Summary
The following activities engage students in exploring the transfer energy by mechanical and electromagnetic waves. Students will gain an understanding of the various factors that influence the energy of a wave through wave simulations, wave diagrams, and scientific investigation.

CLEAR LEARNING TARGETS
“**I can**” statements

- Demonstrate that vibrations cause wave-like disturbances that transfer energy from one place to another.
- Differentiate between transverse and longitudinal waves
- Describe waves by their speed, wavelength, amplitude, and frequency.
- Demonstrate and explain how the wave speed is dependent upon frequency and wavelength which is directly related to the materials through which the wave travels.
- Explain that the pitch of a sound wave increases with the frequency and the loudness increases with the amplitude.

Activity Highlights and Suggested Timeframe

| Days 1-2 | **Engagement:** The objective of this activity is to engage students and formatively assess student knowledge related to energy transfer by waves through an engaging set of demonstrations. |
| Days 3-6 | **Exploration:** The objective of the following activities is to give students the opportunity to work with and begin to experience and develop a basic understanding of waves. Students will be doing a kinesthetic activity in which they will act as a wave as well as model waves using slinkys. |
| Days 7-8 | **Explanation:** The objective of the following activities is to give students the opportunity to compare various types of waves (seismic, electromagnetic, ocean, and sound) and explain what they have learned about waves. |
| Day 9 | **Elaboration:** The objective of the following activity is to give students the opportunity to gain deeper understanding of waves through music. An optional Engineering Design Challenge can challenge students to take this lesson to the next level. |
| Day 10 and on-going | **Evaluation:** Formative and summative assessments are used to focus on and assess student knowledge and growth to gain evidence of student learning or progress throughout the unit, and to become aware of students misconceptions related to energy transfer through waves. A teacher-created short cycle assessment will be administered at the end of the unit to assess all clear learning targets. |
| Day 11 | **Extension/Intervention:** Based on the results of the short-cycle assessment, facilitate extension and/or intervention activities. |
LESSON PLANS

NEW LEARNING STANDARDS:
7.PS.3 Energy can be transferred through a variety of ways.

- Vibrations cause wave-like disturbances that transfer energy from one place to another. Mechanical waves require a material (medium) in which to travel. The medium moves temporarily as the energy passes through it, but returns to its original undisturbed position. Mechanical waves are classified as transverse or longitudinal (compression) depending on the direction of movement of the medium.

- Waves can be described by their speed, wavelength, amplitude and frequency. The energy of a mechanical wave depends upon the material, decreases with increasing wavelength, and increases with amplitude. The pitch of a sound wave increases with the frequency and the loudness increases with amplitude. While light and other electromagnetic waves do not require a medium and can travel through a vacuum, they can travel through some media, such as clear glass. A wave travels at a constant speed through a particular material as long as it is uniform (e.g., for water waves, having the same depth). The speed of the wave depends on the nature of the material (e.g., waves travel faster through solids than gases). For a particular uniform medium, as the frequency (f) of the wave is increased, the wavelength (\( \lambda \)) of the wave is decreased. The mathematical representation is \( v_{wave} = \lambda \cdot f \).

SCIENTIFIC INQUIRY and APPLICATION PRACTICES:
During the years of grades K-12, all students must use the following scientific inquiry and application practices with appropriate laboratory safety techniques to construct their knowledge and understanding in all science content areas:

- Asking questions (for science) and defining problems (for engineering) that guide scientific investigations
- Developing descriptions, models, explanations and predictions.
- Planning and carrying out investigations
- Constructing explanations (for science) and designing solutions (for engineering) that conclude scientific investigations
- Using appropriate mathematics, tools, and techniques to gather data/information, and analyze and interpret data
- Engaging in argument from evidence
- Obtaining, evaluating, and communicating scientific procedures and explanations

*These practices are a combination of ODE Science Inquiry and Application and Frame-work for K-12 Science Education Scientific and Engineering Practices

COMMON CORE STATE STANDARDS for LITERACY in SCIENCE:
CCSS.ELA-Literacy.RST.6-8.3 Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.
CCSS.ELA-Literacy.RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
CCSS.ELA-Literacy.RST.6-8.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6–8 texts and topics.
CCSS.ELA-Literacy.RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic.

*For more information: http://www.corestandards.org/assets/CCSSI_ELA%20Standards.pdf
### STUDENT KNOWLEDGE:

**Prior Concepts Related to Energy Transfer**

PreK-2: Temperature changes are observed. The sun is the principal source of energy. It affects the temperature of Earth (ESS) and supplies life’s energy (LS).

Grades 3-5: Objects with energy have the ability to cause change. Electrical, heat, light and sound energy are explored. Earth’s resources can be used for energy (ESS). Energy is transferred and transformed by organisms in ecosystems (LS).

Grade 6: Energy is identified as kinetic or potential and can transform from one form to another (gravitational, potential, kinetic, electric, magnetic, heat, light, sound). Density depends on the mass and volume of a substance. Thermal energy is related to the motion of particles.

**Future Application of Concepts**

Grade 8: Gravitational, chemical and elastic potential energy and seismic waves (ESS) are explored.

High School: Energy and work are explored mathematically.

### MATERIALS:

**Engage**

- Waves, Waves, Waves Demo
- Dancing Salt
  - Two ten inch coffee cans/bowls
  - Plastic Wrap
  - Large Rubber bands
  - Construction Paper
  - Salt
  - Spoon
  - Coat Hanger Chimes/Wire Hangers
  - Yarn
  - Scissors
  - Sturdy Table

**Tuning Fork Lab**

- Tuning Forks with various pitches
- Rubber Stopper or rubber mallet
- Plastic Container
- Water
- Sturdy Table

**Rubber Band Guitar**

- Cardboard box-shoebox
- Styrofoam
- Variety of Rubber Bands
- Paper Towel Cardboard Tube
- Scissors
- Tape

**Making Music With Water Glasses**

- 5 or more drinking glasses or glass bottles
- Water
- Wooden stick such as a pencil

**I Can See the Light**

- Various Sized Flashlight
- Water
- Construction Paper
- Glass Container
- Various Sized Objects (Cans)

### VOCABULARY:

**Primary**

- Amplitude
- Electromagnetic Waves
- Force
- Frequency
- Longitudinal
- Mechanical Energy
- Medium
- Pitch
- Transverse
- Vibrations
- Wave Speed
- Wavelength
- Waves

**Secondary**

- Absorb
- Reflection
- Refraction
<table>
<thead>
<tr>
<th><strong>The Waves Exercise</strong></th>
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</thead>
</table>
| • Computer Access  
• SMARTboard  
• Handouts  
• Large Open Space |  |

<table>
<thead>
<tr>
<th><strong>Making Waves</strong></th>
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</table>
| • Slinkys  
• Meter Stick  
• Handouts |  |

<table>
<thead>
<tr>
<th><strong>Explain</strong></th>
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<tbody>
<tr>
<td><strong>Ride the Waves Handout</strong></td>
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<thead>
<tr>
<th><strong>Soap in the Microwave</strong></th>
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</table>
| • Microwave  
• Bar of Ivory Soap  
• Paper Plate and/or Shallow  
• Microwavable Shallow Container |  |

<table>
<thead>
<tr>
<th><strong>Elaborate</strong></th>
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<tbody>
<tr>
<td><strong>Mystery of Music</strong></td>
<td></td>
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</table>
| • Various Musical Instruments  
• Handout |  |

<table>
<thead>
<tr>
<th><strong>Design Challenge</strong></th>
<th></th>
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</table>
| • Various Materials  
• Design Challenge Handout |  |

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<thead>
<tr>
<th><strong>SAFETY</strong></th>
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</table>
| • All lab safety rules, procedures, and precautions should be taken into consideration  
• Caution: soap in the microwave will be hot when removed. |  |

<table>
<thead>
<tr>
<th><strong>ADVANCED PREPARATION</strong></th>
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<tbody>
<tr>
<td>• Gather all needed supplies and materials for demonstrations/activities/investigations.</td>
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<table>
<thead>
<tr>
<th><strong>ENGAGE</strong> (2 days)</th>
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<tbody>
<tr>
<td><strong>What is the teacher doing?</strong></td>
<td><strong>What are the students doing?</strong></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Waves, Waves, Waves Demonstrations</strong> (Days 1-2)</th>
<th><strong>Waves, Waves, Waves Demonstrations</strong> (Days 1-2)</th>
</tr>
</thead>
</table>
| • Use various Teacher Background Information Pages for activity instructions and set-up.  
• Explain to students that they will be doing a series of demonstrations to learn about waves.  
• Set up different demos throughout the classroom prior to lesson.  
• Discuss lab safety procedures.  
• Facilitate as groups move from | 1. Students will follow all CCS Lab Safety Guidelines.  
2. Students will work at each demo station to experience different ways waves are exhibited.  
3. Students will complete Waves, Waves, Waves questions at each station. |
**Objective:** The objective of the following activities is to give students the opportunity to work with and begin to experience and develop a basic understanding of waves. Students will be doing a kinesthetic activity in which they will act as a wave as well as model waves using slinkys.

<table>
<thead>
<tr>
<th>What is the teacher doing?</th>
<th>What are the students doing?</th>
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<tbody>
<tr>
<td><strong>The Wave Exercise</strong></td>
<td><strong>The Wave Exercise</strong></td>
</tr>
<tr>
<td><em>(Days 3-4)</em></td>
<td><em>(Days 3-4)</em></td>
</tr>
<tr>
<td>- Teacher will review concepts learned from the demonstration activities.</td>
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</tr>
<tr>
<td>- Explain that they will be learning about waves.</td>
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<tr>
<td>- Facilitate activity using Teacher Background Page for activity instructions and set-up.</td>
<td></td>
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<tr>
<td>- Allow students time to complete The Wave Exercise Vocabulary either using teacher led information or information from CPO Physical Science Textbook.</td>
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</tr>
<tr>
<td><strong>Making Waves</strong></td>
<td><strong>Making Waves</strong></td>
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<tr>
<td><em>(Day 5)</em></td>
<td><em>(Day 5)</em></td>
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<tr>
<td>- Teacher will review and go over waves vocabulary.</td>
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<tr>
<td>- Teacher will introduce Making Waves Activity.</td>
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<tr>
<td>- Assist students in completing activity.</td>
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<tr>
<td>- Review and go over concepts upon completion of the activity.</td>
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</tbody>
</table>

**EXPLORE** *(4 days)*

(How will the concept be developed? How is this relevant to students' lives? What can be done at this point to identify and address misconceptions?)

