Sonar & Echolocation

Subject Topics: Physics and Biology

Grades: 9th – 12th

Essential Questions:

Big ideas
• Sound is an important part of observation, communication and survival for some marine and terrestrial animals, as well as humans.
• Sonar technologies used by humans are similar to echolocation (biosonar) in animals.
• Sound propagation occurs as a sequence of mechanical waves compress molecules in a media such as water or air.
• The distance of an object such as a submarine or a large predator can be determined by multiplying the speed sound travels in a particular media by half the time it takes the sound to travel to the object and back to the transmitting object or animal.

Big questions
• How do sonar technology and natural echolocation compare?
• How do humans and animals, such as bats, whales and dolphins, use the propagation and reflection of sound waves?

Guiding questions
• Why is sound an important survival tool for some animals, such as whales and bats?
• Why are sound and hearing sometimes superior to using light and vision, especially in water?
• Why do different animals use different frequencies of sound waves?
• How does an animal use sound waves to locate objects?
• What animals use sounds waves to locate objects?
• Can and how do humans use sound to make observations about their environment?
• What are the two types of sonar?
• How does echolocation compare to sonar?
• How is distance calculated using sound waves?
• Who uses sonar technology and for what purpose do they use it?
• What are some of the variables that must be considered when making sonar calculation?
Lesson Overview:
In this 5E lesson, students will investigate how sound can be used to navigate, communicate, locate objects, and create 3-D images of surroundings. Students will explore how sonar technology compares to natural echolocation used by animals. Students will conclude the lesson by applying their knowledge of sonar technology and related equations by creating a 3-dimensional model using data collected from a sonar system.
Learning Objectives:
Students will compare natural echolocation to sonar technologies.
Students will distinguish between passive and active sonar.
Students will investigate both active and passive echolocation and sonar techniques.
Students will evaluate the importance of echolocation in the survival of animals, such as whales and bats.
Students will research how sound is used as a tool to observe, examine, and survey the natural world by both humans and animals.
Students will be able to correctly use the distance formula to calculate distances between objects.
Students will apply knowledge of sonar technology by constructing a 3-D model using sonar data.

Knowledge
• Students will know the definitions of the vocabulary words: sonar, active sonar, passive sonar, biosonar, echolocation, echosounder, reflection, echo, sound waves, frequency, Hertz, hydrophone and transponder
• Students will know the calculation for distance using speed and time.
• Students will know the difference between active and passive acoustics.

Comprehension
• Students will compare active sonar to echolocation.
• Students will demonstrate how humans and animals can gather much information about their surrounding using sound.
• Students will be able to calculate the distance of an object using sonar data.

Application
• Student will use both passive and active echolocation to make predictions about the environment around them.
• Students will use their understanding of how sound is used to observe and examine the natural world to problem solve real-world scenarios.
• Students will use the distance formula to create a 3-D model of a riverbed.

Analysis
• Students will explore various examples of echolocation/sonar being used in the real world.
• Students will analyze their environment using biosonar.

Synthesis
• Students will create a three-dimensional model using sonar data.

Evaluate
• Students will evaluate the importance of sonar technology and the influences it has in various professions.
• Students will make recommendations based on calculations and models they have developed.
Next Generations Science Standards Framework

- LS4: Biological Evolution: Unity and Diversity
  LS4.C: Adaptations: How does the environment influence populations of organisms over multiple generations?

- PS4: Waves and Their Applications in Technologies for Information Transfer
  PS4.A: Wave Properties: What are the characteristic properties and behaviors of waves?
  PS4.C: Information Technologies and Instrumentation: How are instruments that transmit and detect waves used to extend human senses?

Common Core Math Standards

- HSN-Q.A.1. Use units as a way to understand problems and to guide the solution of multi-step problems; choose and interpret units consistently in formulas; choose and interpret the scale and the origin in graphs and data displays.
- HSN-Q.A.2. Define appropriate quantities for the purpose of descriptive modeling.
- HSN-Q.A.3. Choose a level of accuracy appropriate to limitations on measurement when reporting quantities.
- HSA-CED.A.4. Rearrange formulas to highlight a quantity of interest, using the same reasoning as in solving equations. For example, rearrange Ohm's law $V = IR$ to highlight resistance $R$.
- HSA-REI.B.3. Solve linear equations and inequalities in one variable, including equations with coefficients represented by letters.

