Lesson Focus

Lesson focuses on how pendulums have been used to measure time and how mechanical mechanism pendulum clocks operate. Students work in teams to develop a pendulum out of everyday objects that can reliably measure time and operate at two different speeds. They will determine the materials, the optimal length of swing or size of weight to adjust speed, and then develop their designs on paper. Next, they will build and test their mechanism, compare their results with other student teams, and share observations with their class.

Lesson Synopsis

The "Pendulum Time" lesson explores how the pendulum has been a reliable way to keep time for centuries. Students work in teams to build their own working clock using a pendulum out of every day materials. They will need to be able to speed up and slow down the motion of the pendulum clock. They sketch their plans, consider what materials they will need, build the clock, test it, reflect on the assignment, and present to their class.

Age Levels

8-18.

Objectives

- Learn about timekeeping and engineering.
- Learn about engineering design and redesign.
- Learn how engineering can help solve society's challenges.
- Learn about teamwork and problem solving.

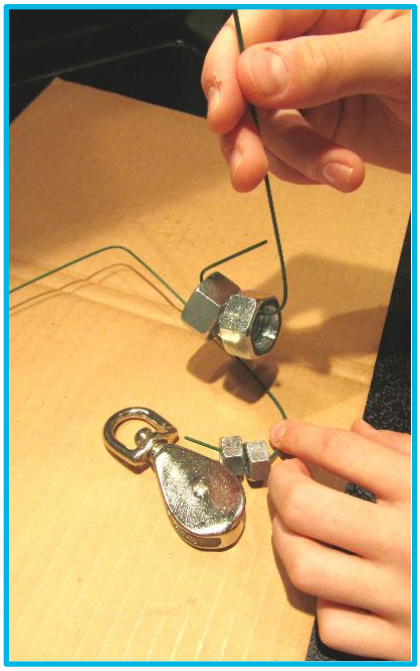
Anticipated Learner Outcomes

As a result of this activity, students should develop an understanding of:

- timekeeping
- engineering design
- teamwork

Lesson Activities

Students explore how the pendulum clock has proved to be a very accurate way of measuring time over the centuries. Students work in teams to build their own pendulum clock out of everyday items. They conduct research, determine and draw a design, gather parts, build the clock, test it, complete a reflection sheet, and share their experiences with the class.



Resources/Materials

- Teacher Resource Documents (attached)
- Student Resource Sheet (attached)
- Student Worksheet (attached)

Alignment to Curriculum Frameworks

See curriculum alignment sheet at end of lesson.

Internet Connections

- TryEngineering (www.tryengineering.org)
- A Walk Through Time (www.nist.gov/pml/time-and-frequency-division/popular-links/walk-through-time)

Recommended Reading

- Time's Pendulum: From Sundials to Atomic Clocks, the Fascinating History of Timekeeping and How Our Discoveries Changed the World (ISBN: 978-0156006491)
- The Pendulum: A Case Study in Physics (ISBN: 978-0199557684)
- Make Your Own Working Paper Clock (ISBN: 978-0060910662)

Optional Writing Activity

- Write an essay or a paragraph about whether you think a pendulum clock would work on the moon.

Optional Extension Activity

- Have students build a working metronome that can keep a beat at equal time intervals. Have students explore the concept of isochronism.

For Teachers: Teacher Resource

Lesson Goal

The "Pendulum Time" lesson focuses on how pendulums have been used to measure time and how mechanical mechanism pendulum clocks operate. Students work in teams to develop a pendulum out of everyday objects that can reliably measure time and operate at two different speeds. They will determine the materials, the optimal length of swing or size of weight to adjust speed, and then develop their designs on paper. Students build and test their mechanism, compare their results with others, and share observations.

Lesson Objectives

- Learn about timekeeping and engineering.
- Learn about engineering design and redesign.
- Learn how engineering can help solve society's challenges.
- Learn about teamwork and problem solving.