**Making Waves** *(Day 5)*

1. Students use slinkys to explore and explain the differences between transverse and longitudinal waves.
2. Students will follow all CCS Lab Safety Guidelines.
3. Students will complete Making Waves Lab Activity Sheet.

**UnitedStreaming-Elements of Physics: Waves, Sounds & Electromagnetism [20:00] (Day 6)**

1. Students will be actively engaged in watching movie and taking notes on the Cornell Notes Template.
2. Students will participate in reviewing important waves concepts and terms.
**Objective:** The objective of the following activities is to give students the opportunity to compare various types of waves (seismic, electromagnetic, ocean, and sound) and explain what they have learned about waves.

**EXPLAIN**

(2 days)

(What products could the students develop and share? How will students share what they have learned? What can be done at this point to identify and address misconceptions?)

<table>
<thead>
<tr>
<th>What is the teacher doing?</th>
<th>What are the students doing?</th>
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</thead>
<tbody>
<tr>
<td><strong>Ride the Waves (Days 7-8)</strong></td>
<td><strong>Ride the Waves (Day 7-8)</strong></td>
</tr>
</tbody>
</table>
| - Pass out the Ride the Waves Student WS  
  - [www.unitedstreaming.com](http://www.unitedstreaming.com)  
  - Show the video clip: Types of Waves [1:15]  
  - Facilitate students through the Student WS.  
  - Seismic Waves:  
    - Project the Seismic Waves Simulation:  
      - [http://sunshine.chpc.utah.edu/labs/seismic/seismic.swf](http://sunshine.chpc.utah.edu/labs/seismic/seismic.swf)  
      - Click on a house to observe how the seismic waves travel through the earth.  
      - Facilitate students through the Student WS.  
  - Article reading:  
    - Students use the 3-2-1 strategy to read the Science News for Kids article: Quake, quake, go away by Stephen Ornes. See attached.  
      - [http://www.sciencenewsforkids.org/2013/03/quake-quake-go-away/](http://www.sciencenewsforkids.org/2013/03/quake-quake-go-away/)  
    - Soap in the Microwave Demo and Electromagnetic Waves:  
      - Facilitate the soap in the microwave demo using ivory soap...  
      - [http://www.youtube.com/watch?v=7lAO0wMN0dA](http://www.youtube.com/watch?v=7lAO0wMN0dA)  
      - See Teacher Page  
  | 1. Watch Videoclip: Types of Waves [1:15] and complete section of the student WS. |
|   | 2. As a class, students observe the Seismic Waves simulation and complete section of the student WS. |
|   | 3. Students use the 3-2-1 strategy for reading the article: Quake, quake, go away and complete the section of the student WS. |
|   | 4. Soap in the Microwave Demo and Electromagnetic Waves:  
    - Students predict what will happen when a bar of ivory soap is placed in the microwave and observe. Complete section of the student WS. |
<p>|   | 5. Students analyze the electromagnetic spectrum diagram and complete section of the student WS. |</p>
<table>
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<tr>
<td>1. Ocean Waves: Facilitate as students complete the WS.</td>
<td>6. Students use a ruler to measure the waves in order to determine the wavelength and amplitude.</td>
</tr>
<tr>
<td>2. <strong>Sound Waves</strong>: Facilitate as students complete the WS.</td>
<td>7. Students use their knowledge of transverse wave properties in order to diagram and answer questions about sound (compressional) waves.</td>
</tr>
</tbody>
</table>

**Objective:** The objective of the following activity is to give students the opportunity to gain deeper understanding of waves through music.

**What is the teacher doing?**

**The Mystery of Music**

**(Day 9)**

- Work with the music teacher to access various musical instruments. (i.e. guitar, brass, woodwind, piano, drums, etc.)
- Consider having students bring in their own instruments and present how they are played and make sound.
- Facilitate as students to explore how sound waves are produced and travel through the instrument.
- See teacher Answer Key

**What are the students doing?**

**The Mystery of Music**

**(Day 9)**

1. Students explore various musical instruments.
2. Students identify the following:
   - The source of the sound (how the vibrations are created) through transfer of mechanical energy.
   - Medium(s) through which the sound travels
   - How wavelength and amplitude can be changed and how it affects the sound (i.e. pitch and loudness)
3. Students who bring their own instruments can explain how they are played.

**Optional Engineering Design Challenge: Music Miracle**

**(Days 10-12)**

- See provided Teacher Background Information

**Optional HW or RICA article:**

### EVALUATE

*(on-going)*

*(What opportunities will students have to express their thinking? When will students reflect on what they have learned? How will you measure learning as it occurs? What evidence of student learning will you be looking for and/or collecting?)*

### Objective:
The objective of the assessments is to focus on and assess student knowledge and growth to gain evidence of student learning or progress throughout the unit, and to become aware of students misconceptions related to energy transfer through waves.

<table>
<thead>
<tr>
<th>Formative</th>
<th>Summative</th>
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</thead>
<tbody>
<tr>
<td><strong>How will you measure learning as it occurs?</strong></td>
<td><strong>What evidence of learning will demonstrate to you that a student has met the learning objectives?</strong></td>
</tr>
<tr>
<td>- Consider developing a teacher-created formative assessment.</td>
<td>1. Waves of Music activity will assess students' ability to identify the creation and source of wave, the medium in which a wave travels, and how changing the properties of waves can change the pitch and loudness of sound.</td>
</tr>
<tr>
<td>1. <strong>Waves, Waves, Waves Demos</strong> will assess students prior knowledge of various sound waves, mediums through which waves travel, and vibrations, as they relate to changes in frequency and wavelength.</td>
<td>2. Optional Engineering Design Challenge of a musical instrument using the design cycle will assess students' ability to apply all knowledge of waves to create a working musical instrument.</td>
</tr>
<tr>
<td>2. <strong>The Wave Exercise</strong> will assess students' progression of knowledge related to wave properties.</td>
<td>3. Teacher-created short cycle assessment will assess all clear learning targets.</td>
</tr>
<tr>
<td>3. <strong>Ride the Waves</strong> activities will assess student knowledge related to various types of waves and their properties.</td>
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</tbody>
</table>

### EXTENSION

#### (1 day or as needed)

<table>
<thead>
<tr>
<th>EXTENSION</th>
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</thead>
<tbody>
<tr>
<td>1. Electromagnetic Waves Research Project – students research a topic of their choice related to electromagnetic waves and devices (i.e. cell phones, radio, x-rays, chemotherapy, microwaves, ghost-hunting devices, etc.)</td>
</tr>
<tr>
<td>2. CPO Laboratory Investigation 9B: Waves</td>
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</tbody>
</table>

### INTERVENTION

<table>
<thead>
<tr>
<th>INTERVENTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. <a href="http://www.unitedstreaming.com">www.unitedstreaming.com</a> related videos</td>
</tr>
<tr>
<td>2. Consider using the book <em>Light and Sound</em> by Barbara Sandall and Laverne Logan for additional activities on Light and Sound.</td>
</tr>
</tbody>
</table>

### COMMON MISCONCEPTIONS

- Hitting an object harder changes the pitch of the sound produced.
- Human voice sounds are produced by a large number of vocal cords that all produce different sounds.
- Loudness and pitch of sounds are the same things.
- You can see and hear a distinct event at the same moment.
- Sounds can travel through empty space (a vacuum).
- Sounds cannot travel through liquids and solids.
- Sound waves are transverse waves (like water and light waves).
- Matter moves along with water waves as the waves move through a body of water.
When waves interact with a solid surface, the waves are destroyed. In actual telephones, sounds (rather than electrical impulses) are carried through the wires. Light is not considered to exist independently in space. Light is not conceived as moving from one point to another with a finite speed. An object is seen whenever light shines on it, with no recognition that light must move between the object and the observer’s eye. Light is not necessarily conserved. It may disappear or be intensified. Gamma rays, X-rays, ultraviolet light, visible light, infrared light, microwaves and radio waves are all very different entities. Light fills the room as water fills a bathtub. The mechanisms between the light, the object and the eye are not recognized to produce vision.

Strategies to address misconceptions:
Misconceptions can be addressed through the use of Unitedstreaming video clips, pictures/diagrams, simulations, as well as through the use of models.

DIFFERENTIATION

Lower-level: Provide additional text resources (tradebooks, articles) that are appropriate for the reading level of the students. Consider having students watch videos or websites for more insight.

Higher-Level: Consider having students assist other classmates having difficulties.

Strategies for meeting the needs of all learners including gifted students, English Language Learners (ELL) and students with disabilities can be found at the following sites:
ELL Learners:
Gifted Learners:
Students with Disabilities:

ADDITIONAL RESOURCES

List any additional resources teachers using the lesson might find helpful. Include a very brief description of the resource.

Textbook Resources:
CPO Physical Science Textbook
• Chapter 9.2: Waves pp. 225-231
• Chapter 9.3: Sound pp. 232-242
• Chapter 10.1: Light pp. 250-252
CPO Physical Science Laboratory Investigations
• Lab 9B: Waves

Glencoe Physical Science w/ Earth Science
• Chapter 10.1: The Nature of Waves pp.288-293
• Chapter 10.2: Wave Properties pp.294-299
• Chapter 10.3: The Behavior of Waves pp.301-309

Go to http://www.glencoe.com/ose/ and type in the following code to be able to access the Student Edition-B5FA9588B5
Websites:
- Longitudinal Waves and Tuning Forks- http://www.physicsclassroom.com/mmedia/waves/tfl.cfm
  - Use the free samples for various Waves Animations & Tutorials

Discovery Ed:
- Waves: Energy in Motion (23:08)
- Heat Transfer [2:18]
- Elements of Physics: Waves, Sounds & Electromagnetism (20:00)

Literature:
- Walker, Sally, Investigating Light, 2011.

Movies/Videos and other media:
- Bill Nye: Waves- YouTube- (23:03)- https://www.youtube.com/results?search_query=bill+nye+waves&oq=bill+nye+waves&gs_l=youtube.3..0l2.130639.133662.0.133738.18.12.2.4.4.0.168.854.11j1.12.0...0...1ac.1.11.youtube.PiikZ7R3v_E
- Music Everywhere Glass & Water- YouTube (1:21) - https://www.youtube.com/watch?v=Fwspiu1yLQ
- Longitudinal and Transverse Waves-BSB Year 1—YouTube- (0:41) http://www.youtube.com/watch?v=mOjlRnnmRk-w
- Just Like and Echo Song-Mr. Parr- YouTube- (3:36) http://www.youtube.com/watch?v=mqX2f_yrHCQ
- Light Song-Mr. Parr-YouTube (3:15) http://www.youtube.com/watch?v=LyHEHEch8gg
Whenver something vibrates it is creating sound. The sound travels in the form of a wave through a medium. The medium is anything that has molecules touching each other. If there is no medium, there is no sound. In the following demonstration students will be able to see the sound waves as they cause the salt to dance on the plastic wrap. They will also hear the tapping as the sound wave reaches their eardrums. Sound waves travel through air and cause plastic wrap to wiggle.

