Module 3 – Nautical Science

Unit 5 – Physical Science

Chapter 23 - Sound and Sonar

Section 1 – The Essence of Sound

What You Will Learn to Do

Demonstrate an understanding of Physical Science

Objectives

1. Explain the effects that density and temperature have on sound

2. Explain how the ear detects sound

Key Terms

CPS Key Term
Questions 1 - 4

Key Terms

Eardrum - A membrane of the middle ear that vibrates in response to sound waves; the tympanic membrane

Ear Canal - The narrow, tube like passage through which sound enters the ear; the external auditory canal

Key Terms

Sound intensity -	The essential organ of hearing and equilibrium that is located in the temporal bone, in innervated by the auditory nerve and includes the vestibular, the semicircular canals and the cochlea
Inner ear -	The amount of energy or power in a sound wave at any given location

Opening Question

Discuss how frequency of a sound wave determines what the human ear can hear.

1.

2.

3.

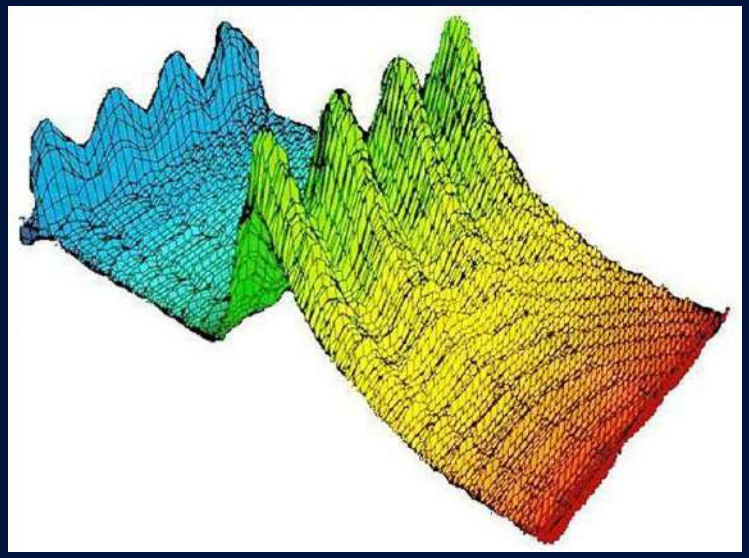
(Use CPS "Pick a Student" for this question.)

Warm Up Questions

CPS Lesson
Questions 1 - 2

Introduction

Wave energy is classified by two types which are material and electromagnetic waves.



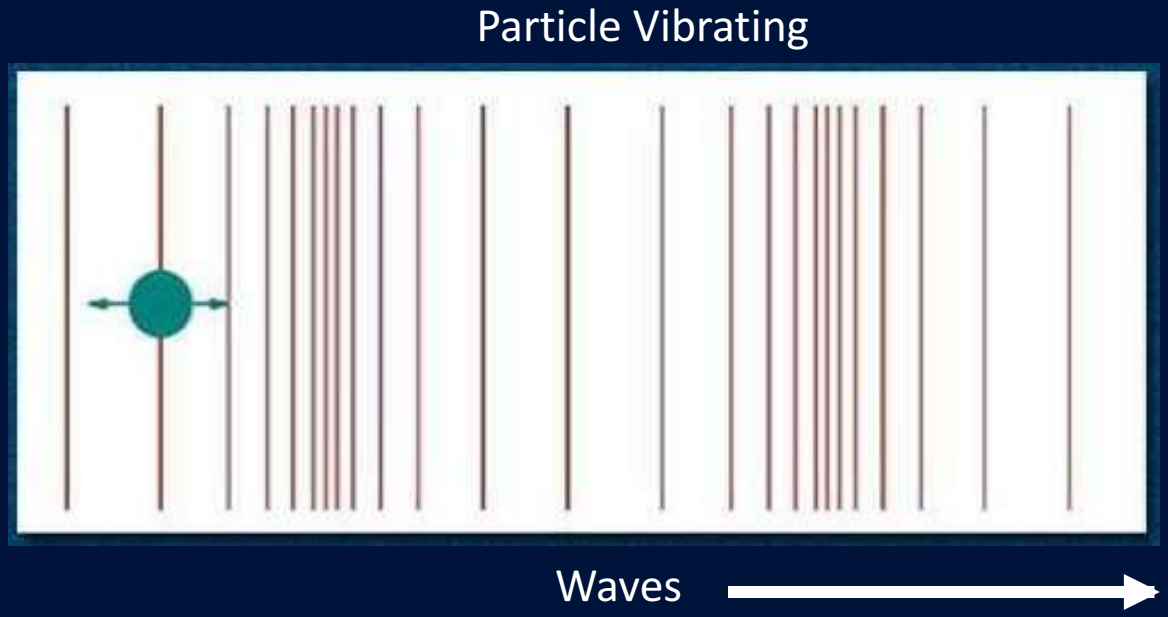
Sound is a material wave.

Introduction

Sound originates at a source of energy which causes matter to vibrate.

