National Aeronautics and Space Administration

NASA eClips™

Educator Guide

NASA'S REAL WORLD

POLYIMIDE FOAM

Educational Product	
Educators & Students	Grades 6-8

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EDUCATOR GUIDE

NASA eClips™

Polyimide Foam

NASA's REAL WORLD MATHEMATICS

Grade Level:
6-8

Subjects:
Physics, Physical Science

Teacher Preparation Time:
40 Minutes

Lesson Duration:
Two 55 minute class meetings.

National Standards:

National Science Education Standards (NSES)

Science as Inquiry

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

Physical Science

- Transfer of energy
- Properties and changes of properties of matter

Science and Technology Standards

- Abilities of technological design

National Council of Teachers of Mathematics (NCTM)

Measurement

- Understand measurable attributes of objects and the units, systems, and processes of measurement
- Apply appropriate techniques, tools and formulas to determine measurements.

Connections

- Recognize and apply mathematics in contexts outside mathematics

International Society for Technology in Education: National Educational Technology Standards (ISTE/NETS)

Communication and Collaboration

- Communicate information and ideas effectively to multiple audiences using a variety of media and formats

Digital Citizenship

- Exhibit a positive attitude toward using technology that supports collaboration, learning, and productivity

Technology Operations and Concepts

- Select and use applications effectively and productively

Essential Questions:

- What is sound?
- How can sound be changed?
- How is the advancement of science driving the advancement of technology?

Instructional Objectives:

Students will:

- deepen their understanding of sound and its properties;
- experiment to determine the most efficient sound insulators; and
- design the most effective and cost efficient combination of materials to suppress sound.

Lesson Overview:

Students are introduced to sound and the properties of polyimide foam. They investigate the sound insulating properties of different materials. Thinking and acting like engineers, students use the design process to find the most effective and cost efficient combination of materials to suppress sound. This lesson is developed using the 5E model of learning and uses NASA eClips™ video segments.

Icons flag five areas of interest or opportunities for teachers.

- **Technology Icon** highlights opportunities to use technology to enhance the lesson.
- **Modification Icon** denotes opportunities to differentiate the lesson.
- **Resources Icon** relates this lesson to other NASA educator resources that may supplement or extend the lesson.
- **Connections Icon** identifies opportunities to relate the lesson to historical references and other topics or disciplines.
- **Check for Understanding Icon** suggests quick, formative assessment opportunities.

Materials List:

ENGAGE

- metal slinky

EXPLORE

Per group of 2 or 3

- 10.5 cm cardboard tube, such as the tube used in a roll of bathroom tissue
- 9 cm x 9 cm square of one of the following insulators:

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  - o newspaper
  - o bubble wrap
  - o cotton quilt batting
  - o high density foam
- meter stick

Per class

- battery operated quartz movement clock with a second hand or other device that will produce a regular ticking sound (**NOTE**: do not use devices that produce a high-pitched electronic beeping noise such as a cooking timer or alarm clock). As an alternative, teachers can download the file "Tick Tock" located in the Technology Tools section of the Teacher Toolbox

http://www.nasa.gov/audience/foreducators/nasaeclips/toolbox/techtools.html

This file is a 5 minute loop of a metronome sound that can be played on a computer.

EXTEND

Per group of 2 or 3

- bubble wrap
- high density foam
- newspaper
- cotton quilt batting
- meter stick

5E Inquiry Lesson Development

ENGAGE (10 minutes)

1. Ask a student volunteer to hold one end of the metal slinky stationary on the demonstration table. Note: A plastic slinky will not work for this demonstration.

2. Stretch the slinky until the other end extends to the opposite side of the table. Give the slinky a few quick pushes from one end.

3. Ask students to describe what happens. *(It compresses and stretches as the energy transfers along the slinky.)*

4. Point out the compressions, places along the wave path where the slinky is pushed together, and rarefactions, places where the slinky is stretched out while this is demonstrated.