**Materials:**
1.) Coffee can and or bowl/container
2.) Plastic food wrap to cover one can
3.) Large rubber band
4.) Salt
5.) Construction Paper
6.) Spoon

**Procedures:**
1.) Stretch the plastic wrap over the top of one can #1. Pull it tightly so it is smooth like a drum. Use the rubber band to help hold it in place. (You can seal the plastic wrap to a glass container in place of the can and rubber band.)
2.) Sprinkle salt on the plastic wrap.
3.) With opened end down of can #2, hold can #2 about 3" above can #1. (The closed end is now up.)
4.) Roll the piece of paper to form a megaphone. Have students talk or yell into the megaphone. Students should not being blowing into the megaphone.
5.) While you are holding can #2, tap the closed end with a spoon, like you would a drum.

**Extensions:**
Move the can you tapped to different angles and record what happens. Will the salt dance using objects that do not focus the sound as the can does? Have students design an experiment that creates an echo (Sound waves bouncing back to the same point).
**Dancing Salts Activity**

Whenever something vibrates it is creating sound. The sound travels in the form of a wave through a medium. The medium is anything that has molecules touching each other. If there is no medium, there is no sound. In the following demonstration you will be able to see the sound waves as they cause the salt to dance on the plastic wrap. You will also hear the tapping as the sound wave reaches your eardrums. Sound waves travel through air and cause plastic wrap to wiggle.

**Materials:**
1.) Coffee can and or bowl/container
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**Extensions:**
Move the can you tapped to different angles and record what happens. Will the salt dance using objects that do not focus the sound as the can does? Design an experiment that creates an echo (Sound waves bouncing back to the same point).
COAT HANGER CHIMES TEACHER BACKGROUND INFORMATION

Learners will - using nothing more than a coat hanger and some string - explore and understand sound energy and how it moves.

Materials:
Plastic and Wire Hangers
Yarn
Scissors
Sturdy Table

Picture from: http://www.wired.com/images_blogs/photos/64/hangerchromethree.jpg

Procedures:
1. Students will Select a hanger and strike it against the table. They will observe the sound it makes.
2. What can students do to hear the VIBRATION better?
3. Have students wrap the ends of the string around each of their index (pointer) fingers two times. Make sure there is still a lot of string between their fingers and the hangers.
4. Students will put the tips of their index fingers in their ears.
5. Have students bend forward and allow the coat hanger to strike against the table, (like an elephant swinging its trunk.) What do they hear?
6. Ask: Why is the sound louder when you have your fingers in your ears?

What's Going On?
To have a sound, you must have something that vibrates. The first time students struck the hanger against the table, what was the MEDIUM that the VIBRATION traveled through? A medium can be anything that a sound wave travels through. Only a VACUUM (an area where there are no molecules) can not be a medium.

Sound
Ask: What was the medium that the sound wave traveled through when you had your fingers in your ears?

Sound travels more quickly through a denser medium. Air, which is a gas, is not very dense. Not all of the vibrations will reach students ears. When the students put their fingers in their ears, the vibration is traveling through the string and the bones in their fingers directly to their ears. A lot more vibrations reach your ears more quickly.

Have students try all of the different hangers on the table. Ask: Will they all sound the same? Can you pick out one that won't vibrate much at all? Will the hangers sound different if you strike them against the floor? Have students explore!!
COAT HANGER CHIMES ACTIVITY

Objective: Using nothing more than a coat hanger and some string you will explore and understand sound energy and how it moves.

Materials:
Plastic and Wire Hangers
Yarn
Scissors
Sturdy Table

Procedures:
1. You will select a hanger and strike it against the table. Observe the sound it makes.

2. What can you do to hear the VIBRATION better?

3. Wrap the ends of the string around each of your index (pointer) fingers two times. Make sure there is still a lot of string between your fingers and the hangers. The picture to the left will help you.

4. Put the tips of your index fingers into your ears.

5. Bend forward and allow the coat hanger to strike against the table, (like an elephant swinging its trunk.)

6. What do you hear?

7. Why is the sound louder when you have your fingers in your ears?

What's Going On?
To have a sound, you must have something that vibrates. The first time you struck the hanger against the table, what was the MEDIUM that the VIBRATION traveled through? A medium can be anything that a sound wave travels through. Only a VACUUM (an area where there are no molecules) can not be a medium.

Sound
What was the medium that the sound wave traveled through when you had your fingers in your ears?

Will they all sound the same?

Can you pick out one that won’t vibrate much at all?

Will the hangers sound different if you strike them against the floor?
TUNING FORKS LAB  TEACHER BACKGROUND INFORMATION

Objective: The objective of the activity is for students to compare the sounds produced by tuning forks. Students will observe the behavior of sound waves and how they differ in different mediums.

Materials:
Various Pitched Tuning Forks (C, G, E, C if possible)
Thick Block of Wood
Glass or Plastic Container
Water

Procedure:
1.) Have students look at each tuning fork. Near the handle, the frequency (Hz) and tone (letter) of each is written. Record the frequencies for each tuning fork next to its tone.

2.) Allow students to take a tuning fork and hit it on a rubber stopper, if a rubber mallet or rubber stopper is not available they may use the rubber sole of their shoe.

3.) After you hit the tuning fork, bring it near your ear. You will need to listen carefully to the sound produced. Repeat until you have heard all four forks. Make sure that you do not hit the forks on any other surfaces.

4.) Have students rank the sounds from highest to lowest. They will need to Record their rankings in the “Sound” column.

5.) Students will then place the handle of the vibrating tuning fork on the thick block of wood. They will hold their ear close to the block and listen to the wood. They will repeat for all four tuning forks. Students will record their observations (the difference between the sound through the air and through a solid below).

6.) Students will then lightly place one tine of a vibrating tuning fork, upside down, into the cup of water. They will record the behavior of the water.
**TUNING FORKS LAB ACTIVITY**

**Objective:** The objective of the activity is to compare the sounds produced by tuning forks. You will observe the behavior of sound waves and how they differ in different mediums.

**Materials:**
Various Pitched Tuning Forks (C, G, E, C if possible)
Glass or Plastic Container
Water

**Procedure:**
1. Look at each tuning fork. Near the handle, the frequency (Hz) and tone (letter) of each is written.

2. Take a tuning fork and hit it on a rubber stopper, if a rubber mallet or rubber stopper is not available you may use the rubber sole of your shoe.

3. After you hit the tuning fork, bring it near your ear. You will need to listen carefully to the sound produced. Repeat until you have heard all four tuning forks. Make sure that you do not hit the forks on any other surfaces.

4. Next, rank the sounds from highest pitch to lowest pitch. You will need to record the rankings in the “Sound” column.

5. Place the end of the vibrating tuning fork handle on the thick block of wood. Hold your ear close to the block and listen to the wood. You will repeat for all four tuning forks. Record your observations (the difference between the sound through the air and through a solid below).

6. Lightly place one tine of a vibrating tuning fork, upside down, into the cup of water. Observe and record the behavior of the water.
RUBBER BAND GUITAR TEACHER BACKGROUND INFORMATION

Adapted from:
http://www.nyphilkids.org/lab/make_rubberguitar.html

Objective: The purpose of this activity is to create a simple musical instrument to illustrate waves.

Materials:
A shoebox or tissue box
Various sized rubber bands
A pen or a pencil
Scissors

Photo from: http://www.allkidsnetwork.com/crafts/music/images/tissue-box-guitar.jpg

Procedures:
1. First, stretch a rubber band, pull it and then let it go. It should vibrate quite visibly. Notice, however, how quiet it is. That is because the only thing vibrating is that little piece of rubber.

2. Cut a hole in one of the sides of the box and insert the cardboard tube.

3. Take the rubber band and stretch it around the box so that it passes over the open top of the box.

4. Pluck the rubber band and you should hear the sound much louder, especially with a corrugated cardboard box or Styrofoam box. You should be able to feel the box vibrating when the string vibrates.

5. Put more rubber bands on the box.

6. Be careful to not wrap too many rubber bands around the box or it may collapse and or break.

7. When putting on the different sized rubber bands, note a difference sound.

8. **Consider creating a rubber band guitar that has the rubber bands running the length of the opening.

9. To tune your rubber band box guitar, you can make the strings tighter or looser across the open top. Take the rubber band at the side of the box and stretch it out and down to make it tighter. When you put it back against the box, the rubber will have enough "grab" to hold on the tuning for a while. Experiment with the other rubber bands to find a tuning you like.
**RUBBER BAND GUITAR ACTIVITY**
Adapted from: http://www.nyphilkids.org/lab/make_rubberguitar.html

**Objective:** The purpose of this activity is to create a simple musical instrument to illustrate waves.

**Materials:**
- A shoebox
- Various sized rubber bands
- A pen or a pencil
- Scissors

**Procedures:**
1. First, stretch a rubber band, pull it and then let it go. It should vibrate quite visibly. Notice, however, how quiet it is. That is because the only thing vibrating is that little piece of rubber.

2. Cut a hole in one of the sides of the box and insert the cardboard tube.

3. Take the rubber band and stretch it around the box so that it passes over the open top of the box.

4. Pluck the rubber band and you should hear the sound much louder, especially with a corrugated cardboard box or Styrofoam box. You should be able to feel the box vibrating when the string vibrates.

5. Put more rubber bands on the box.

6. Be careful to not wrap too many rubber bands around the box or it may collapse and or break.

7. When putting on the different sized rubber bands, note a difference sound.

8. **Consider creating a rubber band guitar that has the rubber bands running the length of the opening.**

9. To tune your rubber band box guitar, you can make the strings tighter or looser across the open top. Take the rubber band at the side of the box and stretch it out and down to make it tighter. When you put it back against the box, the rubber will have enough "grab" to hold on the tuning for a while. Experiment with the other rubber bands to find a tuning you like.
MAKING MUSIC WITH GLASS  TEACHER BACKGROUND INFORMATION

Objective: Students will be creating a water glass xylophone to examine differences in waves.

