - What examples of real catapults are there?

11. After students have finished brainstorming questions, answer each of them. Record criteria and constraints on the board or on chart paper.
    - **Accuracy:** The catapult must be able to fling the cotton ball onto the target.
    - **Precision**: The cotton ball must land on the target at least 75% of the time (3 out of 4 trials).
    - **Length:** The catapult must be at least 10 feet away from the target.
    - **Time:**
        - Each student will have 5 minutes to imagine ideas on their worksheets.
        - Teams will then collaborate for 5 minutes to develop a plan.
        - Once the plan has been approved by the teacher, teams will have 15 minutes to create their designs. Any changes to the designs should be reflected in the plan.
        - We will test the accuracy and precision of our designs.
        - Teams will then have 10 minutes to improve their designs.
        - We will test the accuracy and precision of our improved designs.

- **Materials:** *Show students an example of each type of material they will receive. Inform students that they will receive their materials in a Ziploc bag, but the bag is not one of the materials they can use for building.*
    - Cotton balls
    - Plastic spoons
    - Popsicle sticks
    - Unsharpened pencils
    - Rubber bands
    - Binder clips
    - Clothespins
    - Dixie cups
- Ask: **Have you ever seen a catapult before? What was it like? What kinds of materials were they made of?**
    - **Examples of catapults:**

    - Show the students the example images of real catapults. Ask:
        - **How are the designs similar and different?**
        - **What different main features do you see?**
        - Make sure students understand that their designs do not have to look like any of these images, but they can take inspiration from them if they like.

Activity (45 min.)

1. Have students remind you of the next step in the engineering design process. *(Imagine)* Explain that students should be imagining individually and not talking yet. Students will get to share their ideas when it is time to plan.

2. Show students the "Imagine" section at the top of their worksheet. Give students 5 minutes to imagine ideas. Circulate among the students.

3. After 5 minutes, ask the students which step is next in the engineering design process. *(Plan)* Set expectations for how students will interact: taking turns, speaking kindly, voting on ideas, etc. Emphasize that groups can combine ideas; they don't just have to choose just one. Tell the groups to draw their ideas in the Plan section on their worksheets.

4. Give students 5 minutes to collaborate and form a plan. Circulate during this time, asking students questions:
    a. What do you think about ______'s idea?
    b. Has everyone had a turn to share?
    c. What have you seen in real life that makes you think your design will be successful?

5. After 5 minutes, check each group's design for approval.

6. Ask students which step is next in the engineering design process. *(Create)* Tell students that they will have 15 minutes to create their catapults. Remind students that they can make changes to their design as they build, but that these changes should also be changed in their plan.

7. Give each group their building materials and set a timer for 15 minutes. During this time, students should build their catapults and add any changes they've made to their designs on their worksheets. Circulate during this time, asking students questions:
    a. How did you come up with this idea?
    b. Does your design look like anything you've seen in real life?
    c. What sort of changes have you made to your design so far? Why?
    d. Why do you think your design will be successful?

8. After 15 minutes each group will share their idea with the class and briefly explain how they came up with the design.

9. Then, test each group's design one at a time while the rest of the class watches. Students will place their catapult on the starting line 10 feet from the target. Each group will get 4 trials. After each trial, they should record the distance and accuracy on their worksheet. If a group is having trouble hitting the target from 10 feet, they can move the catapult closer. If a group easily hits the target, they can move their catapult farther from the target. Any groups that move their catapult closer or further from the target should measure and record the distance on their worksheet.

Teacher Tip:

To save time, multiple groups can test at once.

Give students time to walk around and look at other groups' designs before beginning the test.

10. After all groups have tested, students will check off the design criteria they achieved on their worksheet.

11. Ask students which step is next in the engineering design process. *(Improve)* Tell students that they will have 10 minutes to improve their catapults. If a group met all the design criteria during Test 1, challenge them to hit the target from a farther distance. Remind students that they can make changes to their design as they build, but that these changes should also be changed in their plan. Students should answer the Improve question on their worksheet.

