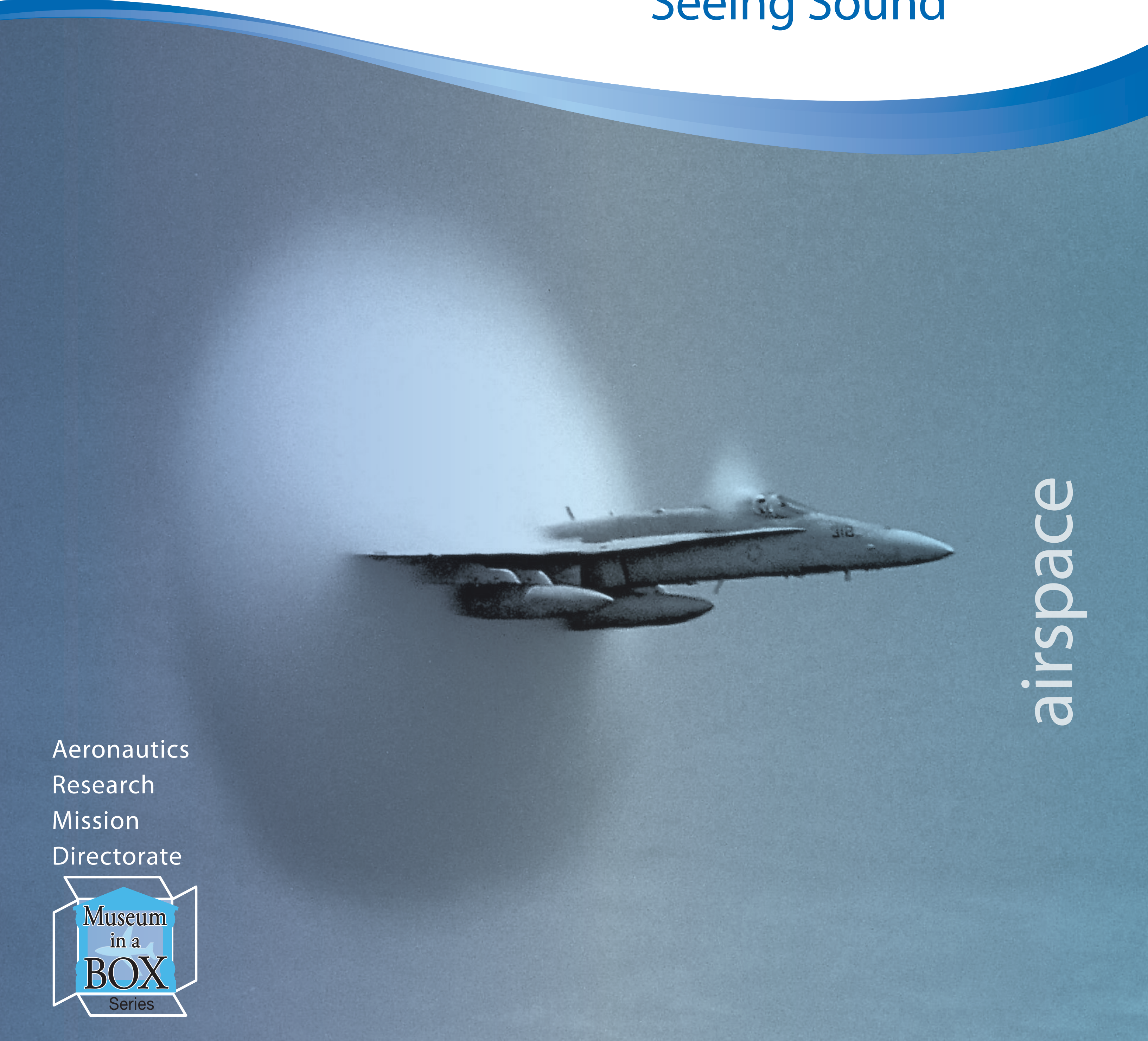
National Aeronautics and Space Administration