Materials:
Eight Identical Water Glasses/Mason Jars
Water
A set of Measuring Cups
Food Coloring (if available)
Plastic Spoon
Sheet of Paper/Post-It Notes
Tape

Procedures:
1.) Using the measuring cups fill each glass/mason jar with the following amounts of water:
   - Cup 1- 14 ounces or 14/8 cups
   - Cup 2- 12 ounces or 12/8 cups
   - Cup 3- 10 ounces or 10/8 cups
   - Cup 4- 8 ounces or 1 cup
   - Cup 5- 6 ounces or 3/4 cup
   - Cup 6- 4 ounces or 1/2 cup
   - Cup 7- 2 ounces or 1/4 cup
   - Cup 8- Empty
2.) Optional---add food coloring into each filled glass/jar to make different colors.
3.) Starting with the glass with the most water and working down to glass with the least amount of water, label the containers from 1-8 using paper/Post-It Notes, etc.
4.) Keep the glasses in order from the most to least water.
5.) Using a plastic spoon, have students gently tap each glass and listen to the sound that is created.
6.) Ask students which glasses produced a lower sound? A higher sound?
   Why each glass makes a different sound- When you tap one of the glasses, the spoon creates a sound wave that travels through the water inside. The pitch of the sound (high or low) depends on the rate of the sound wave’s vibration. Lower-pitched sounds come from slower vibrations, while higher pitched sounds come from faster vibrations. The more water a glass contains, the slower the sound the waves’ vibrations.
7.) Once students feel comfortable, have them tap the glasses to play familiar tunes:
   - This Old Man (1st verse)
   - Happy Birthday
8.) As an extension activity, have students create their own song.
MAKING MUSIC WITH GLASS

Objective: Create a water glass xylophone to examine differences in waves.

Materials:
Eight Identical Water Glasses/Mason Jars
Water
A set of Measuring Cups
Food Coloring (if available)
Plastic Spoon
Sheet of Paper/Post-It Notes
Tape

Procedures:
1. Using the measuring cups fill each glass/mason jar with the following amounts of water:
   - Cup 1 - 14 ounces or 14/8 cups
   - Cup 2 - 12 ounces or 12/8 cups
   - Cup 3 - 10 ounces or 10/8 cups
   - Cup 4 - 8 ounces or 1 cup
   - Cup 5 - 6 ounces or ¾ cup
   - Cup 6 - 4 ounces or ½ cup
   - Cup 7 - 2 ounces or ¼ cup
   - Cup 8 - Empty
2. Optional---add food coloring into each filled glass/jar to make different colors.
3. Starting with the glass with the most water and working down to glass with the least amount of water, label the containers from 1-8 using paper/Post-It Notes, etc.
4. Keep the glasses in order from the most to least water.
5. Using a plastic spoon, gently tap each glass and listen to the sound that is created.
6. Which glasses produced a lower sound? A higher sound?
7. Once you feel comfortable, tap the glasses to play familiar tunes:
   - This Old Man (1st verse)
   - Happy Birthday
8. Create your own song.
I CAN SEE THE LIGHT TEACHER BACKGROUND INFORMATION

Introduction: How does light travel? What happens when light hits or moves through different objects? Today, we will learn about light waves and see how they travel. Light moves in waves, which can bounce off of or go through materials.

Materials:
- Various Sized Flashlights
- Water
- Construction Paper
- Glass Container
- Various Solid Objects

Procedures:
1. Have students shine a flashlight beam through their hands. They can see that flesh and bone will not allow light to pass through. Their hand turns pink—evidence that light is bouncing off. This bouncing of light off a surface is called reflection.

2. Shine the flashlight beam through the large glass container. Hold dark paper at the outside end of container to see evidence that light is coming through the container. Have students look down into the water and see the reflection in it. Experiment with different sizes of beams and flashlights and document what you see.

3. Put a can or other object in the middle of the tank. Shine the flashlight through container and observe what happens when beam passes through water and hits the object. **Do light waves pass through the object or bounce (reflect) off of it?**

4. Next, place dark sheets of paper along the sides and end of the container. Focus a beam on the far end of the container and observe how light shining in at one end hits mostly, but not entirely, on the other end. Refraction causes some light waves to bend and pass through the walls.

5. Shine light through air in container. Observe that light has no reflection or refraction because the medium is just “air,” so there is no material to reflect or refract the beams.

6. Ask students: **How can light from the sun travel all the way from the sun to Earth?**
**I CAN SEE THE LIGHT**

**Introduction:** How does light travel? What happens when light hits or moves through different objects? Today, we will learn about light waves and see how they travel. Light moves in waves, which can bounce off of or go through materials.

**Materials:**
- Various Sized Flashlights
- Water
- Construction Paper
- Glass Container
- Various Solid Objects

**Procedures & Questions:**

1. Shine a flashlight beam through your hands. You can see that flesh and bone will not allow light to pass through. **What is occurring?**

2. Shine the flashlight beam through the large glass container. Hold dark paper at the outside end of container to see evidence that light is coming through the container. Look down into the water and see the reflection in it. Experiment with different sizes of beams and flashlights and document what you see.

3. Put a can or other object in the middle of the tank. Shine the flashlight through container and observe what happens when the beam passes through water and hits the object. **Do light waves pass through the object or bounce (reflect) off of it?**

4. Next, place dark sheets of paper along the sides and end of the container. Focus a beam on the far end of the container and observe how light shining in at one end hits mostly, but not entirely, on the other end.

5. Shine light through the air in the container. Observe that light has no reflection or refraction because the medium is just “air,” so there is no material to reflect or refract the beams.

6. **How can light from the sun travel all the way from the sun to Earth?**
## WAVES, WAVES, WAVES DEMO ACTIVITY

<table>
<thead>
<tr>
<th><strong>Dancing Salts</strong></th>
<th>1.) What is causing the salt to move?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Coat Hanger Chimes</strong></td>
<td>2.) How does the sound travel to your ear when you clang it against the table?</td>
</tr>
<tr>
<td></td>
<td>3.) Describe any difference in sound between the two coat hangers. Why do you think this occurred?</td>
</tr>
<tr>
<td><strong>Tuning Fork</strong></td>
<td>4.) How does the sound differ when using different sized tuning forks?</td>
</tr>
<tr>
<td></td>
<td>5.) Explain why the sound is different when the hitting the different sized tuning forks?</td>
</tr>
<tr>
<td><strong>Rubber Bands Guitar</strong></td>
<td>6.) What you notice about the rubber bands after they have been plucked?</td>
</tr>
<tr>
<td></td>
<td>7.) How does the sound differ when you change the arrangement of the rubber bands on the box?</td>
</tr>
<tr>
<td><strong>Making Music with Glass</strong></td>
<td>8.) Describe how the amount of water affects the pitch of the sound?</td>
</tr>
<tr>
<td></td>
<td>9.) If you were to change the container holding the water, what do you think would happen to the sound produced?</td>
</tr>
<tr>
<td><strong>I Can See the Light</strong></td>
<td>10.) Why do some light waves pass through objects and other times do not?</td>
</tr>
<tr>
<td></td>
<td>11.) How can light from the sun travel all the way from the Sun to the Earth?</td>
</tr>
</tbody>
</table>
### WAVES, WAVES, WAVES DEMO ACTIVITY

<table>
<thead>
<tr>
<th>Activity</th>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dancing Salts</td>
<td>1.) What is causing the salt to move?</td>
<td>The salt is moving based on the vibrations caused by the yelling into the megaphone.</td>
</tr>
<tr>
<td>Coat Hanger Chimes</td>
<td>2.) How does the sound travel to your ear when you clang it against the table?</td>
<td>The waves are traveling through string and bones in each student's fingers and into their ears.</td>
</tr>
<tr>
<td></td>
<td>3.) Describe any difference in sound between the two coat hangers. Why do you think this occurred?</td>
<td>Answers will vary based on the hanger material.</td>
</tr>
<tr>
<td>Tuning Fork</td>
<td>4.) How does the sound differ when using different sized tuning forks?</td>
<td>The pitch is higher on the smaller tuning fork because there is less material for vibration and the vibration will be faster.</td>
</tr>
<tr>
<td></td>
<td>5.) Explain why the sound is different when the hitting the different sized tuning forks?</td>
<td>The sounds are different because there is more or less medium that will be vibrating.</td>
</tr>
<tr>
<td>Rubber Bands Guitar</td>
<td>6.) What you notice about the rubber bands after they have been plucked?</td>
<td>They will move back and forth creating a sound.</td>
</tr>
<tr>
<td></td>
<td>7.) How does the sound differ when you change the arrangement of the rubber bands on the box?</td>
<td>Answers will vary, but generally pitch should go up. The vibrations are affected by the decrease in wavelength.</td>
</tr>
<tr>
<td>Making Music with Glass</td>
<td>8.) Describe how the amount of water affects the pitch of the sound?</td>
<td>The container that has less water will have a lower pitch because the glass will larger/longer wavelength. The container with more water will have a higher pitch.</td>
</tr>
<tr>
<td></td>
<td>9.) If you were to change the container holding the water, what do you think would happen to the sound produced?</td>
<td>Answers will vary.</td>
</tr>
<tr>
<td>I Can See the Light</td>
<td>10.) Why do some light waves pass through objects and other times do not?</td>
<td>It is based on the medium, sometimes light is reflected, absorbed and or allows all light through.</td>
</tr>
<tr>
<td></td>
<td>11.) How can light from the sun travel all the way from the Sun to the Earth?</td>
<td>There is no medium in space. Space is a vacuum.</td>
</tr>
</tbody>
</table>
Objective: This activity is designed to create a physical, kinesthetic lesson for wave theory. In it, the students themselves model the wave. It may be best done outside depending on your students. If so, you may want to use a megaphone or amplifier.

Review your instructions with the students before working on this group activity. Below are instructions as if you were actually talking to the students:

1. Together, we will do “The Wave”.
2. Everybody line up shoulder to shoulder.
3. You can move only when the person on your left moves, etc.
4. Show the students a clip of a “Wave” from an Ohio State football game- http://www.youtube.com/watch?v=seokjJ8D2P8
5. Practice the wave a few times.

Talk about the definition of a wave: the students (up and down) move in place, but the energy moves down the line.

**Students will be using the CPO Physical Science Textbook pp. 225-228 to help complete The Wave Exercise: Vocabulary.

Amplitude
1.) First we will move just our hands a few inches up and down.
2.) Then only are arms up and down.
3.) Then are whole bodies up and down.