Materials

- Student Resource Sheets and Worksheets
- Student Team Materials: stopwatch or clock with a second hand, string, rubber balls, golf balls, pingpong balls --or ball or weight with knob in it, pencil, tape, foil, paper cups, paper clips, wire, plastic or paper plates, glue, pipecleaners, pvc piping, cardboard, paper, Velcro tape, or other materials. (Note: the weight could be fishing weight or another object with a knob on it or students will have to devise a way to have a attach the ball to the string such as holding it in a paper cup)

Procedure

1. Show students the student reference sheets. These may be read in class or provided as reading material for the prior night's homework.
2. To introduce the lesson, consider asking the students how important it is to have a way to accurately measure time. Ask them to observe all the different types of clocks and time measuring devices they have at school and at home.
3. Teams of 3-4 students will consider their challenge, conduct research into how pendulums operate.
4. Teams then consider available materials and develop a detailed drawing showing their pendulum clock including a list of materials they will need to build it.
5. Students build their clock, and test it, and also observe the clocks developed and tested by other student teams.
6. Teams reflect on the challenge, and present their experiences to the class.

Time Needed

Two to three 45 minute sessions.

Notes:

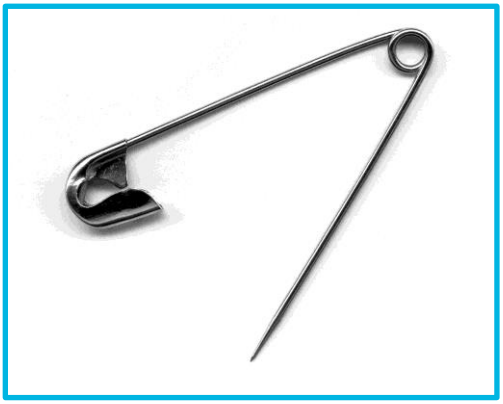
- For younger students, simplify the lesson by having the string/wire taped or tied to a chair frame, and just have them observe and record with a stopwatch the constancy of the pendulum motion.
- For older students, require a gear system or escapement, so the pendulum is a working part of a larger mechanism.

Student Resource: All About Patents

What is a Patent?

A patent for an invention is the grant of a property right to the inventor, issued by a country's Patent and Trademark Office. The procedure for granting patents, the requirements placed on the patentee, and the extent of the exclusive rights vary widely between countries according to national laws and international agreements. In the United States, the term of a new patent is 20 years from the date on which the application for the patent was filed or, in special cases, from the date an earlier related application was filed, subject to the payment of maintenance fees. *Utility patents* protect useful processes, machines, articles of manufacture, and compositions of matter. Some examples: fiber optics, computer hardware, medications. *Design patents* guard the unauthorized use of new, original, and ornamental designs for articles of manufacture. The look of a specific athletic shoe or a bicycle helmet are protected by design patents. *Plant patents* are the way we protect invented or discovered asexually reproduced plant varieties. Hybrid tea roses, Silver Queen corn, and Better Boy tomatoes are all types of plant patents.

Famous Patents



Safety Pin: The patent for the "safety pin" was issued on April 10, 1849 to Walter Hunt, of New York. Hunt's pin was made from one piece of wire, which was coiled into a spring at one end and a separate clasp and point at the other end, allowing the point of the wire to be forced by the spring into the clasp.

Dishwasher: A patent for the first practical dish washing machine was issued December 28, 1886 to Josephine Garis Cochran of Shelbyville, Illinois. She was wealthy, entertained often, and wanted a machine that could wash dishes quickly, and without breaking them. When she couldn't find one, she built it herself.

How to Register a Patent

Each country, or sometimes a region has its own patent procedures. For example, in Europe, there is the European Patent Office; in the United States, the U.S. Patent and Trademark Office manages the patent process. Wherever you are, you have to design your product on paper or on a computer and specifically show why your design is different from others. On the left is one of the first drawings of the Coca Cola bottle, and on the right, is a copy of the patent design. You also need to check to see if someone else has already invented what you think you did! Try searching for a trademark at www.uspto.gov/patents.

