

Waves:
Recording Sound Waves and
Sound Wave Interference
(Teacher's Guide)

OVERVIEW

Students will measure a sound wave by placing the Ward's DataHub microphone near one tuning fork A440 ($f=440\text{Hz}$). Then they will use another tuning fork at a slightly different frequency, record both tuning forks at the same time, and analyze the sound wave interference.

MATERIALS NEEDED

Ward's DataHub
USB connector cable*
2 tuning forks A440
1 metal ring for changing tuning fork frequency
2 resonance boxes
1 beater

* – *The USB connector cable is not needed if you are using a Bluetooth enabled device.*

NUMBER OF USES

This demonstration can be performed repeatedly.

FRAMEWORK FOR K-12 SCIENCE EDUCATION © 2012

* The Dimension I practices listed below are called out as **bold** words throughout the activity.

| | | | | |
|--|---|--|---|---|
| Dimension 1 Science and Engineering Practices | ✓ | Asking questions (for science) and defining problems (for engineering) | ✓ | Use mathematics and computational thinking |
| | ✓ | Developing and using models | | Constructing explanations (for science) and designing solutions (for engineering) |
| | ✓ | Planning and carrying out investigations | ✓ | Engaging in argument from evidence |
| | ✓ | Analyzing and interpreting data | ✓ | Obtaining, evaluating, and communicating information |

| | | | | |
|---------------------------------------|---|--|---|--|
| Dimension 2 Cross Cutting Concepts | ✓ | Patterns | ✓ | Energy and matter: Flows, cycles, and conservation |
| | ✓ | Cause and effect: Mechanism and explanation | ✓ | Structure and function |
| | ✓ | Scale, proportion, and quantity | ✓ | Stability and change |
| | ✓ | Systems and system models | | |

| | | | | |
|------------------------------|-------------------|--|------------------------|--|
| Dimension 3 Core Concepts | Discipline | | Core Idea Focus | |
| | Physical Science | PS4: Waves and Their Applications in Technologies for Information Transfer | | |
| | | PS4.A: Wave Properties | | |

| | | | | |
|----------------|--|--|--------------------------------------|--|
| NGSS Standards | Middle School Standards Covered | | High School Standards Covered | |
| | MS.PS-WER: Waves and Electromagnetic Radiation | | HS.PS-W: Waves | |

NATIONAL SCIENCE EDUCATION STANDARDS © 2002

| Content Standards (K-12) | | | |
|--------------------------|------------------------------------|---|---------------------------|
| ✓ | Systems, order, and organization | ✓ | Evolution and equilibrium |
| ✓ | Evidence, models, and explanation | ✓ | Form and Function |
| ✓ | Constancy, change, and measurement | | |

| Physical Science Standards Middle School | | Physical Science Standards High School | |
|--|--|--|---|
| | Properties and Changes of Properties in Matter | ✓ | Structure of Atoms |
| ✓ | Motion and Forces | | Structure and Properties of Matter |
| | Transfer of Energy | | Chemical Reactions |
| | | ✓ | Motion and Forces |
| | | ✓ | Conservation of Energy and Increase in Disorder |
| | | ✓ | Interactions of Energy and Matter |

✓ Indicates Standards Covered in Activity

LEARNING OBJECTIVES

Core Objectives (National Standards):

- Develop the ability to refine ill-defined questions and direct to phenomena that can be described, explained, or predicted through scientific means.
- Develop the ability to observe, measure accurately, identify and control variables.
- Decide what evidence can be used to support or refute a hypothesis.
- Gather, store, retrieve, and analyze data.
- Become confident at communicating methods, instructions, observations, and results with others.

Activity Objectives:

The purpose of this activity is to study sound waves coming from two tuning forks in order to create a hypothesis. The hypothesis will be tested in an experiment using the Ward's DataHub microphone sensor.

Time Requirement:

30-45 minutes

VOCABULARY

Amplitude (A): Using this term refers simply to the maximum displacement from the rest position.