What’s changing? The height of the wave (measured from the centerline) is called amplitude.
4.) Do a small amplitude wave.
5.) Do a large amplitude wave.
6.) Ask students to compare and contrast the crests and the troughs of a wave.

** Have students complete the vocabulary using the teacher provided information as well as information from the text.

Wave Speed
Now we will do something a little different. We will vary the speed of the wave.
1.) Do slow speed.
2.) Do medium speed.
3.) Do fast speed.
** Have students complete the vocabulary using the teacher provided information as well as information from the text.

Discuss how waves move at different speeds through different kinds of matter.
**Frequency**
1.) First explain that the students have been modeling pulses – a single disturbance. Many waves come from a continuous disturbance moving back and forth – a vibration.
2.) Get one volunteer with a timer, a calculator and possibly a camera. Have him/her stand in front of the middle of the line.
3.) Now we will do the wave one after another for 15 seconds. (This is super cool when the students get in sync.)
4.) The timer person counts how many waves go by in 15 seconds.
5.) Do another continuous wave and have the volunteer try to estimate the wavelength. A photo or video would work well here. What would be the unit for this exercise? (People).

**Transverse & Longitudinal Waves**
Notice, these have all been transverse waves. Everyone’s motion is up and down, but the waves move sideways. How could we model a (longitudinal) wave?

**Comparing Mediums**- Line students up next to each other. In this exercise, students are modeling molecules, which are connected, in varying degrees, to students on either side.

- a. Arms are unhooked. Students are modeling a liquid. Have students notice that it will take longer for the wave to travel down the line.

- b. Have students hook their arms at the elbows to the persons on either side in the line. Now they are modeling a solid. Explain that because the molecules are closer together, the wave travels faster.
## THE WAVE EXERCISE: VOCABULARY

<table>
<thead>
<tr>
<th>Word</th>
<th>Definition</th>
<th>Illustrated example – draw a picture that represents the definition.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wave p.225</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amplitude p.226</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crest p.226</td>
<td></td>
<td></td>
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<tr>
<td>Trough p.226</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wave Speed p.227</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency p.226</td>
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<td></td>
</tr>
<tr>
<td>Wavelength p.226</td>
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<tr>
<td>Transverse Wave p.228</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longitudinal Wave p.228</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
1. WAVE DIAGRAM – Use CPO Textbook page 226
   Include the following: crest, trough, amplitude, wavelength.

   ![Wave Diagram](image)

2. Identify the mediums for the following waves:
   - The Wave Exercise waves: ______________________________
   - Ripples on a pond: ________________________________
   - Sound waves from a stereo speaker: ______________________
   - Seismic (earthquake) waves: _______________________

3. Explain why we see the light from fireworks, before we hear the “boom”.
   _____________________________________________________________________________
   _____________________________________________________________________________
   _____________________________________________________________________________
   _____________________________________________________________________________
### THE WAVE EXERCISE: VOCABULARY

<table>
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<th>Definition</th>
<th>Illustrated example – draw a picture that represents the definition.</th>
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<tbody>
<tr>
<td>Wave p.225</td>
<td>An oscillation that travels from one place to another.</td>
<td></td>
</tr>
<tr>
<td>Amplitude p.226</td>
<td>The height of a wave.</td>
<td></td>
</tr>
<tr>
<td>Crest p.226</td>
<td>The high point of the wave.</td>
<td></td>
</tr>
<tr>
<td>Trough p.226</td>
<td>The low point of the wave</td>
<td></td>
</tr>
<tr>
<td>Wave Speed p.227</td>
<td>The speed at which the wave spreads.</td>
<td></td>
</tr>
<tr>
<td>Frequency p.226</td>
<td>The measure of how often the wave goes up and down at any one place.</td>
<td></td>
</tr>
<tr>
<td>Wavelength p.226</td>
<td>The distance from any point on a wave to the same point on the next cycle of the wave.</td>
<td></td>
</tr>
<tr>
<td>Transverse Wave p.228</td>
<td>A wave in which the oscillations are not in the direction it moves.</td>
<td></td>
</tr>
<tr>
<td>Longitudinal Wave p.228</td>
<td>A wave in which the oscillations are in the direction it moves.</td>
<td></td>
</tr>
<tr>
<td>Medium</td>
<td>The material through which the wave travels.</td>
<td></td>
</tr>
</tbody>
</table>
Name: ____________________ Teacher Answer Key ____________________ Per. __________ Date __________

1. WAVE DIAGRAM – Use CPO Textbook page 226
   Include the following: crest, trough, amplitude, wavelength.

![Wave Diagram]

2. Identify the mediums for the following waves:
   - The Wave Exercise waves: students
   - Ripples on a pond: water
   - Sound waves from a stereo speaker: air
   - Seismic (earthquake) waves: rock/soil

3. Explain why we see the light from fireworks, before we hear the “boom”.
   **Light does not need a medium to travel through and travels at a faster speed. While sound waves must travel through a medium, such as air, and travels at a slower speed.**
Making Waves

Please be gentle with the springs. They are easily tangled and mangled. DO NOT overstretch the springs; they will become permanently deformed.

Materials:
Slinkys   Meter Sticks

Start-Up:
Stretch your spring out to a length of 2 meters, with one person at each end.

Part 1: Longitudinal (compressional) Waves
With your free hand, grasp the spring at the end. Pull the spring straight back towards the end of the spring, compressing the spring. Then release the spring, being careful not to let go of the end of the spring.

1. Describe in words and drawings what you see after releasing the spring.

2. What happens to the wave when it reaches the other end of the spring?

Part 2: Transverse Waves
Move your hand very quickly and sharply to the right and back to its original position. (Practice until you can produce a single large pulse that travels down only one side of the spring.)

3. Describe in words and drawings what you see after releasing the spring.

4. Describe in words and drawings what happens to the wave when it reaches the other end of the spring.

5. Does the size of the wave change as it travels along the spring?
Making Waves

Please be gentle with the springs. They are easily tangled and mangled. DO NOT overstretch the springs; they will become permanently deformed.

Materials:
Slinkys  Meter Sticks

Start-Up:
Stretch your spring out to a length of 2 meters, with one person at each end.

Part 1: Longitudinal (compressional) Waves
With your free hand, grasp the spring at the end. Pull the spring straight back towards the end of the spring, compressing the spring. Then release the spring, being careful not to let go of the end of the spring.

1. Describe in words and drawings what you see after releasing the spring.

2. What happens to the wave when it reaches the other end of the spring? The wave bounces back and travels in the opposite direction.

Part 2: Transverse Waves
Move your hand very quickly and sharply to the right and back to its original position. (Practice until you can produce a single large pulse that travels down only one side of the spring.)

3. Describe in words and drawings what you see after moving the spring.

4. Describe in words and drawings what happens to the wave when it reaches the other end of the spring.

The wave bounces back and travels in the opposite direction, which then interferes with the wave traveling in the opposite direction.

5. Does the size of the wave change as it travels along the spring? No
<table>
<thead>
<tr>
<th>Movie Segments</th>
<th>Notes:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Waves and the Movement of Energy</td>
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<td>The Nature of Waves</td>
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<td>Sound Waves</td>
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<td>The Speed of Sound</td>
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<td>Electromagnetic Waves</td>
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<td>Wave Interference</td>
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<tr>
<td><strong>Summary:</strong></td>
<td></td>
</tr>
</tbody>
</table>
Underwater Racket

The oceans are getting louder, and scientists want to know what that means for marine residents

By Emily Sohn / February 2, 2011 http://www.sciencenewsforkids.org/2011/02/underwater-racket/

Swimming can be as peaceful as it is fun. Underwater, no one can tell you to do your homework or clean your room. Everything sounds muffled, quiet and peaceful.

To the ears of a whale or dolphin, though, the underwater world is getting less peaceful all the time. Noisy ships are more common than they used to be. Sound travels faster and farther underwater than it does in air. In some cases, a single sound can travel all the way across the deep ocean. Changes in the environment are making the oceans louder, too.

For ocean-dwelling animals, it’s like having new neighbors who play loud music all the time, even at night. The noise can hurt animals’ ears. It can make life more stressful for them. It can change their behavior, where they go and maybe even how they talk to each other.

“We know the ocean is getting louder,” says Mark McDonald, an ocean acoustician in Bellvue, Colo. An acoustician is a scientist who studies sound. “It can’t be good for anything that lives in the ocean, but it’s hard to know how bad it is.”

The sound of water

Like light, sound travels as waves that bounce off some objects and get absorbed into others. Inside our ears, sound waves cause three little bones to vibrate. Tiny hairs turn those vibrations into messages that travel to the brain. That’s how we hear what’s happening — birds chirping, computers humming, kids playing.

Some people have voices that are high and shrill like a flute’s. Others have voices that are low and deep like a trombone’s. That quality is called pitch. Some sounds are loud like barking dogs. Others are quiet like droning dishwashers. The level of loudness is called volume. Scientists measure volume in decibels. A normal conversation measures about 60 decibels (dB). A lawnmower is 90 dB. A rock concert is 120 dB. And a gunshot is 140 dB. For people, any sound about 85 dB can damage hearing with enough exposure.

Both pitch and volume exist in water and in air. But sound travels five times faster in water — at a blazing speed of nearly a mile (1,500 meters) a second. Sound also travels farther underwater than it does in air, especially in deeper waters.

Down at about 2,600 feet (800 meters), sound travels through a deep sound channel for thousands of miles across the entire ocean. It would be like someone in New York calling to a friend in California — without the help of a phone.

Surfers and human swimmers don’t usually notice the nuances of noise in water because human ears aren’t designed to listen down there. But scientists have been using tools to monitor the clatter for decades.

At first, most information was kept secret by the military. They were working to detect enemy submarines. These deep-water ships send out sound pulses to navigate. The military’s constant listening picked up lots of other sounds besides submarines. But the military didn’t release the data, because it didn’t want to blow its cover.
In the early 1990s, scientists started releasing evidence that sound was changing underwater — and that it was changing a lot. Recent studies show that the sound level of the ocean has risen by 3 decibels every decade since at least the 1960s. In places with high amounts of shipping and other activity, noise levels have doubled each decade.

In the oceans, sonar pulses can top 200 dB. Large ship engines produce sounds that exceed 180 dB. The rise in ocean noise is due mostly to the rising number of ships in the sea. As engines become more powerful, they also make more noise.