12. Set a timer for 10 minutes. Circulate during this time, asking students questions:
    a. What was successful about your design in the first test? What failed in your design in the first test?
    b. How are you planning to improve your design based on test results?
    c. What sort of changes have you made to your design so far? Why?
    d. Have you changed these in your plan as well?
    e. Why do you think your improved design will be more successful than your first design?

13. After 10 minutes, each group will share their improved idea with the class and briefly explain what part of the design they changed.

14. Then, test each group's design one at a time while the rest of the class watches. Students will place their catapult on the starting line 10 feet from the target. Each group will get 4 trials. After each trial, they should record the distance and accuracy on their worksheet. If a group is having trouble hitting the target from 10 feet, they can move the catapult closer. If a group easily hits the target, they can move their catapult farther from the target. Any groups that move their catapult closer or further from the target should measure and record the distance on their worksheet.

15. After all groups have tested, students will check off the design criteria they achieved on their worksheet.

Reflection (5 min.)

1. Ask the students:
    a. Did your catapult start and end with the same total energy? How do you know? (*Yes, it follows the Law of Conservation of Energy. The elastic potential energy when the catapult was pulled back was transformed into kinetic mechanical energy as the cotton ball was launched into the air.*)
    b. Was your second design more successful than your first design? Why or why not?
    c. What did different groups' designs have in common? Did any of these commonalities seem to contribute to the success of the designs?
    d. How were different groups' designs unique? Did any of these differences seem to contribute to the success of the design?
    e. How would you improve your team's design if you had more time?

2. Have students record their thoughts in the Reflect portion of their worksheets.

Teacher Notes

The pictures below are examples of catapults that could be built from the provided materials. These are examples for the teacher only and should NOT be shown to students.

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Name ________________________

Catapult Challenge Student Worksheet

Imagine at least two solutions to the problem.

Plan: Draw the plan for your design below.

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Test 1

	Distance of catapult	Did it hit the target?
Trial 1		
Trial 2		
Trial 3		
Trial 4		

Was your catapult **accurate**? ☐ Yes ☐ No **Precise**? ☐ Yes ☐ No

Was your catapult successful from at least 10 feet away? ☐ Yes ☐ No

Improve: What will your team improve about your design? Why?

____

____

Test 2

	Distance of catapult	Did it hit the target?
Trial 1		
Trial 2		
Trial 3		
Trial 4		

Was your catapult **accurate**? ☐ Yes ☐ No **Precise**? ☐ Yes ☐ No

Was your catapult successful from at least 10 feet away? ☐ Yes ☐ No

Reflect: Was your improved design more successful? How do you know?

____

____

Did your catapult start and end with the same total energy? How do you know?

____

____

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Practice Activity 3: Energy Transformations

Prep: 10-15 min.

Activity: 45-60 min. (10-15 min. per station)

Science Topic: Energy Transformations

Learning Objectives: Students will...

- Explore the different energy forms.
- Identify examples of energy transformation.
- Cite evidence to support the Law of Conservation of Energy.

Vocabulary

- force
- gravity
- energy
- energy transfer
- work
- potential energy
- kinetic energy
- mechanical energy
- thermal energy
- chemical energy
- radiant energy