Student Worksheet: Build a Pendulum Clock

◆ Research and Planning

You are part of a team of engineers who have been given the challenge of building a working clock based on a pendulum. You'll need to be able to set the clock at two speeds, and will have to figure out how to adjust the materials you are using to make the clock run faster and slower. Yo u'll use every day items such as string attached to a rubber ball to serve as your pendulum. How you design your clock and what materials you use are up to you!

Read the handouts provided to you by your teacher, and if you also have access to the internet visit "A Walk Through Time" (www.nist.gov/pml/general/time to gain understanding of the history and operations of pendulum clocks:

◆ Parts of a Pendulum

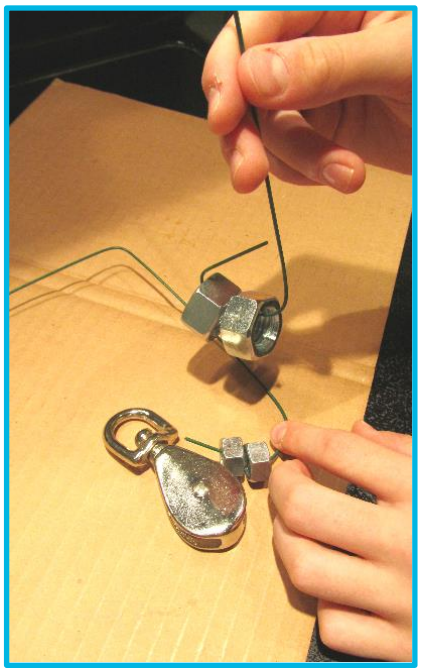
A pendulum is relatively simple, and consists of only a few components: a length of string or wire, a bob or some type of weight, and a fixed point where it is attached to a solid object. Remember that a string may swing in various directions, but for the clock, you'd want to fix it to something, or use another material to keep the motion along a single plane -- back and forth, not wobbling.

◆ Design Phase

You have been provided with many materials from which to design and build your own pendulum clock. Remember that your clock doesn't need to be perfect, but does need to be able to measure time fairly consistently. You can keep a chart or measurements of the "period of the pendulum" -- which is the amount of time that it takes a pendulum to complete one full back-and-forth swing. Consider which materials you would like to use, and list them in the box below. On a separate piece of paper, draw a diagram of the clock you intend to build.

Parts Required:

Student Worksheet: Build a Pendulum Clock



◆ **Measurement Phase**

Measure the length of string you plan to use to attach your weight to in order to form a pendulum. You'll need to keep track of this when you are adjusting the speed at which your pendulum moves. You may wish to weigh your pendulum weight as well to help you set your clock to work at two different speeds

◆ **Build it! Test it!**

Next build your clock and test it. You'll need to be able to record time with your clock and set up your own scale or chart to keep track of the pendulum movements. Use a stop watch to see how many swings of the pendulum occur in 10 seconds. You'll also need to speed up or slow down your clock. (Hint: adjusting the length of string attached to the pendulum might assist with this task.) You may share unused building materials with other teams -- and trade materials too. Be sure to see what other teams are doing and consider the aspects of different designs that might be an improvement on your plan.

◆ **Reflection**

1. How similar was your original design to the actual clock your team built?

2. If you found you needed to make changes during the construction phase, describe why your team decided to make revisions.

3. Was your clock able to measure time at two different speeds? What measurement scale did you devise to measure time with your clock?

4. Which clock that another team made was the most effective or interesting to you? Why?

5. Do you think that this activity was more rewarding to do as a team, or would you have preferred to work alone on it? Why?

6. If you could have used one additional material (tape, glue, wood sticks, foil -- as examples) which would you choose and why?