**Communication interference**

With noisier oceans, scientists are most concerned about marine mammals, such as whales, dolphins and sea lions. These animals depend on sound to communicate with each other. Many also use a form of sonar to navigate.

Here's how sonar works: An animal, much like a submarine, sends out pings of sound and then listens for echoes. By reading the time it takes for those sounds to bounce back to it, the animal can figure out the distance to objects that surround it. The technique allows the animal to avoid predators, catch prey and swim around obstacles.

Extra human-made noise, some researchers fear, might be interfering with ocean animals’ ability to hear each other or find their way.

“Sound is important to these animals,” says Ken Ramirez, a behaviorist and biologist at Shedd Aquarium in Chicago. “Recently, we’ve seen that when something unexpected happens, like the first time an ocean platform is set up or drilling begins, animals are surprised and their behavior patterns change. They may flee or relocate if the noise bothers them.”

There have also been an alarming number of strandings — when groups of dead animals wash ashore. Some studies point to loud noise as a cause.

As more ships traverse the oceans, the volume of sound traveling underwater is increasing. This change can affect humpback whales and other residents who use sound in their daily lives. (miblue5/iStock)

Still, it’s not easy to draw conclusions from these observations, Ramirez says. Other scientists have found that dolphins and whales are really good at adapting to changes in their environment. Even though sea lions may move away from loud noises at first, for example, they eventually get used to those new sounds and stick around.
People are the same way. If you move from the country to the city, you’ll probably have trouble sleeping for a few weeks, bothered by the blaring sounds of traffic, sirens or trains. After a while, you probably won’t notice the noise anymore, and you’ll sleep just fine.

When it comes to ocean animals, there aren’t any perfect studies that clearly demonstrate whether rising levels of noise are good or bad.

“There is so much we still don’t know about how animals use their sound and what impacts various things have on them,” says Ramirez, who works with aquarium staff to make sure that animal tanks sound just like natural ocean environments. “Our learning about these animals is still in its infancy.”

Warmer, louder water

Sound isn’t just getting into the ocean more than it used to. It’s also traveling longer distances. And a gas called carbon dioxide is to blame.

Many human activities — including driving cars and heating homes — release carbon dioxide, or CO₂, into the air. CO₂ is a greenhouse gas. It lingers in the atmosphere and traps heat. It also gets into the oceans. And through some quirks of chemistry, CO₂-rich water absorbs less sound. That allows noises to travel farther.

By 2100, the oceans could absorb as much as 70 percent less sound than they do today, found one recent study. That would make the underwater world even louder than just extra noise would. The study looked only at deep sounds with very low pitches. Boat engines produce those types of noises. So do whales.

One worry is that the pumped-up volume will make it harder for whales and other animals to hear each other. But the opposite could happen, too.

“If the ocean is becoming more transparent to sound, that means that if a whale produces sound, it can travel farther,” says study author Tatiana Ilyina, an oceanographer at the University of Hawaii at Manoa. “That means that his partners at the other end of the ocean can hear better. One impact could be that it would enable mammals to communicate over longer distances.”

“It is a very complicated topic,” she adds. “It’s not very clear at the moment what the implications for marine mammals will be.”

Among other mysteries, blue whales have been singing with deeper voices recently, McDonald has found. In some cases, pitch has dropped by more than 30 percent since the 1960s. Scientists have come up with a few hypotheses to explain the puzzling trend.

One idea is that whales are trying to distinguish their voices from the sounds of ship engines. If that were true, though, the whales should be singing with higher voices, not deeper ones.

“It’s surprising news,” McDonald says. “We haven’t found an answer we think is convincing.”

The mysteries of ocean noise just keep getting deeper and deeper. Glug, glug!
Ride the Waves – Teacher Page


2. Seismic Waves Animation: [http://sunshine.chpc.utah.edu/labs/seismic/seismic.swf](http://sunshine.chpc.utah.edu/labs/seismic/seismic.swf)

3. Quake, quake, go away article
   - Students use the 3-2-1 strategy to read the article…
     Students write down 3 things that they discovered, 2 things that they found interesting, and 1 question that they still have.

4. Electromagnetic Waves: Soap in the Microwave Demonstration

   **Warning**
   - Do not leave the microwave unattended during the activity.
   - Although heating up soap in the microwave will not damage your microwave or the food you heat in it later, it will cause the microwave to smell like soap for a few hours.
   - Do not place metal in the microwave.

   **What you Need**
   - Bar of Ivory® soap
   - Microwave
   - Paper plate / shallow plastic container

   **What to Do**
   1. Place the soap on the plate (or shallow container) and put it in the microwave.
   2. Set the microwave for 2-3 minutes, turn it on, and watch the soap for the entire time. What happens?
   3. Let the soap cool for a few minutes and then take it out of the microwave. What does it feel like? Break off a piece and run it under water. Does it still act like soap?
   4. Be sure to wipe out the microwave when you’re done!
   5. What’s Going On?

The “microwave” part of “microwave oven” actually refers to how your food (or whatever else you put inside) is heated up in the microwave oven. In a previous experiment we talked about how infrared light is part of the electromagnetic spectrum and has slightly longer wavelengths than visible light (red, blue, etc). Microwaves are another type of light – and have even longer wavelengths than infrared light.
This electromagnet spectrum shows all the different kinds of light in order from the longest wavelength to the shortest. Image courtesy NASA.

Microwave ovens send microwaves waves back and forth through your food. This causes the water, fat, and sugar molecules in the food to rotate and bump into each other, which produces heat. This is different than heating food in an oven or on a stove, which are both based on heating by convection.

Microwaves are created inside a microwave oven. As they travel back and forth through the food (or soap) in the microwave, they cause some types of molecules to rotate and hit each other. This produces heat. Image courtesy Explain that Stuff!

5. Ocean Waves
Students measure and compare the wavelength, amplitude, and frequency of waves.

6. Sound Waves
Students label the parts of a compressional wave and answer questions about wave properties as it relates to sound.
Ride the Waves


Name the different types of waves mentioned in the video.

2. Seismic Waves: Observe the Seismic Waves simulation

Where do these types of waves occur? ____________________________

Draw the two different types of seismic waves and label them as either transverse or longitudinal.

Describe how the two different seismic waves travel through the earth. Do they travel in the same directions and at the same speed?

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3. Read the following article: Quake, quake, go away: Use the 3-2-1 strategy to write down what you discovered, found interesting, and a question that you may still have.
Quake, quake, go away

French engineers report success in the first test of an underground seismic shield

By Stephen Ornes / March 1, 2013

An earthquake caused widespread damage to San Francisco in 1989. Scientists are designing a new type of seismic shield that may help protect buildings from tremors. Credit: J.K. Nakata/USGS

The best way to avoid an earthquake might be to make it detour around you. Engineers have designed a new seismic shield to do just that. If successful, it might one day protect a treated area from powerful earthquakes.

The French researchers behind the idea recently tested their system in some loose soil outside Grenoble, a French city near the Alps. It proved successful, they reported in January.

As shields go, this one looks nothing like the one used by Captain America. In fact, if you stumbled upon it, you wouldn’t even know what it was, says Sébastien Guenneau. He’s an engineer who helped design the shield at the Institut Fresnel in Marseille, France. But, he notes, you could easily stumble upon it because this simple “shield” consists of little more than holes drilled into the ground. Big ones.

Guenneau’s team was inspired by the science of invisibility. We can see only things that reflect, absorb or send out light. Light travels as a wave. A device has to stop light waves from bouncing off of an object to make it invisible to our eyes.
In 2006, British and U.S. engineers introduced the first cloaking, or invisibility, device. It looked like a set of concentric metal rings. Those rings were designed to guide incoming waves around a hidden object placed in the center of the cloaking device. But the device didn’t work for light waves that are visible with the naked eye. It cloaked microwaves.

Visible light is a type of electromagnetic radiation, which is energy that travels as waves through space. Microwaves are another type of electromagnetic radiation. These have longer wavelengths than visible light. (A wavelength is the distance from the peak, or crest, of one wave to the peak of the next.) The researchers of the first cloaking device showed that waves of radiation could be manipulated to go around an object.

Guenneau and other researchers suspected that devices could be built to hide big objects from large waves, like those that rock the ground during an earthquake. In fact, the French team predicted that the soil surrounding a building could be turned into a giant shield to protect that structure from seismic waves. Those vibrations, which race through rock and soil, can topple buildings.

To test the idea, Guenneau’s group drilled 30 cylindrical holes into the ground. Lined up in three rows of 10, each hole was 320 millimeters (12.6 inches) in diameter and plunged 5 meters (about 16 feet) deep. Then the engineers turned on a device that sent out ground-shaking seismic waves toward that grid of 30 holes. Sensors sitting on the ground in different places recorded ground motions. Those sensors showed the cloak worked. Within the grid of holes, the seismic waves died out before they made it to the second row. The wave did shake up the ground plenty, however, outside the test grid.

“On the seismic front, we have made really huge progress,” concludes Guenneau. His team reported its work on arXiv, an online collection of scientific papers.

The new test shows that these big holes can buffer seismic waves. That’s a big step. But it’s just the first one. More tests are needed before the team can declare that the shield protects against actual seismic waves triggered by a quake.

http://www.sciencenewsforkids.org/2013/03/quake-quake-go-away/

3-2-1 Strategy
1. What are 3 things you discovered?
   X
   X
   X

2. What are 2 things that you found interesting?
   X
   X

3. What is one question you still have?
   X
Electromagnetic Waves:
Do you listen to the radio, watch TV, or use a microwave oven? All these devices make use of electromagnetic waves. Radio waves, microwaves, visible light, and x-rays are all examples of electromagnetic waves that differ from each other in wavelength. Electromagnetic waves are produced by the motion of electrically charged particles. They travel through empty space as well as through air and other substances.

Use the electromagnetic spectrum diagram to answer the following questions.

1. As frequency of the wave increases, what happens to the wavelength?

2. Explain why we can see the light from the Sun here on Earth, but cannot hear the sound of the nuclear explosions that produce the light.
Ocean Waves

Ocean Waves: Mike “The Surfrider” Johnson went to the ocean to surf on two different days. Compare the ocean waves that he experienced.

Day 1:

Day 2:

Complete the chart below based on the waves above. Use a ruler for measuring.