Time Frame:
Two 90-Minute class sessions

Vocabulary:

- Sonar
- Active sonar
- Passive sonar
- Echolocation
- Biosonar
- Echosounder
- Speed of sound
- Reflections
- Echo
- Sound waves
- Frequency
- Hertz
- Hydrophone
- Transponder
• Neurons
• Acoustics

Background for the Teacher:

Common misconceptions
• Sight is the primary sensory mechanism for navigation in mammals.
  ○ This is addressed in the explore activity as well as the “Bats, Echolocation, and Perception” video clip in the engage.
• Humans are not capable of echolocation.
  ○ This is addressed in the explore activity.
• The only information needed to make distance calculations using sonar are the speed of sound and time it takes for sound waves to travel from the transponder, to an object, and back to a receiver.
  ○ This is addressed in the explain piece and the notes page.
• Sonar and biosonar are used only for navigation and location of objects.
  ○ This is addressed in explain homework extension activity as well as the “Turning Echoes into 3-D Models” activity.
• Typically animals that use biosonar do so because they are blind.
  ○ This is addressed in the “Bats, Echolocation, and Perception” video as well as the explain portion and notes page.

In this lesson students explore how echolocation in animals, such as bats and toothed whales, and sonar technologies compare. Many animals use sound as a tool for observing their surrounding environment. This technique is often referred to as biosonar. Sound can be used passively by just listening to noises coming from the environment or actively by sending out sound calls and listening for echoes of the sound.

Echolocation is the term used when animals actively utilize sound to navigate and hunt for food. Animals who echolocate emit sounds or calls into the environment and listen for those sounds to reflect back to them from surrounding objects. The animals can calculate the distance of objects based on the time it takes those echoes to return to their sensory organs (i.e. ears or auditory bulbs). Animals adapted for echolocation have extremely specialized auditory processing capabilities. Because of this, they not only can determine distance of objects but they can even detect size, density, composition, and identity of objects based on the acoustic characteristics of the echoed sound waves. These highly specialized echolocation techniques are evolutionary adaptations typically found in animals that live or thrive in environments that have limited light (i.e. deep ocean waters or caves.) Animals that are known to use echolocation are toothed whales, certain species of bats, a few species of birds, and shrews on a very basic level. Some humans, who lack the ability to see, have developed heightened levels of auditory processing abilities and can echolocate using sounds called “clicks”. This technique is referred to as flash sonar. Many animals use passive acoustics to make observations about their surroundings. Passive biosonar (simply listening with out transmitting sound) can be helpful in detecting food sources, predators, or other approaching dangers.
Sonar was originally an acronym (SONAR) that stood for SOund Navigating And Ranging. The term sonar is now used to refer to technology that utilizes sound waves to navigate, observe, detect, survey, or locate objects. Today sonar technologies are utilized in many different ways including the United States Navy. Active sonar technology works much like echolocation in animals. Its basic components include an acoustic sound projector and a receiver (in some cases more than one receiver is used.) A sound signal is sent from the projector (sometimes called a transducer when used in water). The receiver(s) (called a hydrophone when used in water) detects the echoed sound waves that reflect off of objects such as the sea floor or vessels. These echoed sounds can be analyzed using an array of equations that take into account variables such as sound wave scattering and absorption, ambient noise levels, water temperature, thermoclines, pressure, salinity and density to name a few. Active acoustic sonar systems are used by the Navy to locate enemy submarines that cannot be “seen” any other way. US submarines are also equipped with active sonar systems, which are used to navigate in deep dark waters as well as detect enemy vessels. Because the enemy can detect active sonar sounds, submarines often employ passive sonar technology to detect enemy vessels. This technique allows Navy personal to listen and analyze incoming sounds from enemy subs or ships without making detectable noises. Both passive and active sonar technology is vital to our country’s national defense. In addition to national defense, sonar is used in various other capacities, including seafloor mapping, ocean monitoring, fishing, healthcare, weather monitoring, and oil exploration. Harry Hess, a geologist and United States Navy officer, discovered the mid-Atlantic ridge using sonar technology. This discovery led to the resurrection of Alfred Wegner’s ideas about continental drift, which were generally dismissed prior to this discovery. Now, continental drift is often considered to be one of the top discoveries ever made within geology.