Overview

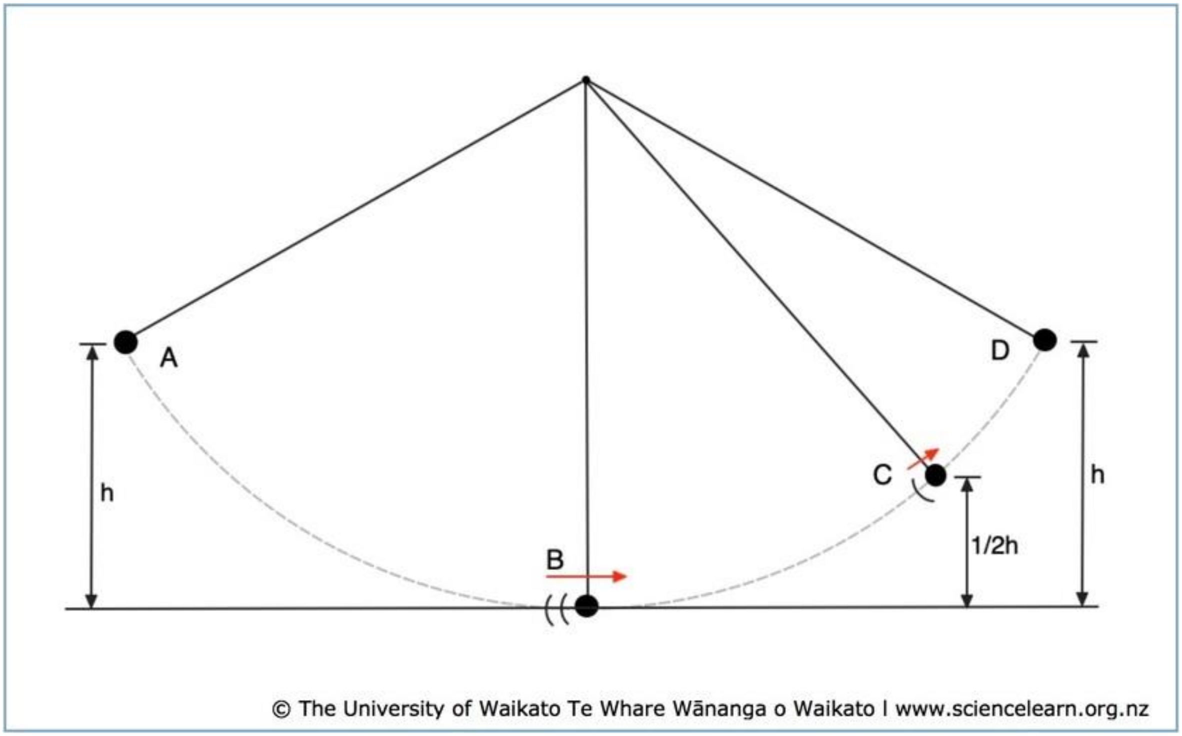
In this pre-activity, students participate in stations to explore different forms of energy and how they transform. Students will observe that energy changes forms but is never created or destroyed.

Background

Pendulum Transfers

A pendulum is a simple example of energy transfer. Beginning at position A (see diagram below), the pendulum fob is not moving. It has some energy because of its height (h) – called gravitational potential energy. When it is allowed to swing, that energy is gradually converted to energy of motion – kinetic energy. When the pendulum is at position B, all its potential energy has been converted to kinetic energy and it is moving at its maximum speed. When the pendulum reaches position C, it has regained half of its potential energy and lost half of its kinetic energy. It continues trading speed for height (kinetic to potential) until it reaches position D, at which point it not moving and has regained almost all its original potential energy.

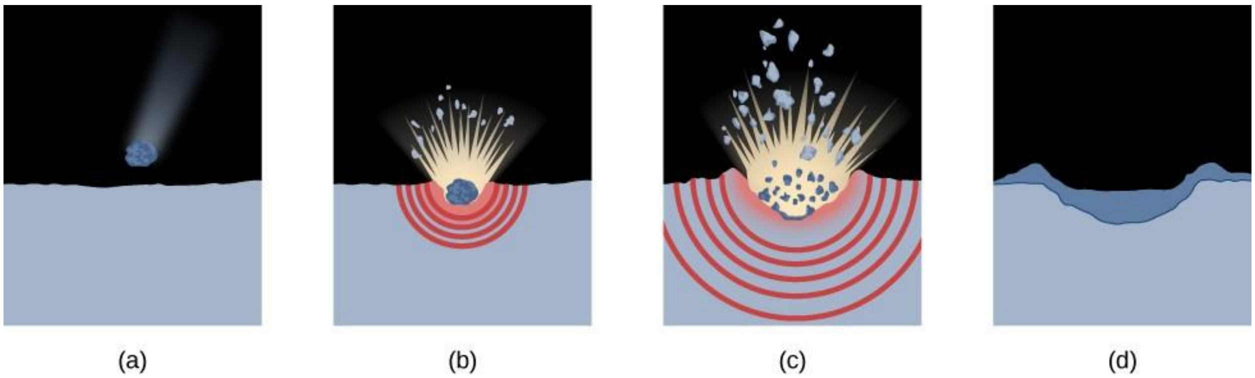
As the pendulum swings back and forth, air resistance (friction) will cause increasing amounts of kinetic energy to transform into thermal energy, until the pendulum eventually comes to a rest at position B.