Constructive Interference: The interaction between two or more waves in which displacements combine to produce a wave with a larger displacement.

Crest: Point of the wave that exhibits the maximum amount of positive or upward displacement from the equilibrium position.

Destructive Interference: The interaction between two or more waves in which displacements combine to produce a wave with a smaller displacement.

Frequency (f): The number of complete waves that pass per second. Equal to the reciprocal of the period, frequency refers to how many waves are made per time interval and measured in units of Hertz (Hz).

Hertz: The unit used to measure frequency of a wave.

Interference: The interaction of two or more waves that combine in a region of overlap.

Longitudinal Wave: A wave in which the vibration of the medium is parallel to the direction the wave travels.

Mechanical Wave: A disturbance in matter that carries energy from one place to another.

Node: Region where the disturbances of the wave are almost zero (point of minimum vibration).

Period (T): Time required for a wave to complete a single cycle, measured in unit seconds.

Periodic Motion: Any motion that repeats at regular time intervals.

Speed of a Wave (V): Distance (λ) traveled by a given point on the wave in a given interval of time (T).

In equation form:
$$V = \frac{\lambda}{T}$$

Surface Wave: A wave that travels along a surface separating two media.

Transverse Wave: A wave that causes the medium to vibrate at right angles to the direction in which the wave travels.

Trough: Point of the wave that exhibits the maximum amount of negative or downward displacement from the rest position.

Wavelength (λ): The distance between a point on a wave and the same point on the next wave.

Wave Train (or wave packet): Series of waves traveling in the same direction and spaced at regular intervals, like a wagon train.



Teacher Notes

INTRODUCTION

If you gently touch the surface of a cup of water with a teaspoon, you will notice an oscillatory movement on the water's surface, even though the spoon only touched one point of the surface area. This happens because when the spoon contacts the water, it creates a wave that propagates through the medium.

- **What do you know about the behavior of waves? How would you describe it?**
- **Name examples of waves that you have noticed in your daily life.**

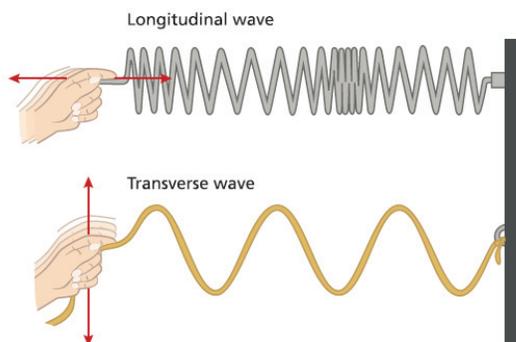
Carry out the experiment activity with your class so that at the end students will be able to answer the following question:

- **How do waves interact with each other?**

BACKGROUND

A wave can be defined as a disturbance or variation that propagates through matter. Waves can be classified depending on the medium and on the direction they travel.

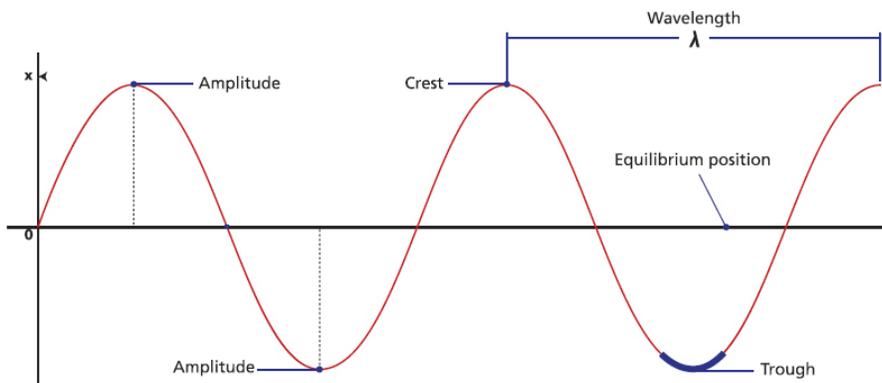
According to the medium of propagation, waves can be classified into two groups: mechanical waves and electromagnetic waves. Mechanical waves are the ones that require a medium to propagate. For example, sound waves travel through the air or some other material. On the other hand, electromagnetic waves, like light waves, do not need a medium to propagate, because they may travel through a vacuum (i.e., empty space).