Basic sonar data can be used to determine distance between objects or the depth of water. The equation used to make these calculations is:

\[
\text{distance} = \text{speed of sound} \times \frac{\text{time}}{2}
\]

The speed of sound varies depending on the type of media the sound is moving through as well as temperature. A list of these speeds can be found on the notes page within this lesson. The time is determined by the sonar device (called echosounders), which measures the amount of time it takes the sound to leave the transmitter, travel to an object (or the seafloor), reflect and return back to the receiver. Because we only want to determine the distance to the object and not to the object and back, the time must be divided by 2. It is important to note that this is a basic sonar technique called echosounding. There are other much more sophisticated types of sonar devices that collect and analyze a vast array of data using complex equations as mentioned above. For more information on these advanced sonar calculations, visit the following website: [http://www.dosits.org/science/](http://www.dosits.org/science/)
Classroom Activities (5E Lesson):

Materials
Yarn
Masking tape
Poster board or other smooth flat objects approximately 3’x3’ (plywood, plastic lids to tubs, etc.)
Noise making devices
Blindfold
Clay (or other materials for build a model)
Rulers
Various tools for molding/carving clay

Engage: 15 min

Handouts/Resources:
PowerPoint: Sonar and Echolocation (Presentation Slides 2-8),
PowerPoint: Name That Sound (see advance prep)
Teacher Resource: Name That Sound PowerPoint Notes (see advance prep)

Optional Technology:
Smart devices (i.e. smart phone, iPod, or iPad) with free oscilloscope app installed (i.e. Spectrum View, Oscillo, or RTA Audio)
Interactive whiteboard

Advance Prep:
Download the Name That Sound PowerPoint file bundle. There is a link to this resource on slide 5 of the Sonar and Echolocation PowerPoint. It takes a few minutes to download all of the sound files that go with the PowerPoint.
Print the Name That Sound PowerPoint Notes page included in the file bundle.

Procedure:
1. If students have little background knowledge of sound and sound characteristics, begin this lesson using one of the following options.

Option 1: As homework prior to beginning this lesson, ask students who have smart phones or other smart devices with app capabilities to download a free oscilloscope app from their app store. Instruct students to explore both low and high frequency sounds using their voices. Students should observe the sound waves generated by the oscilloscope as they make low and high pitch noises. For students who do not have smart devices, here is a website with an interactive oscilloscope: http://www.humanbenchmark.com/games.

Option 2: Prior to beginning this lesson, ask student to explore both low and high frequency sounds using the following website:
After opening the interactive illustration, make sure the switch at the top of the illustration is flipped to “Exploring Pitch and Volume.” This can be done at home or in a school computer lab.

2. Based on the exploration and/or their prior knowledge of sound wave characteristics, ask the students to explain the difference in sound waves at low frequency versus high frequency. If you have a smart board available, have student volunteers come forward and draw high and low frequency sound waves. A box is given on slide 4 for each of the drawings. Remind students that Hertz (Hz) is the unit of measure for frequency.

3. Give the following explanations/instructions (slide 5) before beginning the “Name That Sound Game”:
   - You will be listening to a series of sounds traveling through water.
   - Listen to the sound, use the oscilloscope app of your smart device (if possible) to analyze the frequency, and try to identify the sound source.
   - Hold your fingers up for the response you believe is correct.

4. Complete the Name that Sound PowerPoint presentation giving the students time to guess the sound sources. The PowerPoint Notes document is helpful in discussing each of the sounds.

5. Tap into what students know or think about the topic of natural echolocation and sonar by asking the following guiding questions on presentation slides 6-7:
   - Why is sound so important in animals such as the ones you heard in the game?
   - Why is using sound and hearing sometime superior to using light and vision?
   - Why do you think animals use different frequencies of sounds?
   - How do you think an animal uses sound waves to locate objects?
   - What other animals use sound waves to locate objects?

**Remember that this is an engage activity designed to raise questions, stimulate interest and assess what prior knowledge students have about the topic. Teachers should not spend time explaining the answers to these questions. As the lesson progresses these questions will be answered through inquiry and investigation.**

6. Move to the next slide and show the “Bats, Echolocation, and Perception” video clip. Ask students to watch the video and take note of the terms echolocation and sonar. This will be the introduction of these two vocabulary terms in this lesson.