Source: https://www.sciencelearn.org.nz/resources/2826-energy-transfer

Crater Creation

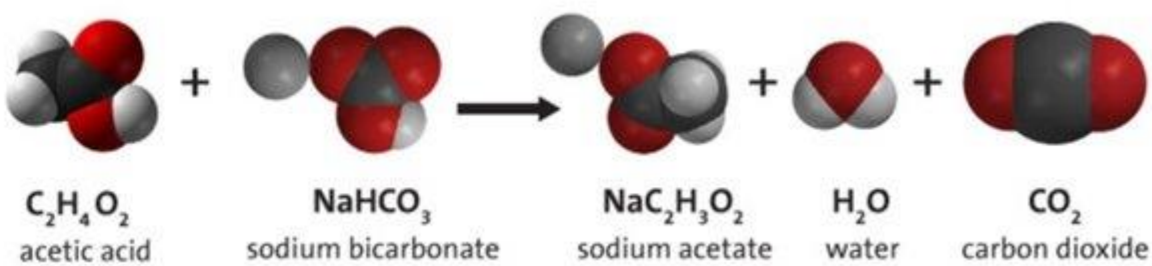
Earth, along with the other bodies of our solar system, contains many craters that have formed over its history through the impact of comets, asteroids, and other debris. An example is the 1.2-kilometer diameter Meteor Crater, created when an asteroid struck northern Arizona approximately 49,000 years ago. When an asteroid makes an impact, it travels at high speeds, carrying large amounts of kinetic energy. During impact, this kinetic energy is quickly transferred to the Earth's crust. This energy takes the form of heat, light, and sound energy, creating shock or pressure waves that fracture rock and shift it away from the point of impact. This results in an indentation in the Earth's crust called a crater. The larger the asteroid and the higher the speed, the more energy it contains, which results in a larger crater.



Source: https://courses.lumenlearning.com/suny-astronomy/chapter/impact-craters/

Carbon Dioxide Sandwich

When baking soda and vinegar are combined, a chemical reaction happens. The acetic acid in vinegar and the sodium bicarbonate in baking soda react to produce sodium acetate, water, and carbon dioxide. When this reaction happens, the bag expands because the carbon dioxide takes up a lot of space. Sometimes more gas is produced than can fit inside the bag, causing the seal on the bag to pop open.



Source: https://www.acs.org/middleschoolchemistry/lessonplans/chapter6/lesson7.html

The chemical reaction of baking soda and vinegar is an endothermic reaction. In an endothermic reaction, more energy is needed to break down the bonds in the reactants (in this case the baking soda and vinegar) than is released. This causes the overall temperature of the system to decrease. In an exothermic reaction, more energy is released than is needed to break chemical bonds, resulting in an increase in temperature. Mixing yeast and hydrogen peroxide is an example of an exothermic reaction.

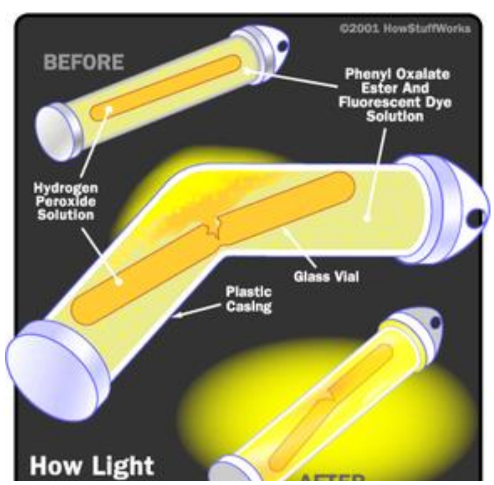
Glow Up!