Waves can be categorized into two groups depending on the direction of their propagation in space: longitudinal waves and transverse waves. In longitudinal waves, the particles of the medium oscillate in a direction parallel to that of the wave's movement. In a transverse wave, the oscillation moves in a direction perpendicular to that of the wave's movement.

If you remember that period and frequency are reciprocal to each other, you can easily obtain the following expression:

$$V = \lambda \cdot f$$



When there is more than one wave in the same space and time, interferences can occur which may be constructive or destructive.

Constructive interference occurs when two waves are superimposed on each other as an addition, either crest over crest or trough over trough. In this case, the final wave has greater amplitude than the original waves, because the amplitude of both is added.

On the other hand, destructive interference occurs when the crest of one wave meets the trough of the other. In this case, the final wave has a smaller amplitude because a positive amplitude is summed to a negative amplitude, in other words, this addition looks like subtraction.

As we mentioned before, sound is a form of mechanical wave caused by the vibration of a medium. Sound travels in space as longitudinal waves, causing a back and forth oscillation of the particles of the medium. Since this oscillation causes temporal changes in air density, high-pressure and low-pressure regions are formed, related to the maximum distance of the particle movement (amplitude).

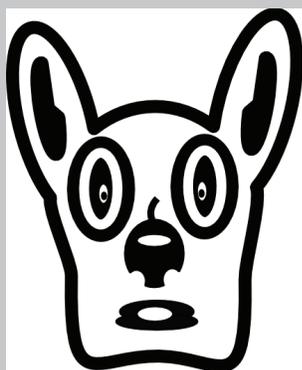
Therefore, sounds are classified as loud or weak depending on the magnitude, referring to the sound intensity. Sound intensity is defined as the amount of acoustic energy that is transported past a given area of the medium per unit time (second).

Acoustic energy depends on acoustic power. Wave amplitude and acoustic power are directly proportional to each other, i.e.,



DID YOU KNOW?

Dogs can hear sounds at a higher frequency than humans. This is why a dog may bark or become scared of a noise even when humans do not hear anything.



the higher the amplitude, the greater the acoustic power. You can conclude accordingly that wave amplitude and sound wave intensity are directly proportional. For this reason, we will use sound wave intensity in unit decibels (dB) as equal to amplitude, even if we know them to be different concepts.

Now students are encouraged to raise a hypothesis which must be tested with an experiment. Students may find it helpful to formulate their hypothesis as an answer to the following questions.

- **Let's record a sound wave. How do you think a sound wave will look?**
- **How do you think that two waves of a similar nature, coming from two different sound sources, will interact with each other?**

CONNECTING THE WARD'S DATAHUB TO A COMPUTER

If you are using a Bluetooth communication device:

Right click on the Bluetooth icon in the lower right corner of the screen and select the Ward's DataHub you are using. The icon will change from gray to blue, as shown at right, indicating that the Ward's DataHub and the computer are now connected.

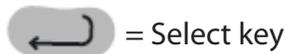


If you are using a USB communication device:

In order to use USB communication, connect the Ward's DataHub and the computer with the USB cable supplied. Click on the USB icon at the lower right corner of the screen. This icon will change from gray to blue, as shown at right, indicating that the Ward's DataHub is connected to the computer via USB.