GRADES **K-8**

Seeing Sound



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Museum in a BOX Series

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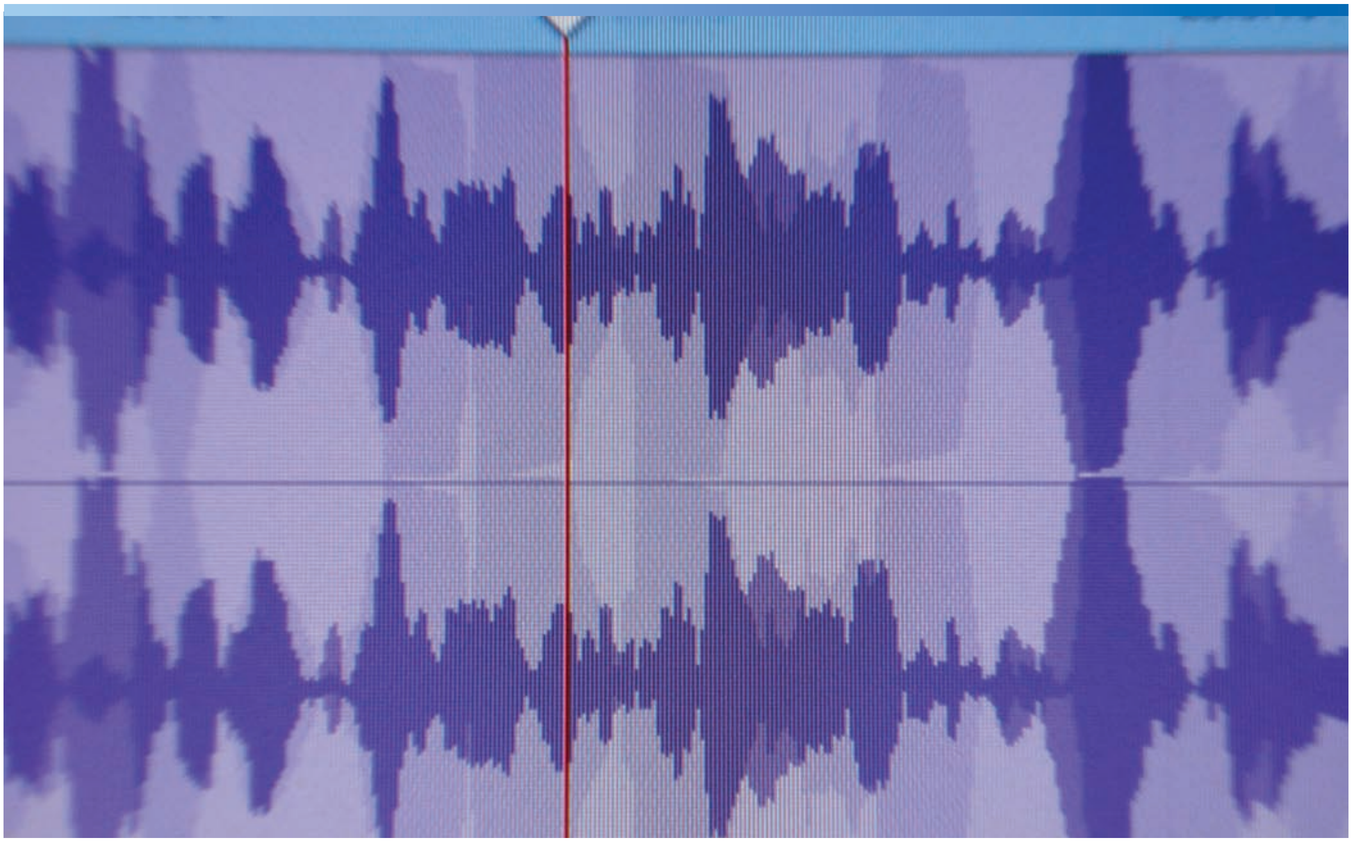
MUSEUM IN A BOX



Seeing Sound

Lesson Overview

In this lesson, students will use a beam of laser light to display a waveform against a flat surface. In doing so, they will effectively "see" sound and gain a better understanding of how different frequencies create different sounds.