Light is a form of energy, which can be emitted through a variety of processes. These processes include:

- **Incandescence -** The emission of light due to heat (as in an ordinary light bulb or a gas lantern)
- **Fluorescence and phosphorescence -** The emission of light in response to radiation energy (as in a fluorescent light bulb or a television)
- **Laser generation -** The concentrated emission of light using stimulated emission

All these processes work on the same basic principle: An outside source of energy excites atoms, causing them to release particles of light called **photons**. When you burn something, for example, heat energy causes the atoms that make up the material to speed up. When the atoms speed up, they collide with each other with greater force. If the atoms are excited enough, the collisions will transfer energy to some of the atom's electrons. When this happens, an electron will be temporarily boosted to a higher energy level (farther away from the atom's nucleus). When it eventually falls back down to its original level (closer to the nucleus), it releases some of its energy in the form of light photons.

A light stick does the same basic thing, but it uses a **chemical reaction** to excite the atoms in a material. The chemical reaction in a light stick usually involves several different steps. A typical commercial light stick holds a hydrogen peroxide solution and a solution containing a phenyl oxalate ester and a **fluorescent dye.** The light stick itself is just a housing for the two solutions involved in the reaction - essentially, it is portable chemistry experiment.



Source: https://science.howstuffworks.com/innovation/everyday-innovations/light-stick.htm

Stored energy is called potential energy. Glow sticks contain potential energy in the form of chemicals: fluorescent dyes and a chemical called hydrogen peroxide. No light can be released until the chemicals are mixed. When you mix the chemicals together by cracking the glow stick, they react to make new chemicals and release excess energy in the form of light, transforming chemical energy into light energy. How brightly the sticks glow depends on the temperature of their environment.

Adding heat to a chemical reaction makes it happen faster, so adding heat to a glow stick makes it produce more light energy for a short period of time. However, a colder glow stick will glow longer since it reacts and releases light energy more slowly.

Teaching Tips

- Set up all stations and materials before the class arrives (see Preparation section below).
- Place a copy of the directions at each station. For larger classes, duplicates of each station can be set up.
- Go over the introductory material and explain the different stations with students before beginning.
- Split students into groups of 3-4.
- Allow each group about 10-15 minutes at each station before rotating to the next one.
- After all groups have visited all stations, lead the class in a discussion to review their answers to the Reflection questions.

Materials

Materials marked with a star are consumable and will need to be replaced for each group.*

Station 1: Pendulum Transfer (Kinetic & Potential Energy)

- 1 Long piece of string (at least 1 meter long)
- 1 Heavy object or weight to tie onto string
- 1 Roll of masking tape
- 1 Meter stick
- 1 Pen or marker
- 1 Stopwatch
- 1 Calculator

Station 2: Crater Creation (Potential & Kinetic Mechanical Energy)

- 1 Marble
- 1 Container (shoebox size or larger)
- Sand to fill container (can use sand from outside, play sand, or craft sand)
- 1 Metric ruler
- 1 Meter stick

Station 3: Carbon Dioxide Sandwich (Chemical & Kinetic Mechanical Energy)

- 3 Sandwich-size Ziploc bags*
- 3 Quart-size Ziploc bags*
- 225 ml Vinegar (per group)*
- 1 Box (4 lbs.) baking soda
- 1 100 ml Graduated cylinder
- 1 Tablespoon measuring spoon
- 1 250 ml Beaker (larger sizes can be used if this size is not available)
- 4 Goggles (per group)
- 1 Plastic tray (cafeteria size or similar)

Station 4: Glow Up (Chemical, Thermal, & Light Energy)

- 3 Glowsticks (any size, same color)*
- 2 Beakers (250 ml or larger; can substitute with any other clear, glass container)
- Hot water*
- Ice*
- Tap water*
- Tongs
- Paper towels

For Each Student

- Energy Transformations worksheets
- Pencil

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Preparation

Station 1

1. You will need access to a table, counter, or other flat horizontal surface.
2. Tape one end of a piece of string about 2 inches from the edge of the table, so that the string hangs over the side.
3. Tie the weight to the other end of the string.

Station 2

1. Fill the container about ¾ full of sand.
2. Tip: have a small cup or container to hold the marble when it is not in use, so that it doesn't roll away.