Explore: 55 min

Handouts/Resources:
- PowerPoint: Sonar and Echolocation (Presentation Slides 9-20),
- Student Handout: Battleship: Exploring How to “See” with Ears

Materials (per group):
- Yarn
- Masking tape
- Poster board or other smooth flat objects approximately 3’x3’ (plywood, plastic lids to tubs, etc.)
- Noise making devises
- Blindfold
Optional Technology:
Smart devices (i.e. smart phone, iPod, or iPad) with a free noisemaker app installed (i.e. Noisemaker, Clicker Training Lite, or Beep Free HD)
Interactive whiteboard

Advance Prep:
Cut yarn - Each group will need 3 lengths of yarn: 1 meter, 2.5 meters, and 4 meters.
Reserve large open space such as gym, hallway, or outside area
- This activity requires a large, open area for groups to spread out. If such an area is unavailable, modifications to group size can be made as noted in the procedure below.
Place tape on floor
- Each group will need a center point noted by tape on the ground. The tape should be positioned in a cross formation with labels noting front, back, right and left as shown in the image. To speed up the activity, you may choose to tape one end of the 3 pieces of yarn under the tape as shown in the image. This will allow student to quickly measure out from the center point of their gaming area.

Procedure:
1. Begin by asking the following inquiry-oriented guiding questions (presentation slide 11):
   - Can and do humans use sound to make observations about location of objects around them?
   - How accurate are humans at using sound to echolocate?
   - What body system(s) are involved in echolocation?
   - There are two different methods of echolocation, any ideas on what those might be?
   **Remember that these are questions to be answered through inquiry investigation. At this point students should offer thoughts/answers but the teachers should not confirm or reject answers. Let the investigation do the teaching.**
2. Explain that the next activity, Battleship: Exploring How to “See” with Ears is designed to answer those questions through investigation.
3. Distribute the handout Battleship: Exploring How to “See” with Ears and give students a brief explanation of the activity. Referring to presentation slide 12 might be helpful in this explanation.
4. Divide students into groups of four. Note: If a large area such as a gym or hallway is not available, groups of 6 can be formed therefore reducing the number of groups and the space needed to complete this activity.
5. Direct the students to follow the instructions on the handout to complete the guided investigation.
6. As students work through the investigation, facilitate, listen for misconceptions and encourage cooperative learning.
7. Draw or display the Battlefield Map (presentation slide 13) on an interactive whiteboard.
8. As students return to the classroom, each student group should plot their data on the Battlefield Map for the entire class to reference.
9. After students have graphed the results and written a conclusion, use presentation slides 14 to explain the basic difference in passive and active acoustic detection. More time will be spent on the differences during the explain activity.
10. Ask students to identify which of the two types were used in the investigation. (Passive)
11. If time allows, move forward with the extension activity outlined below. If not, conclude the activity by revisiting and discussing the guiding questions (presentation slide 18).

**Extension Activity:**
- If time allows, challenge students to prove or disprove that humans are capable of navigating using active echolocation.
- Reconvene groups and distribute two or three of flat boards to each group.
- Instruct students to use the boards and noisemakers to complete the challenge. Give students time to investigate.
- Conclude the activity by discussing their findings and revisiting and discussing the guiding questions.

**Homework Extension:**
- Encourage students who have Internet access to review a video documenting examples of humans utilizing echolocation to navigate.
- Possible search phrases include: “human echolocation video” or “Daniel Kish echolocation.”
- Debrief this assignment at the beginning of the next class session using presentation slide 20.

**Explain:** 30 min

**Handouts/Resources:**
- PowerPoint: Sonar and Echolocation (*Presentation Slides 21-34*)
- Student Handout: Sonar and Echolocation Fill-in-Blanks Notes Page

**Optional Technology:**
- Interactive whiteboard

**Procedure:**
1. Encourage students to share and discuss what they know about sonar and echolocation based on their observations and experiences in the engage and explore activities.
2. Record some of the important findings and observations they are sharing. For those who have access to an interactive whiteboard, a box has been given on presentation slide 22 for you to record student responses.
3. Listen and build upon the discussion from the students. Use this opportunity to provide explanation and new definitions for students.
4. Use presentation slides 23-35 as well as the Sonar and Echolocation Notes Page with graphic organizers and diagrams to provide further explanation.
5. Presentation slide 34 gives students an opportunity to listen to actual sonar pings and the echoes created as the pings reflect off an object.

**Explain (Homework Extension Activity)**
Handouts/Resources:
   Student Handout: Digging Deeper: Researching How Sound as a Tool for Observing, Exploring, and Surveying the Natural World

Technology:
   Internet access

Procedure:
1. Pass out the student handout.
2. Review the instructions and go over the example provided.
3. Assign as homework.