USING THE WARD'S DATAHUB



= Select key



= On/Off and Escape key



= Scroll key

To collect measurements with the Ward's DataHub, it must first be configured as follows:

| | | | |
|---|--------------|--|--------------|
| 1. Turn on the Ward's DataHub by pressing the On/Off/Esc key. | | 8. Press the On/Off/Esc key to return to the setup menu. | |
| 2. Go to setup by using the Scroll key; then select Setup by pressing the Select key. | then | 9. Press the Scroll key to highlight the Number of Samples and then press the Select Key. | then |
| 3. Select the Set Sensors option by pressing the Select key. | | 10. Press the Scroll key until "1000" is highlighted then press the Select key. | then |
| 4. If any sensor(s) appear on the screen, press the key representing that sensor to deactivate it. Once you have a blank window, press the Microphone Sensor key once. | | 11. Press the On/Off/Esc key three times to return to the main operating screen. | x 3 |
| 5. Press the On/Off/Esc key once to return to the setup menu. | | 12. Press the Select key to start measuring. (You are collecting data when there is an icon of a runner in the upper left hand corner of the screen.) | |
| 6. Press the Scroll key to highlight the Sampling Rate and then press the Select Key | then | 13. Once you have finished measuring, stop the Ward's DataHub by pressing the Select key, followed by the Scroll key. | then |
| 7. Use the Scroll key until "25,000/min" is highlighted, then press the Select key. | then | | |



DID YOU KNOW?

Thunder is a sound wave produced as a result of lightning. When lightning occurs, a sudden increase in pressure and temperature in that given area causes a rapid expansion of the surrounding air. This in turn creates a sonic shock wave, similar to a sonic boom, which produces the sound of thunder. The average person can hear thunder from about 10 miles away.



EXPERIMENT 1

We will first record one tuning fork.

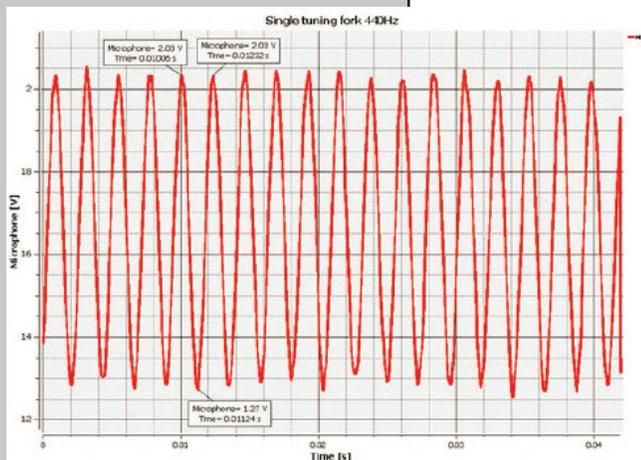
1. Insert the tuning fork into the resonance box.
2. Place the Ward's DataHub about 10 centimeters away from the resonance box.
3. Hit the tuning fork with the beater and wait 1 to 2 seconds for the sound to stabilize.
4. Press the RUN icon in the software.
5. The Ward's DataHub will record 1000 samples in less than a second and then automatically upload all samples to the DataHub software.

RESULTS AND ANALYSIS – EXPERIMENT 1

The following steps explain how to analyze the experiment results.

1. Connect the Ward's DataHub to the computer using the Bluetooth wireless communication channel or USB connector.
 2. In the top menu, click in the  button and select the  button.
 3. Select the last experiment on the list.
 4. Observe the graph displayed on the screen.
 5. Click the  button to zoom in on a section of the graph.
 6. Press the  button and write notes on the graph specifying the maximum and minimum amplitude value.
 7. Press  to select two points on the graph, representing the beginning and end of a single oscillation. Use the time values provided to calculate the period and frequency of the selected wave.
- What does a sound wave look like?
 - What frequency did you obtain?

The graph on the left should be similar to the one the students came up with.





DID YOU KNOW?

Have you ever heard a whip cracking? That loud noise occurs because the tip of the whip is moving so fast it breaks the speed of sound! (Sound travels at 767 miles per hour / 1,230 kilometers per hour.)



EXPERIMENT 2

In this experiment, we will record the sound from two tuning forks at slightly different frequencies.