Station 3

1. If possible, set up this station near a sink and/or paper towel dispenser. If not, place a roll of paper towels at this station to clean up any spills.
2. Label the sandwich bags "50 ml", "75 ml", and "100 ml", respectively.
3. Pour 225 ml vinegar into the 250 ml beaker.
4. Set materials on tray.

Station 4

1. Set up near a sink if possible. The water for this station will need to be replaced in between groups. If you do not have a sink in your classroom, fill a large pitcher of tap water and leave at this station.
2. You will need hot water for this station. If you do not have access to a sink, here are some alternatives:
    a. Store hot water in a thermos. Groups can take the water they need from the thermos and replace the lid, so it stays warm for other groups.
    b. Allow students to use an electric kettle to heat water for their group. If you are using this option, go over safety information before starting the station (avoid touching any metal parts of the kettle or placing hands above the spout as steam can burn).
3. Freeze or purchase ice the day before. Ice can be kept in a cooler at the station for easy student access.

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Introduction

1. Review with students what they have learned about force and motion. Ask:
   - **What is a force?** *(A force is a push or pull that may change the motion of an object.)*
   - **What is the force that pulls objects toward the surface of the earth?** *(gravity)*

2. Lead students in a discussion about energy. Ask:
   - **What is energy?** *(The capacity of an object to move)*
   - **What are some different forms of energy?** *(Answers will vary and could include sound vibrations, solar, potential, kinetic)*
   - **What is potential energy?** *(stored energy)*
   - **What is kinetic energy?** *(energy of motion)*

3. Explain to students that energy is never created or lost, it is simply converted into other forms of energy (Law of Conservation of Energy). Ask:
   - **What are some examples of energy changing forms?** *Answers will vary and could include:*
     - A car going down the hill on a roller coaster (potential energy to kinetic energy)
     - Using a solar panel (radiant and thermal energy to electrical energy)
     - Using batteries to run a flashlight (chemical energy to electrical energy to radiant energy)

4. Explain to students that they will be completing stations to explore energy transformations. In each station they will observe different types of energy and complete a reflection.

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Energy Transformations
Station 1: Pendulum Transfers

Question: How does energy change as a pendulum swings?

Procedure

1. Pull the string back about 30 cm. Mark this spot on the wall with a piece of masking tape.
2. Release the pendulum and count the number of oscillations (movements back and forth) in 1 minute. Record on your worksheet.
3. Repeat 2 more times.
4. Now pull the string back 50 cm and mark the spot on the wall with a piece of masking tape.
5. Release the pendulum and count the number of oscillations in 1 minute. Do this 3 times total and record the data on your worksheet.
6. Compare the average number of oscillations in both tests. Was the pendulum faster in the first or second test?
7. Remove any masking tape from the wall and dispose of it in the trash.

Reflect

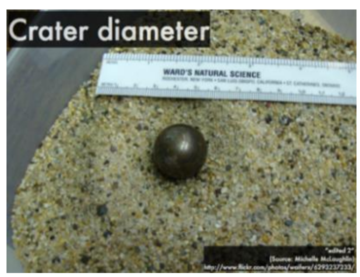
1. Why does the pendulum slow down as it swings back and forth? What is happening to the energy of the pendulum?
2. Was the total energy in the second pendulum test greater than, less than, or equal to the total energy in the first test? How do you know?

Energy Transformations
Station 2: Crater Creation

Question: How does height affect the mechanical energy of a falling object and the work it can exert?

Procedure

1. Drop the marble into the container from a height of 25 cm. Measure the height of the drop from the surface of the sand, not the tabletop.
2. Record the height of the drop in the data table on your worksheet.
3. Carefully remove the marble. Measure and record the diameter of the crater that the marble formed. Smooth the sand.



4. Repeat steps 2-4 dropping the marble from 50 cm, 75cm, and 100 cm. Record your results on your worksheet.

Reflect

1. How are the crater diameter and the height of the ball related?
2. How does the amount of potential energy affect the ball's kinetic mechanical energy?
3. How does the amount of kinetic mechanical energy relate to the work that the marble can do? How do you know?
4. What happened to the energy when you dropped the marble? How do you know?