<table>
<thead>
<tr>
<th>Questions:</th>
<th>Waves on Day 1</th>
<th>Waves on Day 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the wavelength?</td>
<td>cm</td>
<td>cm</td>
</tr>
<tr>
<td>What is the amplitude?</td>
<td>cm</td>
<td>cm</td>
</tr>
<tr>
<td>What happened to the frequency from Day 1 to Day 2?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>What may have caused the changes in the waves?</td>
<td></td>
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</tbody>
</table>
Sound Waves

Sound travels in longitudinal (compression) waves. Their vibrations occur in the same direction as the direction of travel. Sound waves can only travel through a solid, liquid or gas.

1. Use your knowledge of transverse waves to label the sound wave diagram below. Label the wavelength and amplitude of the sound wave.

   ![](sound_wave_diagram.png)

   **Vibrations**
   When an object or substance vibrates, it produces sound.
   - the greater the amplitude, the louder the sound
   - the greater the frequency, the higher the pitch.

2. Which of the following pictures shows a higher pitched sound?

   A. 
   B. 
   C. 
   D.
3. Tell the story of the sound wave below by describing what happens to the sound from beginning to end.

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Ride the Waves – Teacher Answer Key


Name the different types of waves mentioned in the video.
- Light
- Radio
- Transverse
- Sound
- Compression
- Seismic Waves
- Electromagnetic

2. Seismic Waves: Observe the Seismic Waves simulation

Where do these types of waves occur? In the Earth’s Crust

Draw and label the two different types of seismic waves and label them as either transverse or longitudinal.

![S waves - Transverse](image)

![P waves - Longitudinal](image)

Describe how the two different seismic waves travel through the earth. Do they travel in the same directions and at the same speed?

The P Waves (longitudinal waves) travel faster and farther than the S waves. Both wave types travel outward from the source, but some S waves are reflected back.

3. Read the following article: Quake, quake, go away: Use the 3-2-1 strategy to write down what you discovered, found interesting, and a question that you may still have.

In the Earth’s Crust

The P Waves (longitudinal waves) travel faster and farther than the S waves. Both wave types travel outward from the source, but some S waves are reflected back.
Electromagnetic Waves: TEACHER ANSWER KEY
Do you listen to the radio, watch TV, or use a microwave oven? All these devices make use of electromagnetic waves. Radio waves, microwaves, visible light, and x-rays are all examples of electromagnetic waves that differ from each other in wavelength. Electromagnetic waves are produced by the motion of electrically charged particles. They travel through empty space as well as through air and other substances.

Use the electromagnetic spectrum diagram to answer the following questions.

1. As frequency of the wave increases, what happens to the wavelength?
   
   As the frequency increases, the wavelength decreases

2. Explain why we can see the light from the Sun here on Earth, but cannot hear the sound of the nuclear explosions that produce the light.
   
   Since, space is not made of any medium(matter), sound waves cannot travel from the Sun to Earth, as sound waves rely on particle movement or vibration. However, light does not need a medium to travel through, therefore the light reaches Earth.
Ocean Waves – TEACHER ANSWER KEY

Mike “The Surfrider” Johnson, went to the ocean to surf on two different days. Compare the ocean waves that he experienced.

Day 1:

Day 2:

Complete the chart below based on the waves above. Use a ruler for measuring.

<table>
<thead>
<tr>
<th>Questions:</th>
<th>Waves on Day 1</th>
<th>Waves on Day 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>What is the wavelength?</td>
<td>5.5 cm</td>
<td>2.3 cm</td>
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<tr>
<td>What is the amplitude?</td>
<td>1 cm</td>
<td>1 cm</td>
</tr>
<tr>
<td>What happened to the frequency from Day 1 to Day 2?</td>
<td>The frequency of the waves increased.</td>
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</tr>
<tr>
<td>What may have caused the changes in the waves?</td>
<td>The change in wave frequency could have been caused by an increase in energy due to wind and/or ocean currents.</td>
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</table>
Sound Waves – TEACHER ANSWER KEY

Sound travels in longitudinal (compression)waves. Their vibrations occur in the same direction as the direction of travel. Sound waves can only travel through a solid, liquid or gas.

1. Use your knowledge of transverse waves to label the sound wave diagram below. Label the wavelength and amplitude of the sound wave.

Vibrations
When an object or substance vibrates, it produces sound.
- the greater the amplitude, the louder the sound
- the greater the frequency, the higher the pitch.

2. Which of the following pictures shows a higher pitched sound?

A. 
B. 
C. 
D.
3. Tell the story of the sound wave below by describing what happens to the sound from beginning to end.

The sound gradually gets louder as the amplitude of the sound wave increases. The sound suddenly gets very quiet as the sound wave’s amplitude suddenly gets very small. The sound gets louder then quickly quiet, then loud, then quiets down to no sound to the end.
**THE MYSTERY OF MUSIC**

Directions: Observe the different musical instruments that are in your classroom. Complete the table below that compares and contrasts the information about each instrument. Be careful in handling the different instruments.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Sound Source</th>
<th>Medium</th>
<th>How can Wavelength, Frequency and Amplitude be Changed?</th>
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</thead>
<tbody>
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</table>

Columbus City Schools
Curriculum Leadership and Development
Science Department June 2013
THE MYSTERY OF MUSIC

Directions: Observe the different musical instruments that are in your classroom. Complete the table below that compares and contrasts the information about each instrument. Be careful in handling the different instruments.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Sound Source</th>
<th>Medium</th>
<th>How Wavelength, Frequency and Amplitude can be Changed</th>
</tr>
</thead>
<tbody>
<tr>
<td>STRINGS</td>
<td>BOW OR FINGER ON STRING</td>
<td>STRING, BODY</td>
<td>TENSION ON STRING, MECHANICAL ENERGY USED IN PLAYING, THE MATERIALS USED</td>
</tr>
<tr>
<td>PERCUSSION</td>
<td>DRUM STICK, HAND, ETC.</td>
<td>DRUM HEAD, AIR, ETC.</td>
<td>TENSION ON DRUM HEAD, MATERIALS, MECHANICAL ENERGY USED IN PLAYING</td>
</tr>
<tr>
<td>WOODWIND</td>
<td>AIR FLOW</td>
<td>REED, AIR, INSTRUMENT MATERIAL</td>
<td>MECHANICAL ENERGY USED IN PLAYING, THICKNESS OF REED</td>
</tr>
<tr>
<td>BRASS</td>
<td>AIR FLOW</td>
<td>AIR</td>
<td>MECHANICAL ENERGY USED IN PLAYING, SIZE AND SHAPE OF INSTRUMENT</td>
</tr>
</tbody>
</table>

OTHER VARIOUS INSTRUMENTS
MUSIC MIRACLE DESIGN CHALLENGE
TEACHER BACKGROUND INFORMATION

**Teacher Notes:**

In this challenge students will be designing and constructing a musical instrument that the student will be able to play a song with.

**Considerations:**

You may need students to obtain their own supplies. Remind them to ask permission before bringing supplies. Various materials can be used to make an instrument. This is a good time to make the “Awesome Dawson” connections from earlier in the school year. Recall that his supplies came from some unorthodox places.

Below are a few websites that provide information for you on how to build a musical instrument, but the purpose of the challenge is for students to arrive at their own plans. The directions on the websites are very specific and might take all of the challenge out of the design if shared with students. It is good for you to preview some of these plans so that you can facilitate students and make suggestions without giving directions.

Homemade Musical Instruments-Child’s Play Music- [https://www.youtube.com/watch?v=MWXrN3nIZyl](https://www.youtube.com/watch?v=MWXrN3nIZyl)

Blue Man Group Modern Plumbing and PVC- [https://www.youtube.com/watch?v=KuQvgswttz0](https://www.youtube.com/watch?v=KuQvgswttz0)

Homemade Musical Instruments- [https://www.youtube.com/watch?v=SK52EVv9xew](https://www.youtube.com/watch?v=SK52EVv9xew)

Photo from: [http://library.thinkquest.org/5116/images/all_instruments1.JPG](http://library.thinkquest.org/5116/images/all_instruments1.JPG)
Materials: (possible uses for building musical instrument)

<table>
<thead>
<tr>
<th>Boxes of Various Sizes</th>
<th>Aluminum Foil</th>
<th>Tape</th>
<th>Glue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal Hangers</td>
<td>Umbrella</td>
<td>Rubber Bands</td>
<td>Wood</td>
</tr>
<tr>
<td>Transparency Sheets</td>
<td>Glass</td>
<td>Aluminum Can</td>
<td>String</td>
</tr>
</tbody>
</table>

Building the Designs:

Pass out the Design Challenge papers located below. Read over the papers with the class so they understand what they will be doing. You may also wish to use the "Daily Engineering Notebook" to have your students keep track of what they do each day. Use it as a daily exit ticket.

Read Aloud to the class:

A local elementary school has just found out that there will no longer be funding to purchase musical instruments for their school band. With this horrible news, it is up to you to create a musical instrument that the students can play in their band. The students playing the instrument will need to be able to play at least three different sounds with these instruments.

You have learned that all sound is created by vibration and sound waves. In almost all musical instruments there are more than one vibration systems. For instance, in a string instrument the string vibrates and the sounding board vibrates. In a clarinet, a reed vibrates and a column of air vibrates.

The musical instrument can only be created with objects found in your home, garage or here at school. You do not have to spend money to do this project. The recycle bin is a great place to find materials, as is the junk drawer. Be sure to ask a parent about using any materials. Be sure to wash the items as well before blowing into them.
MUSIC MIRACLE DESIGN CHALLENGE

Introduction:
A local elementary school has just found out that there will no longer be funding to purchase musical instruments for their school band. With this horrible news, it is up to you to create a musical instrument that the students can play in their band. The students playing the instrument will need to be able to play at least three different pitches with these instruments.

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The musical instrument can only be created with objects found in your home, garage or here at school. You do not have to spend money to do this project. The recycle bin is a great place to find materials, as is the junk drawer. Be sure to ask a parent/teacher about using any materials. Be sure to wash the items before using them.

Problem Statement Summary:
- Musical instrument makes at least three different pitches
- Made out of materials found in your home, garage, school, etc.
- Be sure to keep any and all drawings, ideas, and or papers as you will need them to write your Lab Report.

Brainstorm: List of supplies you might scavenge to make your instrument.
Develop a scale diagram of an instrument. In your drawing, clarify with labels which material is used for each feature. Include a scale drawing (e.g. 1cm=4cm) so another individual knows the exact dimensions of the real musical instrument.

- Circle the supplies that you actually used in the brainstorm table above.
- Take your list and your sketch to your teacher to get approval to build.

**Design:** After you build your instrument review your initial design. Redraw and label each detail you modified.

*Teacher signature*
Describe the differences from your original design. Explain in detail why you made the changes and modifications.