5. Discuss how the motion of the slinky compares to the motion of a sound wave.

6. (**TECHNOLOGY**) Show the NASA eClips™ video segment *Real World: NASA Inventions - Polyimide Foam* (5:02) to students. This segment can be found on the NASA eClips™ page of the NASA web site:
   http://www.nasa.gov/audience/foreducators/nasaeclips/search.html?terms="polyimide%20 foam"&category=0000
   The video may be streamed or downloaded from the nasa.gov web site; a captioned version is also available at the nasa.gov site.
   (**MODIFICATION**) This video may be streamed from the NASA eClips You Tube™ channel:
   http://www.youtube.com/watch?v=i4kCAP4sQU8&feature=PlayList&p=887C1C3BAAD53F17 &index=6

EXPLORE (15 minutes)

Sound is a form of energy that is produced and transmitted by vibrating objects. When an object makes a sound, the vibrations alternately squeeze air molecules together, a process called compression, and spread them apart, a process called rarefaction. The cycle of compression and rarefaction creates a sound wave. A wave created in this manner is called a longitudinal, or compression, wave. A longitudinal wave can travel through many substances, not just air. The substance a sound is traveling through is called a medium. Sound travels the fastest through a solid medium because the molecules are packed close together and slowest through a gas medium because the molecules are spread further apart.

To visualize how sound is produced think about a vibrating violin string. The string, when plucked, forces the air around the string to bounce back and forth. This disturbance in the molecules travels through the air from particle to particle, carrying energy as it moves.

The loudness of a sound depends on the difference between the density of the medium during compressions and rarefactions and the normal density of the medium. This difference is the height, or amplitude, of the wave. As shown in Figure 1, the larger the amplitude the higher the wave and the more energy is contained in the wave. Sound intensity is the amount of energy transported through a given area of a particular medium per unit of time. Intensity is

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measured in decibels. A loud sound has more energy than a quiet sound and has a higher decibel rating.

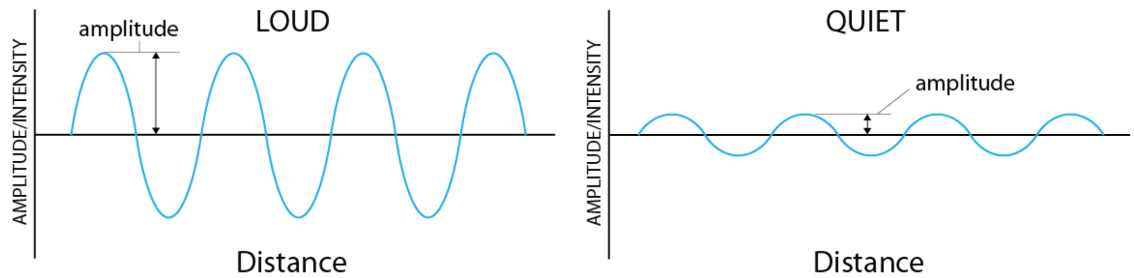

Figure 1. Loud and quiet sound waves.

The decibel scale is based on multiples of 10. The faintest sound a human can hear is the low threshold of human hearing. The loudest sound causes pain and damage to the ear. This corresponds to the highest threshold of human hearing. Table 1 lists the decibel ratings of some common sounds.

Table 1. Decibel Ratings of Common Sounds

Source	Decibel Rating (dB)
Falling leaves	0-10
Whisper	10-20
Soft music	20-30
Normal voices	50-70
Traffic sounds	70-80
Vacuum cleaner	80-90
Chain saw	110-120
Pain threshold *(jet take off)*	130-140
Perforation of ear drum *(gun fired 5-10 cm from ear)*	160 and higher

As a sound wave moves through a substance, the energy of the wave diminishes as the distance traveled increases. This happens because the energy of the wave is being distributed over a greater area of the medium. Materials that are used for soundproofing or sound suppression are materials that absorb this energy. Some substances that are effective in absorbing sounds have holes or open cells that trap the sound.

Procedure

1. Before class begins, find an open area to conduct the activity.

2. Organize students into groups of 2 or 3. Each group will be testing one insulating material. There should be enough groups so that there are at least two different groups testing the same material.

3. Distribute the materials for the activity. Tell students that the 9 cm x 9 cm square of material they are using will be referred to as one unit of material during this lesson.

4. Place the battery-operated, quartz-movement clock in the center of the room.

5. Review the directions in the Student Guide. Emphasize to students the importance of having the same person listen for the ticking sound.

6. Arrange the teams of students around the clock to collect data.

7. **(TECHNOLOGY)** If available, use a data collection device to collect quantitative data on sound intensity.