Objectives

Students will:

1. Observe the vibrations necessary to create sound.

Materials:

In the Box

PVC pipe coupling
Large balloon
Duct tape
Super Glue
Mirror squares
Laser pointer
Tripod
Tuning fork
Tuning fork activator

Provided by User

Scissors

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Time Requirements: 30 minutes

Background

The Science of Sound

Sound is something most of us take for granted and rarely do we consider the physics involved. It can come from many sources – a voice, machinery, musical instruments, computers – but all are transmitted the same way; through vibration.

In the most basic sense, when a sound is created it causes the molecule nearest the source to vibrate. As this molecule is touching another molecule it causes that molecule to vibrate too. This continues, from molecule to molecule, passing the energy on as it goes. This is also why at a rock concert, or even being near a car with a large subwoofer, you can feel the bass notes vibrating inside you. The molecules of your body are vibrating, allowing you to physically feel the music.

As with any energy transfer, each time a molecule vibrates or causes another molecule to vibrate, a little energy is lost along the way, which is why sound gets quieter with distance (Fig 1.) and why louder sounds, which cause the molecules to vibrate more, travel farther. The loudness of a sound is measured in decibels, or dB, with sounds above 120dB having the ability to cause permanent hearing loss to humans. The table below shows how various sources of sound compare (Fig 2).

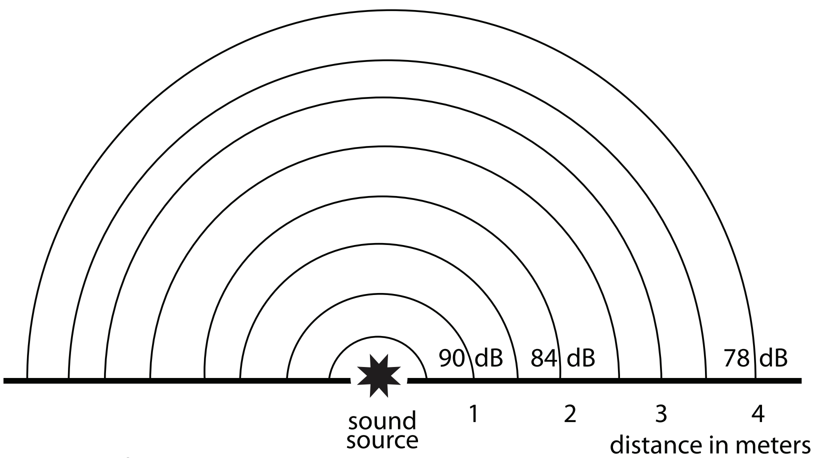


Fig. 1 Sound vs Distance

Jet plane at takeoff	110-140dB
Loud rock music	110-130dB
Chain saw	110-120dB
Thunderstorm	40-110dB
Vacuum cleaner	60-80dB
Normal voices	50-70dB
Whisper	20-50dB
Purring cat	20-30dB
Falling leaves	10dB
Silence	0dB

Fig. 2 A comparison of sound levels

A sound wave is the name given to the pattern a sound creates and can be seen on a waveform monitor. A single tone, such as that produced by a tuning fork, creates a very uniform wave, while human speech, with all the inflections and changes in tone, causes a much more erratic-looking one (Fig. 3).

In this lesson students will create a waveform monitor by using a balloon as a sound absorbing membrane and a laser to visually display the vibrations. While the waveform produced will not have the familiar look to them due to the design of this experiment, they will allow students to physically "see" the sound waves.

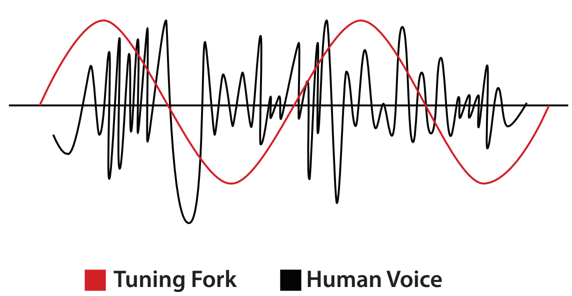


Fig. 3 Sample waveforms

The Sound Barrier & The Sonic Boom

Most people have heard of "breaking the sound barrier" but what does that really mean? The sound barrier is "broken" when an aircraft exceeds the speed of sound. More accurately, it is the point at which the object's speed increases from the transonic range (slower than sound) to the supersonic range (faster than sound).