Elaborate - 60 min

Handouts/Resources:
   PowerPoint: Sonar and Echolocation (Presentation Slides 36-40),
   Student Handout: Turning Echoes into 3-D Models
   Teacher Resource: Turning Echoes into 3-D Models Teacher Page
   Student Handout: Turning Echoes into 3-D Models Rubric

Materials (per group):
   Clay (or other materials for build a model)
   Rulers
   Various tools for molding/carving clay

Optional Technology:
   Access to graphing software such as Office Excel or Create A Graph at http://nces.ed.gov/nceskids/createagraph/

Advanced Prep:
   Copy and cut out data tables located on the top portion of the Turning Echoes into 3-D Models Teacher Page. Each group of 3 students will need 1 data table.

Procedure:
1. Explain to students that they will now apply what they have learned about sonar in a real world situation.
2. Pass out a Turning Echoes in 3-D Models handout (page 1 only) to each student.
3. Allow time for students to read through the background information and as well as the problem their group will be working to solve.
4. Use presentation slide 37 to briefly discuss the background information and the following guiding questions: What is an echosounder?
How are echosounders used in mapping ocean floors and riverbeds?
How can data provided by echosounders be used in “seeing” under the water?

5. Before dividing students into groups make sure they understand the Problem, Tasks and what is required in the presentation. These are outlined on presentation slides 38-39.

6. Divide students into groups of 3 and distribute a data table, the handout Turning Echoes into 3-D Models Rubric, and craft supplies to each group.

7. Allow students time to complete the three tasks using the rubric for guidance.

8. Move around the room clarifying content and re-teaching when needed. Stress the importance of using the rubric.

Evaluate 20 min

Handouts/Resources:
Student Handout: Turning Echoes into 3-D Models Rubric

Procedure:
1. As groups finish building the model, they must present their recommendations to the ship’s captain (teacher).
2. Students should use the rubric to prepare for the presentation.
3. At the end of the presentation, give students an opportunity to demonstrate overall understanding of concepts and skills by asking the following four open-ended questions:
   ▪ How is the technology you used to create a 3-D model similar to the echolocation techniques used by animals?
   ▪ What is some other ways sonar can be used to observe, survey or examine the natural world?
   ▪ What equation did you use to make calculation for building your 3-D model? Explain the parts of that equation and why it was the appropriate equation to use in this situation.
   ▪ Explain why sound waves were used to map the riverbed rather than other types of waves such as light.

EVALUATION OPPORTUNITIES
1) Participation
2) Direct questioning
3) Lab/activity sheets
4) Homework assignments
5) Presentation at end of lesson
6) Summary of student rubric scores

Re-teaching – As you proceeded through the lesson
• Teachers can use the opportunity given on presentation slide 4 to re-teach characteristics of sound such as intensity and frequency. They can also review waves characteristics such as wavelengths, amplitude, peaks, troughs and interference.
• At the beginning of the elaborate activity “Turning Echoes into 3-D Models” teachers have an opportunity to re-teach basic concepts of active sonar technology.
• After students have researched additional uses of sonar technology in the “Digging Deeper” extension activity, teachers can have students share out their findings and use the opportunity to clarify and expand.
• During the labs the teacher can move around the room listening for misconceptions and clarifying.
• As the teacher moves around the room during cooperative learning activities, they can check for understanding and re-teach concepts as needed.
• After the notes pages have been completed, students can pair up and quiz each other on the information contained on the notes pages.
• After students have completed their presentations during the evaluate piece, the teacher can spend a few minutes re-teaching or clarifying concepts that students seemed to be unclear on during the presentation.

Additional resources


Multiple authors. Discovery of Sound in the Sea. University of Rhode Island. Web. 01 Feb 2012


Battleship: Exploring How to “See” with Ears

(Instruction Page 1)

Materials:
3 lengths of yarn – 1m, 2.5m, and 4m
Noisemaker
Blindfold

Purpose:
Answer the following questions by conducting an investigation, making observations, recording data, and drawing conclusions based on that data.

1) Can and do humans use sound to make observations about location of objects around them?
2) How accurate are humans at using sound to echolocate?
3) How accurate are humans at perceiving distance and direction of sound?

Guided Investigation:

Objective:
During this investigation each student will have an opportunity to test his or her ability to accurately echolocate. Each member will rotate through the following roles:

1 - submarine listening for nearby battleships
2 – battleships emitting sounds that the submarine can detect
1 – facilitator and data recorder

The submarine will be blindfolded while the two battleships strategically position themselves around the submarine. They will then give off two sets of sounds using their noisemaker. The goal of the submarine is to listen to the noise emitted by the battleships and “sink” them. Correctly pointing in their direction and giving a correct distance (1, 2.5, or 4 meters) accomplish this.