__________________________________________________________________________________________

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**Build:** Obtain the materials from your teacher based on your brainstorm list. Follow all of the classroom procedures and guidelines in building your musical instrument.

**Test:** Once the musical instrument is complete, can your instrument make sounds? Do the sounds have different pitches created by different frequencies?

**Evaluate and Modify:** Brainstorm ideas by which your design can be improved. Draw or write the changes that you decide to make.
Retest your instrument exactly as you did earlier. Did the instrument sound or work better?

**Performance:**
After your final design is created, work with 1-2 other students to develop your own song that can be played with at least 3 different pitches on each of the instruments.
### THE MUSIC MIRACLE INSTRUMENT RUBRIC

<table>
<thead>
<tr>
<th>Category</th>
<th>Excellent (4)</th>
<th>Good (3)</th>
<th>Fair (2)</th>
<th>Poor (1)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Construction</strong></td>
<td>Great care taken in construction process so that the instrument is neat,</td>
<td>Construction was careful and accurate for the most part, but 1-2 details</td>
<td>Construction accurately followed the plans, but 3-4 details could have</td>
<td>Construction appears careless or haphazard. Many details need refinement</td>
</tr>
<tr>
<td></td>
<td>attractive and follows plans accurately.</td>
<td>could have been refined for a more attractive product.</td>
<td>been refined for a more attractive product.</td>
<td>for a strong or attractive product.</td>
</tr>
<tr>
<td><strong>Scientific Knowledge</strong></td>
<td>Explanations indicate a clear and accurate understanding of scientific</td>
<td>Explanations indicate a relatively accurate understanding of scientific</td>
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<td>principles underlying the construction and modifications.</td>
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<td><strong>Function</strong></td>
<td>Instrument functions extraordinarily well, producing at least 3 frequencies</td>
<td>Instrument functions well, and can produce sounds of at least 2</td>
<td>Instrument functions pretty well, but has limited frequency or</td>
<td>Flaws in function with complete failure to produce different amplitude</td>
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<td></td>
<td>and multiple amplitudes.</td>
<td>frequencies and various amplitudes.</td>
<td>amplitude capabilities.</td>
<td>and frequency.</td>
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<tr>
<td><strong>Materials</strong></td>
<td>Appropriate materials were selected and creatively modified in ways that</td>
<td>Appropriate materials were selected and there was an attempt at</td>
<td>Appropriate materials were selected.</td>
<td>Inappropriate materials were selected and contributed to a product that</td>
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<tr>
<td></td>
<td>made them even better.</td>
<td>creative modification to make them even better.</td>
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<td>performed poorly.</td>
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**Comments:**

**Total Points**
Music of the Future

Scientists create new technologies that can make any surface — from a desk to a wall — sing.


People don’t have to go to outer space to make music in new ways. Technologies using computers and sensors are being created that will let people do that right here on Earth.

NASA/JPL

The musical instruments of the future may be right in front of your eyes and on the tables, walls and windows around you. All it takes to use them is the right hardware, and a little imagination.

In Switzerland, a team of scientists and artists are working together on new technology that can transform almost any surface into a musical instrument. The technology is called MUTE, short for Multi-Touch Everywhere. Using MUTE, a person can use a computer to translate taps on different parts of a table or a wall as different sounds.

For example, you may record and save different sounds on a computer — anything from a snare drum or trumpet to clapping hands or a sneeze. Then, you program your computer to play one of these recorded sound snippets whenever you tap a certain spot on a table top or wall. The left side of a table might play snare drum beats, the right side a melody on a trumpet. If you tap the two sides at the same time, you’ll hear both sounds come together as a song. The system uses a camera and lasers to see where you’ve tapped on the table.
This is the computer program used to assign different sounds to different parts of a surface. Sensors tell the computer when someone taps on one of the colored regions.

Alain Crevoisier / Future Instruments

What’s more, the programmed surface doesn’t even have to be solid — it can float right in front of you, explains musician and MUTE developer Alain Crevoisier. “It can even work in the air,” he says. “Since the lasers are creating a plane of light, what we actually detect is when you cross this plane with either the hands or sticks or mallets.” Imagine, for example, a virtual piano hovering in front of your face.

When the MUTE system is installed on a surface, it also uses acoustic sensors to track the location of a performer’s tap. (For more information on acoustics, see the sidebar below story, “What is acoustics?”) “When you tap the table you generate vibrations,” says Crevoisier, a researcher at the Music Conservatory of Geneva. The vibration travels through the surface as an acoustic wave, and when the vibration strikes the sensor, the sensor sends an electric signal to the computer.

The device is not a musical instrument in the way we normally think about instruments. But that’s part of the beauty of it, says Crevoisier. It allows a person to be creative. “It’s more like we are providing a means for people to design their own instruments,” he says. His system adds a layer of music to already existing sounds. On a regular drum, for example, a drum beat is just the sound of the drum. But on a drum outfitted with MUTE technology, a drum beat could be both the sound of the drum and a control for some other sound layered on top of that.

Crevoisier’s work on new musical instruments grew out of his participation in a project called TAI-CHI (pronounced ty-chee), which stands for “tangible acoustic interfaces for computer-human interactions.” An interface is a device, or a lot of devices working together, that allow people to communicate with machines. A tangible object is one that you can touch. The keyboard of a personal computer, for example, is a tangible interface between you and your computer. So is your mouse.
Sound waves are measured by height, called amplitude, and width, called frequency. At top, the sound waves have a lower frequency and, to our ears, a lower pitch. The bottom image shows a sound wave with a higher frequency, which we would hear as high-pitch.

NOAA Ocean Explorer

In the TAI-CHI project, Crevoisier and his colleagues showed that acoustics, or the science of sound, could be used to turn any surface into a musical instrument. They also showed that the technology could lead to a new kind of interface.

Here’s how: The sensors pinpoint the place on a surface where a person taps.

One way to do this requires at least three sensors on the surface. When a person taps the table, the sound waves travel to the sensors, and each sensor records the exact time when the waves reached it. By knowing where the sensors are located and what the surface is made of, a computer program can use the waves’ arrival times to figure out exactly where the surface had been tapped.

Another method to pinpoint a tap uses only one acoustic sensor, but it is more complicated. A user needs to fine-tune the device very carefully, and provide the computer with lots of information about the surface material itself.

Acoustic sensors could be used to build new kinds of computers that look nothing like traditional desktop models. Unlike a keyboard and mouse, which require a user to remain in front of a computer screen, acoustic sensors would allow a user to interact with the computer almost anywhere. You could use your fingers to draw a picture on a wall, for example, and record the drawing with your computer.
This device, built with TAI-CHI technology, is called the Sound Rose because when a person taps on the table, a colorful flower appears. A person's taps are tracked using acoustic sensors, and the images are projected from the ceiling.

Alain Crevoisier / Future Instruments

Or, imagine a restaurant owner, who could glue menus to the top of his tables and install acoustic sensors underneath. Diners could then order simply by tapping on the menu. The vibration from the tap would be picked up by the sensors, which would be able to figure out where the tap came from. A computer could match that location to a dish on the menu and send the order to the kitchen.

In another example, perhaps someone in a wheelchair could mark a spot on the wall, a table top or the arm of a chair to serve as a switch. It might be for turning on or off a light, for turning up or down the volume on a television or even for sending out a distress alarm. A simple tap on the spot could trigger the sensors, which could relay the information to a computer. The technology would allow people to make any surface into an interface to control some action.

Crevoisier isn’t the only one looking at ways to use acoustic sensors in future devices. Another European company, for example, is finding ways to use them to make a “smart apartment,” where any surface — mirrors, tables, counters, walls — can be used to interact with the house computer, to do tasks like change the lighting, turn on the television or raise the temperature.
The Touch Wall, created by Microsoft Corporation, made its debut in May of this year.

Microsoft

Other researchers around the world are developing other kinds of new tangible interfaces, though not all of them use acoustic sensors. The computer company Microsoft has developed a device called TouchWall, for example, which converts almost any surface to a computer interface by using sophisticated laser trackers, cameras and a projector.

Look around again. The future of computing and of musical instruments may be all around you.
Question Sheet: Music of the Future – Teacher Page


SCIENCE

Before Reading:
– How would you describe a musical instrument?
– How does it make sound?
– Sometimes computers are attached to musical instruments, like a piano. What might be the advantage of that?
– Computers have inputs and outputs. Outputs include your computer’s speakers, monitor and electrical signals that control other devices such as a printer. But how do you input commands to your computer, telling it what you want it to do? What device or devices do you use?

During Reading:
– Mute usually means to utter no sound. But in this story, the MUTE technology does what?
– A computer keyboard is a type of sensor. But in MUTE and TAI-CHI other types of sensors are used. What do they sense?
– These sensors rely on acoustics. What is that?
– What’s a Sound Rose?
– How might TAI-CHI speed a restaurant order?

After Reading:
– How might systems based on acoustic sensors change the idea of what a musical instrument is?
– How might the same idea be applied to improve the lives of people with disabilities or the elderly? Where would you install them to simplify your life?
– What are the advantages of a standard computer mouse as an input device, compared to acoustic sensors?
– What are the risks of making a spot on your desk or the kitchen table into a computer-input device? (Hint: What if you put a book or milk glass down hard?)

SOCIAL STUDIES
– In a few short years, computers went from being room-sized machines to machines as small, portable as a notebook or, in some cases (such as iPods or Blackberries), a deck of cards. Discuss how acoustic-input devices might expand the way we think of computers and where we use them.
– How would the MUTE and TAI-CHI systems change the way we make music? Is that a good thing or would you prefer the old acoustical instruments — strings, winds, drums and horns? Explain your preference.
– How might these acoustic-sensor inputs to computers save energy in homes or businesses?

LANGUAGE ARTS
– Imagine a computer-controlled world without keyboards. Describe a day in your life in this world.
– You’re going to make a MUTE-based musical instrument, recording sounds that your instrument will later associate with various spots on a tabletop. Describe in two paragraphs what sounds you’d collect and why. Imagine a band made out of five such MUTE systems. Describe in up to three paragraphs the challenges you might encounter — and have to overcome — in writing or orchestrating music for this MUTE combo. (HINT: What would happen if this band travels a lot.)
– Imagine that your neighbor was injured in an auto accident and confined to a wheelchair with no use of her legs. Describe how, as a MUTE or TAI-CHI engineer, you would set up their bedroom, living room and kitchen to maximize that neighbor’s use of those rooms and what’s in them.