EXPLAIN (30 minutes)

1. Lead a class discussion to determine how to evaluate the relative sound insulating ability of the four materials. Use the following questions to guide the discussion:

   a. Identify the controls and variables in this experiment. *(The control is the uninsulated tube. The independent variable is the presence or absence of any of various types and configurations of insulating material. The dependent variable is the distance until the sound can't be heard.)*

   b. Identify the constants in this experiment. *(The constants include: same person listening, same clock used, etc.)*

   c. There were two parts to the data collection process: listening for sound and measuring distance from the sound producing object. What is the difference between these types of data? *(Descriptions of sound are qualitative data. Measuring the distance from the sound producing object is quantitative data. The distance can be measured in specified units, allowing data sets from different groups to be compared. Qualitative data is more difficult to compare between groups because descriptions such as "loud" or "quiet" are somewhat subjective.)*

d. What quantitative data from the experiment can you use to compare sound insulation? *(Students should compare the distances traveled when using the uninsulated tube and the insulated tube.)*

e. Why is quantitative data used? *(It's easier to present quantitative data in tables and graphs and then make comparisons and generalizations. Student descriptions of sounds may vary widely. Note: Sounds can be heard at varying distances depending on student hearing acuity. Not all students hear quiet/low intensity sounds.)*

f. What other information might be considered when judging the sound insulating ability of the different materials? *(The configuration of the materials should also be considered. For example, was the material stuffed in the tube, rolled up and put in the tube, or used to cover the tube opening?)*

2. Ask students to post their results on the board. In their groups, challenge students to rank the materials from worst sound insulator to best sound insulator. Students should record their rankings in Table 2 on page 4 of the Student Guide and should explain their ranking system.

3. Ask groups to present their results and explanations.

4. (**CONNECTIONS**) Ask the school nurse to talk to the class about hearing, hearing tests, and differences in individual ability to hear different sound frequencies.

EXTEND (45 minutes)

1. Challenge students to create a composite sound insulator from the materials they investigated in the EXPLORE section. Review the design process with your students using the Middle School and High School Design Process Packet. This packet can be downloaded at:

http://www.nasa.gov/audience/foreducators/nasaeclips/toolbox/howto.html

a. Students should be given the following constraints in designing the composite:

i. Construct the best insulator for $10. Assign costs to the materials as follows:
- 1 unit of bubble wrap - $2
- 1 unit of high density foam - $4

- 1 unit of newspaper - $1
- 1 unit cotton quilt batting - $4
- 1 cardboard tube - $3

  Note: 1 unit of a material is 9 cm X 9 cm square

Allow students to request other materials. These additional materials should also be assigned a unit cost.

ii. An entire unit of material does not need to be used in the final product however partial units cannot be purchased.

b. Students should agree as a class on the procedure to measure the sound insulating ability of their design.

c. **(TECHNOLOGY)** Ask the students to document the design and building process using digital images.

d. **(TECHNOLOGY)** Ask the students to create a multimedia presentation of their project.

2. Challenge students to design and perform a hearing test.

EVALUATE (10 minutes)

1. Use questions, discussions, and work in the Student Guide to assess students' understanding.

2. Ask students to summarize their learning by answering these journal questions:

a. What is sound?
(Sound is a form of energy that can be transmitted through many different materials by the vibration of molecules within the material.)

b. What is sound volume?
(Sound volume is a measure of the amount of energy contained in sound. The louder the sound the more energy it contains.)

c. Why is it important to regulate or control sound volumes?
(High intensity sounds can damage a person's physical and mental health, sounds can interfere with other activities (noise pollution), etc.)

d. What characteristics make a material a good sound insulator? Support your answer with information collected during the EXPLORE and EXPLAIN activities.
(Answers will vary but should include the concept that "dead air" or air pockets that are trapped within a solid structure are better insulators.)

e. How is the advancement of science driving the advancement of technology?
(As scientists discover new materials and the properties of these new materials, engineers can use these materials to come up with better solutions to problems such as sound insulation.)

Self Healing Materials

Essential Questions

- *What is sound?*
- *How can sound be changed?*
- *How is the advancement of science driving the advancement of technology?*

Background

NASA engineers are constantly developing new materials to build safe, lightweight space vehicles. Polyimide foam is a new insulating material developed by engineers Erik Weiser, Robert Cano, and Brian Jensen at NASA Langley Research Center.

Figure 1. From left to right: Erik Weiser, Roberto Cano and Brian Jensen with samples of polyimide foam.
Credit: NASA

Polyimide foam is a lightweight material that can be formed into a variety of shapes. The foam was originally developed as a thermal insulator for reusable launch vehicles. The engineers worked to keep the density and weight of the material low while improving temperature and sound insulation qualities. They also improved its flame resistance.