As an object passes through the air, the air resistance creates a series of pressure waves both in front of and behind that object, similar to how the hull of a boat creates wake in the water. These pressure waves travel at the speed of sound, which for most aircraft isn't a problem. As the speed of the object increases however, the waves are forced together, or compressed, because they cannot get out of each other's way. By the time the object reaches the speed of sound, these pressure waves are compressed so tightly they become a single wave, with the pressure being as high as 7,000 Pa, or 144 pounds per square foot. It is this increase in pressure that creates the infamous "Sonic Boom".

(Image Courtesy of the United States Navy)

Img. 1 An F/A-18 breaking the sound barrier

In rare instances, you can actually see the sound barrier being broken. Image 1, which is also on the cover of this lesson, is an F/A-18 Hornet with a white cloud enveloping the rear of the aircraft. This cloud was created by a large drop in air pressure behind the wing at the precise moment the aircraft broke the sound barrier. Notice the smaller cloud that also formed near the rear of the cockpit, which is another sonic boom.

Pilots of jet aircraft often refer to their speed in relation to the speed of sound, using the term "mach number", which is the ratio of the aircraft's speed compared to that of the speed of sound. Mach 1, for example, is the speed at which sound travels, while Mach 2 equates to twice the speed of sound. Most airliners move fairly slowly for takeoff and landing but fly at approximately Mach .80 (M .80), or 80% of the speed of sound, when up at cruising altitude.

While sound waves are not usually able to be seen as they are when some aircraft break the sound barrier, the following activity will allow students to visualize sound waves firsthand.

Activity 1

Building a Waveform Monitor

GRADES K-8

Time Requirements: 30 minutes

Materials:

In the Box

PVC pipe coupling
Large balloon
Duct tape
Super glue
Mirror squares
Laser pointer
Tripod
Tuning fork
Tuning fork activator

Provided by User

Scissors

Worksheets

None

Reference Materials

None

Key Terms:

Frequency (sound)
Pitch (sound)
Volume
Waveform
Waveform monitor

Objective:

Students will observe the vibrations necessary to create sound.

Activity Overview:

In this activity, students will use a beam of laser light shined against a mirror on a vibrating balloon membrane to display a waveform against a flat surface. In doing so, they will effectively "see" sound and gain a better understanding of how different frequencies create different sounds.

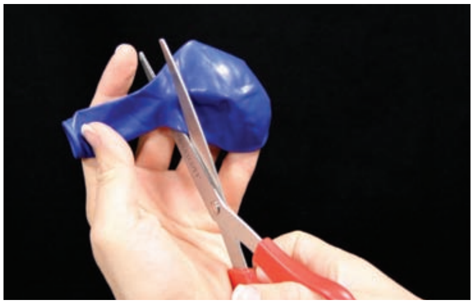
Watch video of demonstration.

Activity:

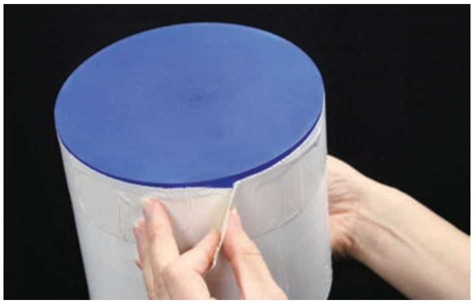
1. **Begin this activity by discussing with the students how sound waves are transmitted, using the Background information provided.**

2. **Explain how it is possible to see sound by converting the sound waves to kinetic energy (movement).** As you build the apparatus described below, explain to the students how each item works and how it can be used to see sound waves.