Instructions for setting up experiment:

1. Refer to the diagram below to help you visualize what the gaming area will look like.

2. The two players representing battleships (shown as a triangles) must position themselves at a distance of 1 meter, 2.5 meters, or 4 meters (represented by dotted lines) from the center point marked with tape. They should use the yarn to help them measure those distances from the center. They are free to choose where they want to be located around the center point.

3. As they position themselves, the submarine should be standing to the side, blindfolded, and ears covered.

4. When the battleships are set, the facilitator will positions the submarine on the tape facing forward (represented by the star).

5. When everyone is set, the facilitator with tap the submarine on the shoulder so they know to uncover their ears.
Battleship: Exploring How to “See” with Ears
(Instructions - page 2)

6. The two battleships will use their noisemakers to give off two sounds approximately 4 to 5 seconds apart. They should not make the sounds at the same time.

7. As the battleships make the noises, the submarine must remain facing forward and listen for directions and distance of the battleships.

8. After the battleships have made two sounds each, the submarine will try and sink the battleships by pointing in the battleship’s direction and giving a distance of 1m, 2.5m, or 4m.

9. The battleship should verbally indicate whether the submarine hit or missed them. Note: The submarine does not have to point exactly at the battleships center. If they point extremely close to the ship, it is considered a hit. The facilitator has the final say if it is a close call.

10. The facilitator’s job is to plot the position of the battleships on the observation sheet. They should mark where the battleships are located on the “map” using the following key:
   - Red dots = Sunk battleship
   - Blue dots = Submarine aimed in the correct location but missed distance
   - Black dots = Missed battleship

11. The students will rotate positions and play again. This will happen until everyone has had a chance to be the submarine.

12. If your classroom is equipped with an interactive whiteboard, you will need to plot your dots on the master map displayed on the interactive whiteboard. If not, your teacher should have a master map drawn on the board for you to plot your results on.

13. Once everyone has plotted their results, fill in the data table provided and graph the results.

14. Using the information from your results, write a brief conclusion paragraph. Make sure they conclusion answers the three questions

   - *Can and do humans use sound to make observations about location of objects around them?*
   - *How accurate are humans at using sound to echolocate?*
   - *How accurate are humans at perceiving distance and direction of sound?*
Battleship: Exploring How to “See” with Ears
(Data – page 3)

Battlefield Map:

**KEY**
- Red dot = Sunk battleship
- Blue dot = Correct location but missed distance
- Black dot = Missed battleship

Class Data:

<table>
<thead>
<tr>
<th></th>
<th>Sunk (red dots)</th>
<th>Correct Direction (blue dots)</th>
<th>Missed (black dots)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1m  2.5m  4m</td>
<td>1m  2.5m  4m</td>
<td>1m  2.5m  4m</td>
</tr>
<tr>
<td>Front</td>
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<td>Right</td>
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<td>Left</td>
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<tr>
<td>Back</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>
Battleship: Exploring How to “See” with Ears
(Data/Results - page 4)

Results (Graph):

Make sure to choose an appropriate graph to analyze the data collected. It must include a title, key, and axis labels.

Conclusion:

_________________________________________________________________________________________________________________________
_________________________________________________________________________________________________________________________
_________________________________________________________________________________________________________________________
_________________________________________________________________________________________________________________________
_________________________________________________________________________________________________________________________
**Sonar**

An acronym for **SO**** N**_________**And R**_______. It is a technique that utilizes sound waves as a tool for navigating, locating, and observing.

<table>
<thead>
<tr>
<th></th>
<th><strong>Active</strong></th>
<th><strong>Passive</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>How it Works</strong></td>
<td>Uses a sound transmitter and a receiver (__________). This type of sonar creates a pulse of sound and then listens for ________ of the pulse.</td>
<td>This type of sonar listens to sounds from surrounding objects without transmitting active __________ wave.</td>
</tr>
<tr>
<td><strong>Uses</strong></td>
<td>Fisherman – detect fish under or around boat</td>
<td>Used by military for quiet undetectable underwater surveillance and security.</td>
</tr>
<tr>
<td></td>
<td>_______ – detect enemy subs/ships or torpedoes</td>
<td><em>Explore more uses in the homework activity “Digging Deeper”</em></td>
</tr>
<tr>
<td></td>
<td><em>Explore more uses in the homework activity “Digging Deeper”</em></td>
<td></td>
</tr>
<tr>
<td><strong>Visual Explanations</strong></td>
<td>The sub sends out “ping” type sounds (green), which ________ off the enemy ship (red).</td>
<td>The sub listens to sounds produced by the enemy ship (blue) without sending out any _________.</td>
</tr>
</tbody>
</table>

**Sonar and Echolocation Fill-in-Blanks Notes Page (Page 1)**

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Key Points

#1
Sound is often utilized in water by human and marine mammals rather than light because sound wave travels much better than _______ waves. In other words, it is easier to hear in the water than it is to _______.