1. Use the previous Ward's DataHub Setup, except change the number of samples to 10,000.
2. Secure the tuning fork metal ring in the center of the second tuning fork (this will slightly change its frequency).
3. Insert this second tuning fork into the second resonance box.
4. Place the tuning forks 20 centimeters away from each other, where both resonance boxes are open and facing each other.
5. Place the Ward's DataHub microphone in the center between the tuning forks.
6. Hit both tuning forks with the beater and wait 1 to 2 seconds for the sound to stabilize.
7. Press the RUN icon in the Ward's DataHub software.
8. The Ward's DataHub will record 10,000 samples in less than a second and then automatically upload all samples to the Ward's DataHub software.

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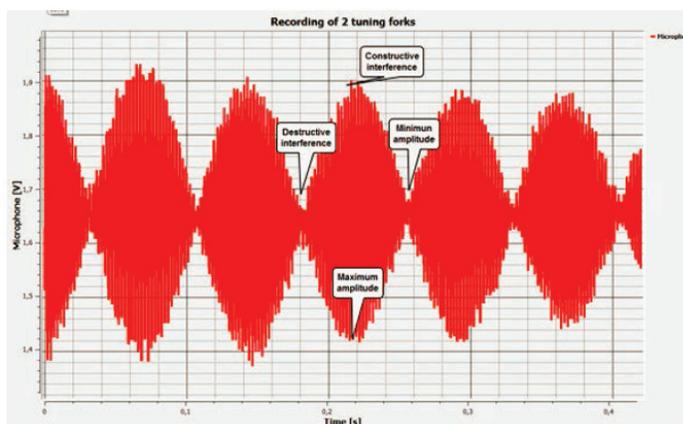
RESULTS AND ANALYSIS – EXPERIMENT 2

The following steps explain how to analyze the experiment results.

1. If the Ward's DataHub did not download automatically, press the  download button and select the last experiment on the list.
2. Observe the graph displayed on the screen.
3. Click the  button to zoom in on a section of the graph.
4. Press the  button and write notes on the graph specifying the maximum and minimum amplitude value.
5. Press  to select two points on the graph, representing the beginning and end of a single oscillation. Use the time values provided to calculate the period and frequency of the selected wave.

- **How do your results relate to your original hypothesis?**
- **Where would you mark the maximum amplitude and the minimum amplitude?**
- **Where would you mark constructive interference and destructive interference?**

The graph below should be similar to the one the students came up with.



CONCLUSIONS AND ASSESSMENTS

1. What is a wave?

Students should explain that a wave is a perturbation of the medium that travels from its source in all directions.

2. **Describe** a sound wave, mentioning the medium and the propagation direction.

Students should indicate that, relating the medium of propagation, sound waves are mechanical waves. According to the propagation direction, we can categorize them as longitudinal waves.

3. According to the graphs, what kinds of interferences did you record? Why did these interferences appear? **Explain.**

Students should analyze the graphs and observe the wave amplitude variation in time. They should establish that the amplitude increases and decreases alternatively, concluding that the experiments registered both constructive and destructive interference. Constructive interference occurred because of the crest of one wave superimposed over the crest of the other. The destructive interference was the product of a wave trough superimposing over the crest of another.

4. What concepts of sound waves and wave interference can be obtained from the graphs?

Students should understand the concepts presented in the teacher background. They should use the graphs to obtain the necessary parameters to calculate values. As the y-axis on each graph displays sound wave intensity and the x-axis displays time in seconds, students should be able to obtain several characteristics such as amplitude, trough, crest, period and frequency.

Students should reach the following conclusions:

We can describe the "anatomy of waves" by naming the parts of it, for example: wave train, node, amplitude, period and wavelength. Besides the direct information that may be extrapolated from the graph, we can also calculate some parameters indirectly. In this way, we can obtain frequency and speed of propagation.

When there is more than one wave in the same space and time, interferences can occur which may be constructive or destructive. Constructive interference occurs when two waves are superimposed on each other as an addition, either crest over crest or trough over trough. In this case, the final wave has greater amplitude than the original waves, because the amplitude of both is added. Both types of interferences were observed during the experiment.