3. **To start, take a large balloon and cut off the neck, or the part you would normally blow into.** This is to make the opening larger and allow the balloon to be stretched more easily.



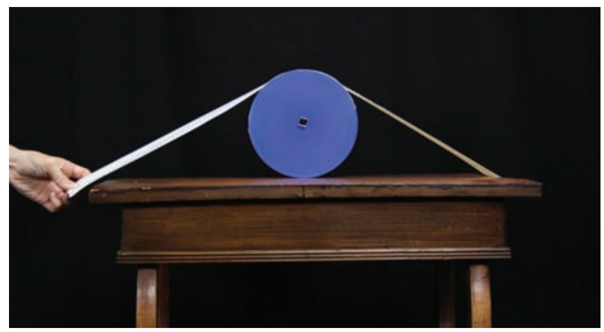
4. **Use duct tape to secure the balloon over one end of the PVC pipe, making something that looks like a drum.**



5. **At this stage, show the students how the balloon can vibrate by tapping on it.** Explain that this device is exactly like their ears; a hollow chamber with a thin skin covering it.

6. **Next, glue a small square of mirror to the center of the front of the balloon.** Hold it firmly for a few seconds to allow the glue to dry before letting go.

7. **Once the glue has dried, turn the device on its side, with the balloon end facing either a light-colored wall or a large sheet of white paper taped to a wall.** Using tape, firmly secure the device to the table so it cannot move.



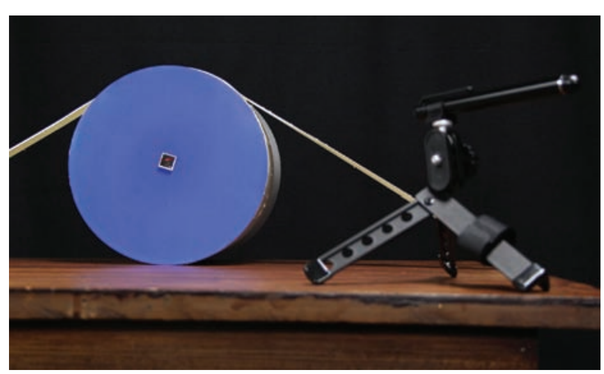
Caution: The next steps involve the use of a low power laser. While chance of injury is very low, advise the students to NEVER point the laser into someone's eyes, or to stare directly at the beam.

8. **Remove the laser pointer from its case and if necessary, install the batteries per the instructions.**

9. **Explain to the students that a laser is simply a very concentrated beam of light.** If desired, point the laser at the wall to show them the red dot of light that is created when the button is pushed.

10. **Open the legs of the tripod and place it on the table in front and to the side of the balloon assembly.** Insert the laser pointer into the cradle on the top, ensuring that one of the arms is holding the button firmly in the ON position.

11. **Lastly, align the laser dot so that the beam of light is aimed at the mirror on the balloon and reflected onto the wall or large sheet of paper.**

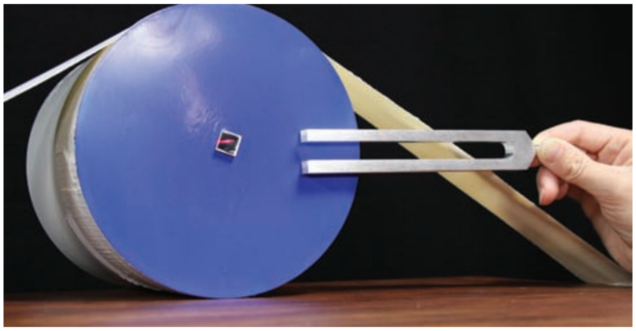


12. **At this point the dot on the wall should still resemble a dot, with very little movement.** Explain that this is because there are no sound waves being captured by the balloon.

13. **Ask a student to speak loudly into the open end of the PVC pipe while the rest of the class watches the effect it has on the light on the wall.**

14. **Have the students take turns whispering, shouting or singing into the balloon device.** If available, try other sound sources such as radios and musical instruments.