#2
Basic physics calculations are used to calculate _______ using active sonar. The equation is:

\[ distance = \text{rate} \times \text{time}/2 \]

See the explanation on next page.

#3
_______________________ was used by animals way before scientists developed sonar. The abilities of these animals are still much better than today’s sonar technology.

#4
The fundamental technology and components of sonar were covered in this notes page. It is important to note that there are _______ types of sonar systems. Some are very _______ and can provide military and others with vast amounts of information.
**Basic Sonar Distance Calculation**

\[
\text{distance} = \text{speed of sound} \times \frac{\text{time}}{2}
\]

**D = speed X time/2**

Speed of sound in ocean water = ____________

Time = ______ seconds

Because we only want to know the distance to the ship and not to the ship and back we must divide by 2.

Distance = ____________ X _______ = ____________

**Although we are using basic calculations to determine distance, please note that there are many variables that affect the propagation of sound waves and must be taken into account when analyzing sonar information. These include: water/air ________________, density, absorption and scattering of sound ________________, ambient noise.**
Instructions:

- You must research 4 ways sound is used as a tool to observe, explore, and/or survey the natural world.
- An example has been given, so that you know what information you must provide.
- Because we have already discussed military uses and the example given covers the topic as well, you must choose 4 other ways sound is used as a tool for observation.
- One of the three must explore how an animal (other than bats) uses sound as an observation tool.
- You must provide a credible reference for each example. Wikipedia can only be cited on one of the 4.
- You should use the Discovery of Sound In the Sea (https://dosits.org/science/) website for at least 1 out of the 4 (no more than 2).

Example:

<table>
<thead>
<tr>
<th>Who</th>
<th>Explanation</th>
<th>Website Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Military forces</td>
<td>Sound can be used to find submarines traveling underwater. This can be done by actively transmitting pings and listening for the echo or by passively listening to sounds made by the submarines. Underwater acoustic stations can listen for distinctive sounds that are created during nuclear testing in or just above the waters surface Scanning sonars use sound to find harmful objects such as underwater mines.</td>
<td><a href="https://dosits.org/science/">https://dosits.org/science/</a></td>
</tr>
<tr>
<td>Who</td>
<td>Explanation</td>
<td>Website Reference</td>
</tr>
<tr>
<td>-----</td>
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<td>------------------</td>
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</tr>
</tbody>
</table>
Turning Echoes into 3-D Models
(Page 1)

Background:
Measuring water depths and producing images of seafloors and riverbeds is necessary in preventing collisions with reefs, rock, wreckage from large ships or boats, or the ground itself. One of the most common ways to measure water depths is through a basic active sonar system called an echosounder. These systems use a transducer that emit sound pulses aimed straight down into the water. The sound waves reflect off the bottom and return to the boat. A receiver records the reflected sound waves. The time the sound takes to move from the boat, to the bottom, and back again is used to calculate the distance to the bottom.

Problem:
A large shipping vessel needs to navigate down a river to deliver a load. There is a small stretch of the river that the ship’s captain is particularly worried about because the river widens and becomes shallower. The particular stretch of the river he is concerned about is approximately 30 meters wide (about 110 feet). The ship’s captain says he must have a water depth of at least 5 meters (about 16.5 feet) to navigate safely. He has asked that a 3-D model be made of the river bottom.

Tasks: (see rubric)
1. Graph the data using one of the following: pencil and paper, Office Excel, or https://nces.ed.gov/nceskids/createagraph/
2. Create a 3-D model of the river bottom based on the criteria outlined on the rubric. (Note: NASA’s Engineering Design Process has been provided as a reference on page 2. This can be used to help you in your design and construction process.)
3. Using that model, make a recommendation to the captain about where he should navigate on the river as he moves though this shallow area.