The foam can insulate in temperatures as low as -240°C (-400°F) and as high as 204°C (400°F). Its resistance to fire makes this foam even more promising for other applications. NASA engineers believe that polyimide foam insulation could

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help contain and slow the spread of flames. The U.S. Navy and Coast Guard are interested in using the foam as interior insulation on ships. Right now, the cost of polyimide foam is too high to use as home insulation. However the cost is expected to go down as more polyimide foam is produced.

Resources

Article: *Langley Engineers Win NASA Commercial Invention of the Year*

http://www.nasa.gov/centers/langley/news/researchernews/rn_polyimidefoam.html

Video: *Real World: NASA Inventions - Polyimide Foam (5:02)*

http://www.nasa.gov/audience/foreducators/nasaeclips/realworld/playlist.html

Vocabulary

amplitude - Amplitude is a measure of the height of a sound wave which determines the sound's volume.

compression - Compression is the process of molecules being pressed closer together.

compression wave - A compression wave is a wave that is propagated by the compression of molecules in a substance.

decibel - The decibel (dB) is a unit of sound intensity.

density – Density is a measure of how closely packed together a substance is.

insulator - An insulator is a material or substance that does not conduct heat, sound, or electricity easily.

intensity – Sound intensity is the amount of energy transferred by a sound wave per unit time.

longitudinal wave – A longitudinal wave is a wave whose particles vibrate parallel to the direction the wave is traveling.

rarefaction – Rarefaction is the process of molecules becoming more spread out (as opposed to compression).

sound - Sound is a form of energy produced and transmitted by vibrating objects.

sound wave - A sound wave is a series of compressions and rarefactions traveling through a substance.

EXPLORE

1. Obtain the following materials:
   - 10.5 cm cardboard tube
   - 9 cm x 9 cm square of one of the following insulators:
     - o newspaper
     - o bubble wrap
     - o cotton quilt batting
     - o high density foam
   - meter stick

2. Record your insulator material in Table 1.

3. Use the 9 cm x 9 cm piece of sound insulating material to insulate the tube.

4. Use the following protocol to collect data on the sound insulating ability of the material:

   a. Select one person in your group to be the “listener.”

   b. For each trial, the listener will:
      i. hold the tube up to one ear and cover the other ear with a hand.

      ii. stand one meter away from the clock.

      iii. stand sideways so the tube is pointed at the clock. See Figure 2.

   c. To gather data, the listener:

      i. starts to move away from the clock, keeping the tube pointed at the clock (see Figure 3);

      ii. continues to move away from the clock until the ticking can no longer be heard.

   d. Once the listener has stopped moving, the other group members measure the distance traveled by the listener and record the measurement in Table 1.

   e. If available, use a data collection device to collect quantitative data on sound intensity and record in a new table of your own design.

5. Repeat steps 3 and 4 using the same material and listener each time. Try configuring the material in different ways to increase the sound insulating ability of the material. Record the distances and sketch the best insulating configuration.

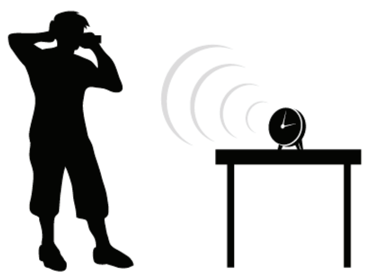

Figure 2. Initial position of listener.

Figure 3. Movement of listener away from the sound source.

Table 1. Distance from Clock

Insulator assigned:

Experimental condition	Distance moved (m) until no sound heard
No sound insulation	
With sound insulation	

EXPLAIN

Table 2. Ranking of Sound Insulation Ability of Various Materials

1 (worst insulator)	2	3	4 (best insulator)

1. In the space below, make sketches of the best insulating configuration.

2. Explain your ranking system below.

ANSWER KEY

EXPLORE

Table 1. Distance from Clock

(Answers will vary depending on the actual type and thickness of the materials used, the sound source used, and the level of background noise)

Insulator assigned: Cotton quilt batting

Experimental condition	Distance moved (m) until no sound heard
No sound insulation	3
With sound insulation	1

EXPLAIN

Table 2. Ranking of Sound Insulation Ability of Various Materials

(Answers may vary depending on the actual type and thickness of the materials used)

1 (worst insulator)	2	3	4 (best insulator)
newspaper	bubble wrap	cotton quilt batting	high density foam

1. In the space below, make sketches of the best insulating configuration.

Sketches will vary depending on the class results.

2. Explain your ranking system below.

Answers will vary but students should justify their answers based on the class data for distance moved. The best insulator would correspond to the shortest distance until the sound is no longer heard. The worst insulator would correspond to the longest distance.