15. **Lastly, demonstrate the effect a tuning fork has on the balloon.** To do this, strike the fork firmly on the activator to start it vibrating, then place it gently against the skin of the balloon.
You should see a perfectly round sound wave pattern displayed by the laser.



Discussion Points:

1. **What causes sound?**
Sound can only be generated through vibration. When we speak, play music or otherwise produce sound, the air is vibrated which in turn vibrates our ear drums, allowing us to hear it. In a vacuum such as in space, there is no air to vibrate and therefore it is silent. Sound can also be transmitted through other solid materials although it does not do so as efficiently as air.

2. **How did things like volume and pitch change how the light reflected on the wall?**
The light pattern generated was directly related to the type of sound being made in the PVC pipe. Higher pitched voices, like those from younger children and females, had tighter, or more closely spaced waves while adults or men, with their lower voices, created waves that were further apart. The name given to this wave property is called a frequency.

3. **What happened when the tuning fork was placed against the balloon?**
It is difficult to demonstrate, however, if done correctly two things should have happened. Firstly, the sound should have been amplified by the PVC pipe in the exact same way our ears amplify the sounds we hear. Second, the waveform on the wall should have been a perfect circle, as opposed to the wavy lines seen in the students' voices. This is because the tuning fork emits a perfect, constant pitch, or frequency, unlike our voices which vary in pitch as we speak or sing.

4. **Did the pattern created by the laser light look familiar when playing music or using our voices?**
Many computer programs, such as iTunes and Windows Media Player, have a waveform monitor which is visible while the music is playing. The waveform shown on the screen will look similar in appearance to the light pattern displayed on the wall.

NATIONAL SCIENCE STANDARDS K-4

SCIENCE AS INQUIRY

• Abilities necessary to do scientific inquiry

• Understanding about scientific inquiry

PHYSICAL SCIENCE

• Property of objects and materials

SCIENCE AND TECHNOLOGY

• Abilities of technological design

• Understanding about science and technology

NATIONAL SCIENCE STANDARDS 5-8

SCIENCE AS INQUIRY

• Abilities necessary to do scientific inquiry

• Understandings about scientific inquiry

PHYSICAL SCIENCE

• Properties and changes of properties in matter

SCIENCE AND TECHNOLOGY

• Abilities of technological design

• Understanding about science and technology

Reference Materials

Glossary

Frequency (sound):
The number of repeated cycles of a waveform in a specific unit of time

Pitch (sound):
The height of a voice or note (the pitch of a child's voice is higher than that of an adult's); higher-pitched sounds have shorter wavelengths than lower-pitched sounds

Volume:
The amplitude, or loudness of a sound

Waveform:
The shape of a soundwave illustrated by plotting the pitch value against time

Waveform Monitor:
An electronic device used to display a waveform in an electronic form