Data:
A boat with an echosounding device has traveled straight across the river as shown in the diagram below. The data collected by the echosounder on the boat is shown in the following data table. The temperature of the water is about 65°F to 70°F.
Turning Echoes into 3-D Models
(Page 2)

This following design process can be used to help you develop your 3-D model.

Engineering Design Process

**STEP 1: Identify the Problem** -- Students should state the challenge problem in their own words. Example: How can I design a _______ that will _______?

**STEP 2: Identify Criteria and Constraints** -- Students should specify the design requirements (criteria). See the rubric for more information on criteria and constraints. Example: Our 3-D model must be to scale.

**STEP 3: Brainstorm Possible Solutions** -- Each student in the group should sketch his or her own ideas as the group discusses ways to solve the problem. These drawings should be quick and brief.

**STEP 4: Generate Ideas** -- In this step, each student should develop two or three ideas more thoroughly. These are to be drawn neatly, using rulers to draw straight lines and to make parts proportional. Parts and measurements should be labeled clearly.

**STEP 5: Explore Possibilities** -- The developed ideas should be shared and discussed among the team members. Students should record pros and cons of each design idea directly on the paper next to the drawings.

**STEP 6: Select an Approach** -- Students should work in teams and identify the design that appears to solve the problem the best. Students should write a statement that describes why they chose the solution. This should include some reference to the criteria and constraints identified above.

**STEP 7: Build a Model or Prototype** -- Students will construct a scaled model based on their drawings. The teacher will help identify and acquire appropriate modeling materials and tools.

**STEP 8: Refine the Design** -- Students will examine and evaluate their designs based on the criteria and constraints. Groups may enlist students from other groups to review the solution and help identify changes that need to be made. Based on criteria and constraints, teams must identify any problems and proposed solutions.

Reference:
NASA’s Engineering Design Challenge,
https://www.nasa.gov/audience/foreducators/best/cdp.html


**Turning Echoes into 3-D Models**

*(Teacher Page)*

Cut this page into 3 different data tables. One data table should be given to each group.

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<th>Position (meters)</th>
<th><em>Time</em> (seconds)</th>
</tr>
</thead>
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<td>0.00085</td>
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<tr>
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<td>0.00137</td>
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<td>10 m</td>
<td>0.00314</td>
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<tr>
<td>12 m</td>
<td>0.00478</td>
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<tr>
<td>14 m</td>
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<tr>
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<tr>
<td>24 m</td>
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<tr>
<td>30 m</td>
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</table>

*This is the time it takes the echo to return to the boat.*

<table>
<thead>
<tr>
<th>Position (meters)</th>
<th><em>Time</em> (seconds)</th>
</tr>
</thead>
<tbody>
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<td>0.00410</td>
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<tr>
<td>30 m</td>
<td>0.00137</td>
</tr>
</tbody>
</table>

*This is the time it takes the echo to return to the boat.*

**Keys:**

![Graph 1](image1)

![Graph 2](image2)

![Graph 3](image3)
Turning Echoes into 3-D Models Rubric

**Graph**

- Title
- Appropriate graph type chosen to analyze data (i.e. bar, line, scatter, etc)
- X and Y axis correctly labeled
- Data correctly plotted on the graph

<table>
<thead>
<tr>
<th>Possible Points</th>
<th>Points Earned</th>
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<tbody>
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**3-D Model**

- Scaling - The model should be scaled down to an appropriate size. It should be large enough to give the captain a detailed look at the shape of the riverbed but not so large that unreasonable amounts of materials are used during its construction.
- Accuracy – the riverbed model should have the correct shape/profile based on the data
- Creativity – the builders creatively construct the model using materials provided

<table>
<thead>
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**Presentation to Captain**

- Present the model to the captain. Be sure to discuss the scale and actual depths of the riverbed.
- Based on your 3-D model, make an appropriate recommendation about the overall safety of navigating down the river. Discuss where he should navigate on the river as he moves though this shallow area.
- Present possible problems or concerns your group might have about navigating in this area.
- Be prepared to answer the following questions about the use of sound to navigate and make observations about the world around us.
  
  *How is the technology you used to create a 3-D model similar to the echolocation techniques used by animals?*
  *What is some other ways sonar can be used to observe, survey or examine the natural world?*
  *What equation did you use to make calculation for building your 3-D model? Explain the parts of that equation and why it was the appropriate equation to use in this situation.*
  *Explain why sound waves were used to map the riverbed rather than other types of waves such as light.*

<table>
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<th>Possible Points</th>
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**Total** 70