For Teachers: Alignment to Curriculum Frameworks

Note: Lesson plans in this series are aligned to one or more of the following sets of standards:

- U.S. Science Education Standards (http://www.nap.edu/catalog.php?record_id=4962)
- U.S. Next Generation Science Standards (http://www.nextgenscience.org/)
- International Technology Education Association's Standards for Technological Literacy (http://www.iteea.org/TAA/PDFs/xstnd.pdf)
- U.S. National Council of Teachers of Mathematics' Principles and Standards for School Mathematics (http://www.nctm.org/standards/content.aspx?id=16909)
- U.S. Common Core State Standards for Mathematics (http://www.corestandards.org/Math)
- Computer Science Teachers Association K-12 Computer Science Standards (http://csta.acm.org/Curriculum/sub/K12Standards.html)

◆National Science Education Standards Grades K-4 (ages 4-9)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- Abilities necessary to do scientific inquiry
- Understanding about scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of the activities, all students should develop an understanding of

- Properties of objects and materials
- Position and motion of objects

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- Abilities of technological design
- Understanding about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- Science and technology in local challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Science as a human endeavor

◆National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- Abilities necessary to do scientific inquiry
- Understandings about scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop an understanding of

- Properties and changes of properties in matter
- Motions and forces
- Transfer of energy

CONTENT STANDARD E: Science and Technology

As a result of activities in grades 5-8, all students should develop

- Abilities of technological design
- Understandings about science and technology

For Teachers: Alignment to Curriculum Frameworks

◆National Science Education Standards Grades 5-8 (ages 10-14)

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- Science and technology in society

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- History of science

◆National Science Education Standards Grades 9-12 (ages 14-18)

CONTENT STANDARD A: Science as Inquiry

As a result of activities, all students should develop

- Abilities necessary to do scientific inquiry

CONTENT STANDARD B: Physical Science

As a result of their activities, all students should develop understanding of

- Motions and forces
- Conservation of energy and increase in disorder
- Interactions of energy and matter

CONTENT STANDARD E: Science and Technology

As a result of activities, all students should develop

- Abilities of technological design
- Understandings about science and technology

CONTENT STANDARD F: Science in Personal and Social Perspectives

As a result of activities, all students should develop understanding of

- Personal and community health
- Science and technology in local, national, and global challenges

CONTENT STANDARD G: History and Nature of Science

As a result of activities, all students should develop understanding of

- Historical perspectives

◆Next Generation Science Standards Grades 2-5 (Ages 7-11)

Matter and its Interactions

Students who demonstrate understanding can:

- 2-PS1-2. Analyze data obtained from testing different materials to determine which materials have the properties that are best suited for an intended purpose.

Motion and Stability: Forces and Interactions

Students who demonstrate understanding can:

- 3-PS2-1. Plan and conduct an investigation to provide evidence of the effects of balanced and unbalanced forces on the motion of an object.

For Teachers: Alignment to Curriculum Frameworks

◆Next Generation Science Standards Grades 2-5 (Ages 7-11)

Engineering Design

Students who demonstrate understanding can:

- 3-5-ETS1-1.Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
- 3-5-ETS1-2.Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
- 3-5-ETS1-3.Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.

◆Next Generation Science Standards Grades 6-8 (Ages 11-14)

Engineering Design

Students who demonstrate understanding can:

- MS-ETS1-1 Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
- MS-ETS1-2 Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

◆Standards for Technological Literacy - All Ages

The Nature of Technology

- Standard 1: Students will develop an understanding of the characteristics and scope of technology.
- Standard 3: Students will develop an understanding of the relationships among technologies and the connections between technology and other fields of study.

Technology and Society

- Standard 4: Students will develop an understanding of the cultural, social, economic, and political effects of technology.
- Standard 6: Students will develop an understanding of the role of society in the development and use of technology.
- Standard 7: Students will develop an understanding of the influence of technology on history.

Design

- Standard 8: Students will develop an understanding of the attributes of design.
- Standard 9: Students will develop an understanding of engineering design.
- Standard 10: Students will develop an understanding of the role of troubleshooting, research and development, invention and innovation, and experimentation in problem solving.

For Teachers: Alignment to Curriculum Frameworks

◆Standards for Technological Literacy - All Ages
Abilities for a Technological World

- Standard 11: Students will develop abilities to apply the design process.
- Standard 12: Students will develop abilities to use and maintain technological products and systems.
- Standard 13: Students will develop abilities to assess the impact of products and systems.