Fig. 1 Sound vs Distance

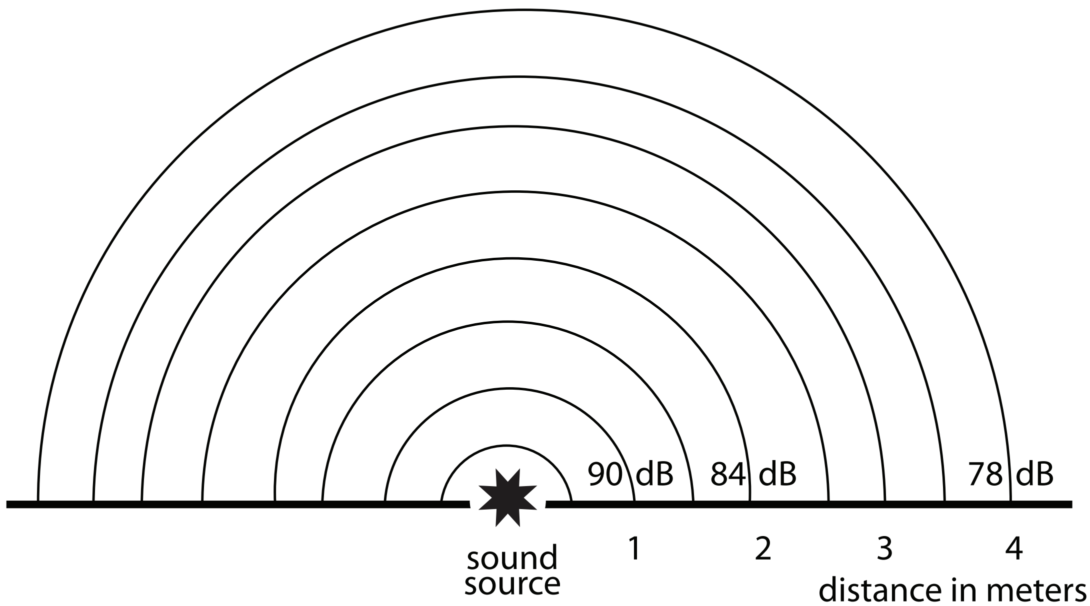


Fig. 2 A comparison of sound levels

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Loud rock music	110-130dB
Chain saw	110-120dB
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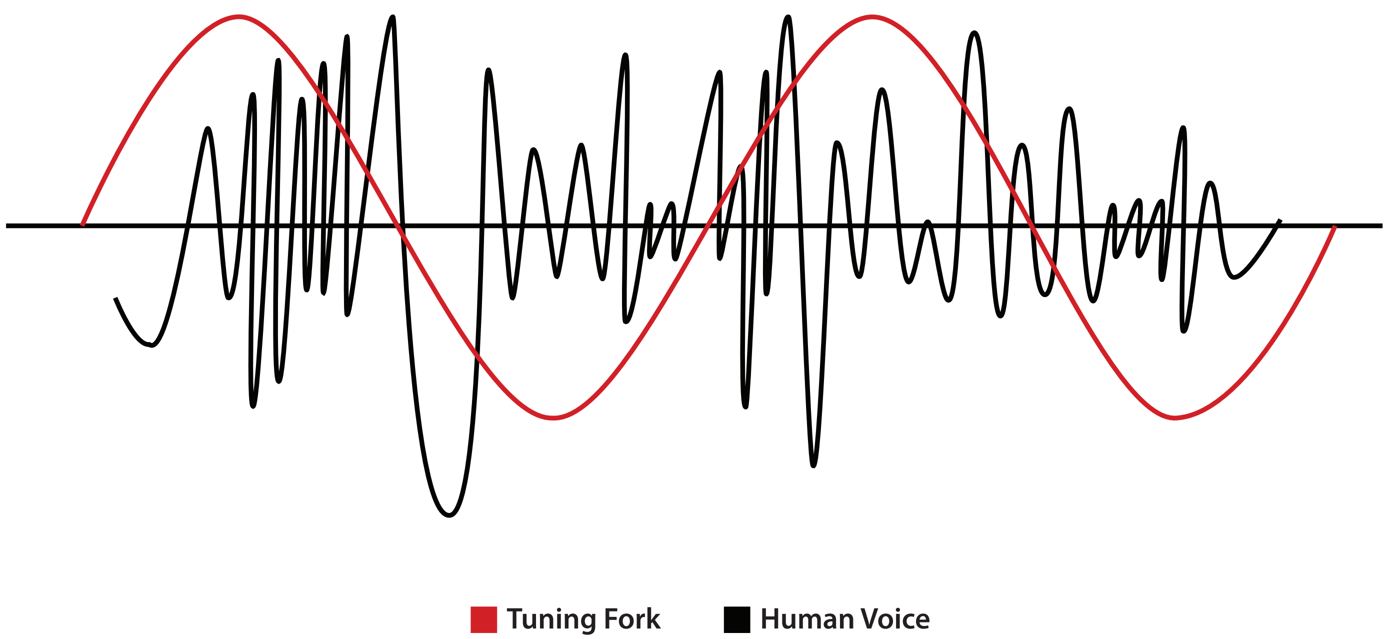
Fig. 3 Sample waveforms



Images

Img. 1 An F/A-18 breaking the sound barrier

(Photo courtesy of the United States Navy)

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