DID YOU KNOW?

Sound travels four times faster in water than in air, and sound does not occur at all in a vacuum. Therefore, you could yell at the top of your lungs in space and there would be no sound.

ACTIVITIES FOR FURTHER APPLICATION

The aim of this section is for students to extrapolate the knowledge acquired during this class and apply it to different contexts and situations. Furthermore, it is intended that students question and present possible explanations for the experimentally observed phenomena.

1. If the speed of a wave's propagation is 400 m/s and its wavelength is 1.2 m, calculate the wave period.

Students should use the concepts explored during the class to answer this physics problem. They should extract the variables needed to solve the problem and identify correctly the unknown factor. Following is the problem's solution:

Variables:

$$\text{Speed} = 400 \text{ [m/s]}$$

$$\lambda = 1.2 \text{ [m]}$$

$$T = \text{unknown}$$

Solution:

If you remember

$$v = \frac{\lambda}{T}$$

you can rearrange the expression to become

$$T = \frac{\lambda}{v}$$

Using the data of the problem statement, you can obtain the value of the unknown factor:

$$T = \frac{(1,2 \text{ [m]})}{(400 \text{ [m]}) \text{ s}}$$

$$T = 0.003 \text{ [s]}$$

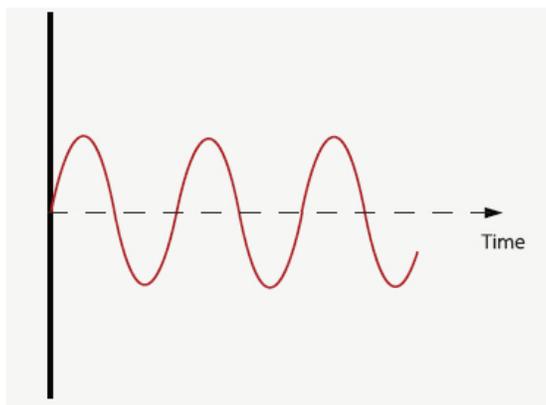
2. Match the concepts on the left to the corresponding statement on the right.

- | | |
|------------------------|---|
| A Frequency | 1 $V = \lambda \cdot f$ |
| B Mechanical wave | 2 Can travel through empty space (vacuum) |
| C Crest | 3 Distance between two consecutive crests or troughs |
| D Wave | 4 Electromagnetic wave |
| E Amplitude | 5 Its unit of measurement is Hertz |
| F Wave train | 6 Packets of waves moving together |
| G Speed of propagation | 7 Needs matter to propagate |
| H Electromagnetic wave | 8 Highest point of a wave |
| I Wavelength | 9 Maximum distance of a wave from the equilibrium point |
| J Longitudinal wave | 10 Sound wave |
| K Transversal wave | 11 Perturbation that travels through space |

Students should apply their knowledge and obtain the following matches.

$A = 5$ $E = 9$ $I = 3$
 $B = 7$ $F = 6$ $J = 10$
 $C = 8$ $G = 1$ $K = 4$
 $D = 11$ $H = 2$

3. Find and write down the following concepts in the figure: wave train, amplitude, trough, crest, equilibrium line, and wavelength.



Students should label the figure characterizing the wave with the concepts they have learned during the class. They should obtain an image similar to the one presented in the theoretical background.

Waves:
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(*Student Guide*)

INTRODUCTION

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- **Name examples of waves that you have noticed in your daily life.**

After carrying out this experiment, you should be able to answer the following question:

How do waves interact with each other?

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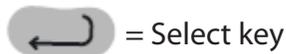


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2. **Describe** a sound wave, mentioning the medium and the propagation direction.

3. According to the graphs, what kinds of interferences did you record? Why did these interferences appear? **Explain.**

4. What concepts of sound waves and wave interference can be obtained from the graphs?

5. Write a **concluding** paragraph describing what you observed during the experiments.