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Energy Transformations

Station 3: Carbon Dioxide Sandwich

Question: What energy transformations take place during a chemical reaction?

Procedure

1. Put on goggles before beginning this station.
2. Measure out 50 ml vinegar in the graduated cylinder. Pour this into the sandwich bag labeled "50 ml".
3. Close the bag, KEEPING as much air in the bag as possible.
4. Repeat steps 2 & 3 for the "75 ml" and "100 ml" bags.
5. Measure 1 tablespoon of baking soda into each of the quart-size bags.
6. Place one bag of vinegar inside each bag of baking soda.
7. Close the quart-size Ziploc bags, REMOVING as much air as possible.
8. Place the sealed quart-size bags on the tray.
9. Pop the smaller, inside bag with the vinegar without popping the larger baking soda bag. This works best if there is a lot of air in the vinegar bag, and very little air in the baking soda bag.
10. Shake the bag to fully mix the ingredients.
11. Observe what happens to each of the bags.
12. Throw bags into the trash and wipe up any spills.
13. Wash your hands before you switch to the next station.

Reflect

1. What kind of reaction did you witness?
2. Which bag got the biggest? Why do you think this happened?
3. What do you think the results would be if you added warm vinegar instead of room temperature vinegar?
4. What energy transformation happened in this reaction?

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Energy Transformations
Station 4: Glow Up!

Question: How does adding thermal energy affect energy transformations?

Procedure

1. Fill one beaker with hot water. Be careful to avoid touching the beaker with your bare hands.
2. Add ice to the second beaker and fill it with cold water.
3. Snap the glowsticks and shake them. This releases the chemicals inside and starts the chemical reaction.
4. Place one glowstick in the beaker of hot water, one in the beaker of ice water, and leave the third glowstick on the table.
5. Set a timer for 3 minutes. Observe what happens to the glowsticks and record them on your worksheet.
6. After three minutes, use the tongs to remove the glowsticks from the water and place them side-by-side on the table with the third glowstick.
7. Dispose of glowsticks in the trash.
8. Use the tongs to carefully pour water down the drain. Remember to not touch the hot water beaker with your bare hands.

Reflect

1. What energy transformation took place when you cracked the glowstick?
2. Which glowstick was the brightest? Why do you think this happened?
3. Which glowstick was the dimmest? Why do you think this happened?

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Pendulum Transfers Student Worksheet

Observe

Test #1: 30 cm	Trial 1	Trial 2	Trial 3	Average
Number of oscillations				

Sketch the motion of the pendulum. Label where the pendulum had the maximum potential energy (PE) and and where it had the maximum kinetic energy (KE).

Test #2: 60 cm	Trial 1	Trial 2	Trial 3	Average
Number of oscillations				

Reflect: Why does the pendulum slow down as it swings back and forth? What is happening to the energy of the pendulum?

____

____

Was the total energy in the second pendulum test greater than, less than, or equal to the total energy in the first test? How do you know?

____

____

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Name ______________________

Crater Creation Student Worksheet

Observe

Drop Height (cm)	Crater Diameter (cm)
25	
50	
75	
100	

Reflect: How are crater diameter and the height of the ball related?

____

How does the amount of potential energy affect the ball's kinetic mechanical energy?

____

How does the amount of kinetic mechanical energy relate to the work that the marble can do? How do you know?

____

____

Where did the energy go when you dropped the marble? How do you know?

____

____

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Carbon Dioxide Sandwich Student Worksheet

Observe

50 ml vinegar	75 ml vinegar	100 ml vinegar

Reflect: What kind of reaction did you witness?

____

Which bag got the biggest? Why do you think this happened?

____

____

What do you think the results would be if you added warm vinegar instead of room temperature vinegar?

____

____

What energy transformation happened in this reaction?

____

____

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Name ______________________

Glow Up! Student Worksheet

Observe

Ice Water	Room Temperature	Hot Water

Reflect: What energy transformation took place when you cracked the glowstick?

____

____

Which glowstick was the brightest? Why do you think this happened?

____

____

Which glowstick was the dimmest? Why do you think this happened?

____

____