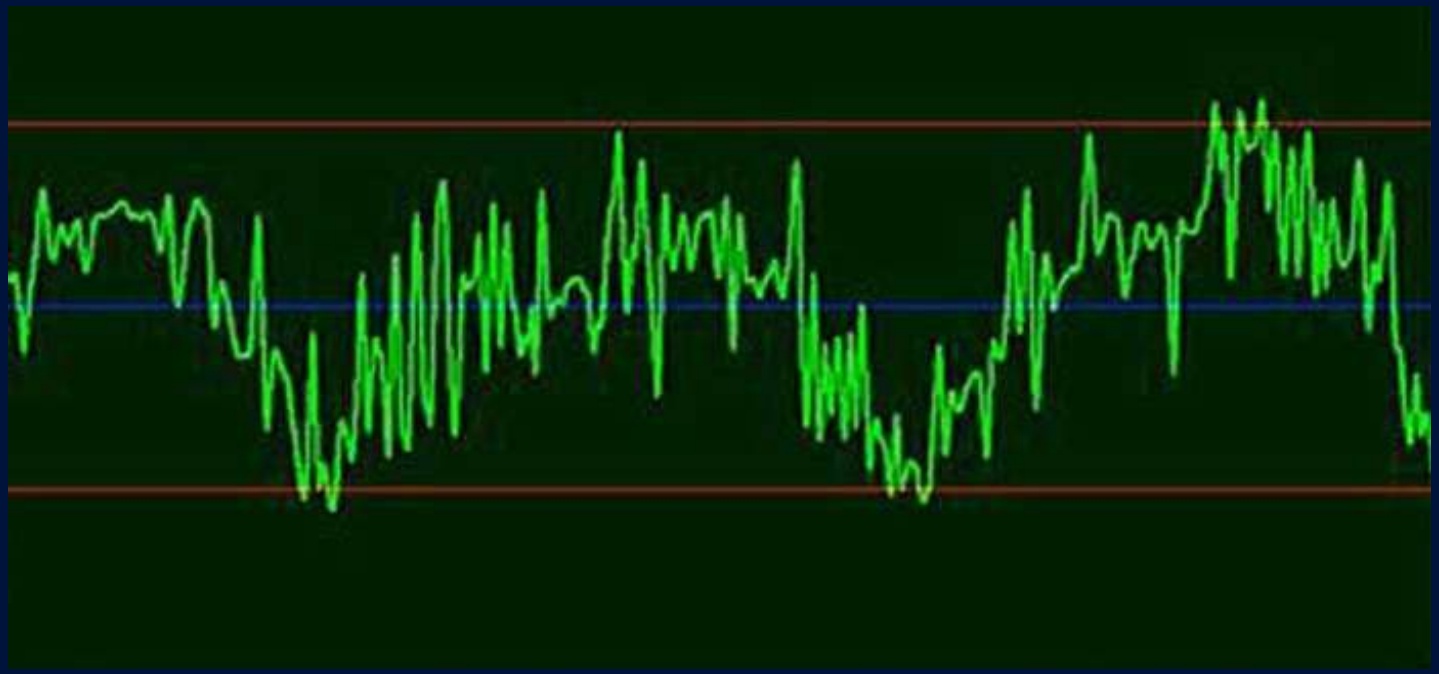
Introduction

These vibrations enter the material surrounding the source (the medium) in the form of a series of longitudinal pressure waves.



Introduction

Source



Each wave carries with it a certain amount of energy imparted to it by the source as it vibrates.

Introduction

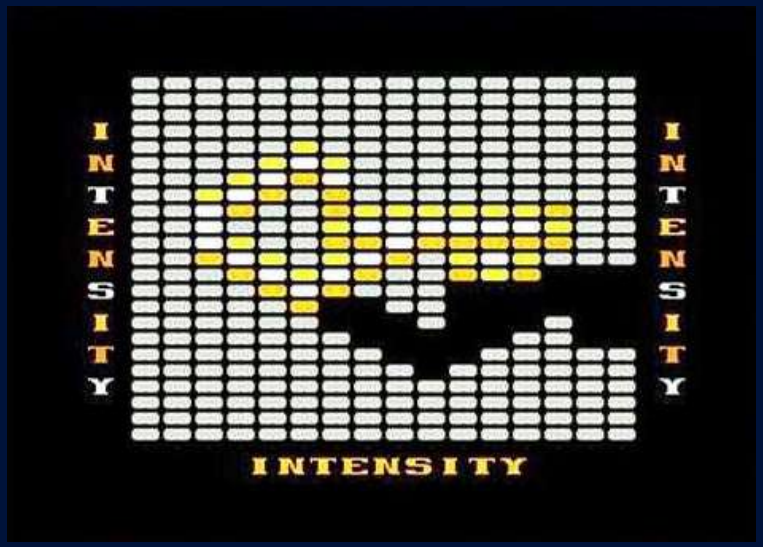
In a medium with uniform density and temperature, waves spread in expanding three-dimensional spheres similar to ripples in water.

Available energy in a wave is spread over an ever-increasing area as each sphere expands.

Introduction

With the area of a sphere being $4\pi r^2$, the energy per unit area falls off rapidly as the distance (the radius r) from the sound source increases.

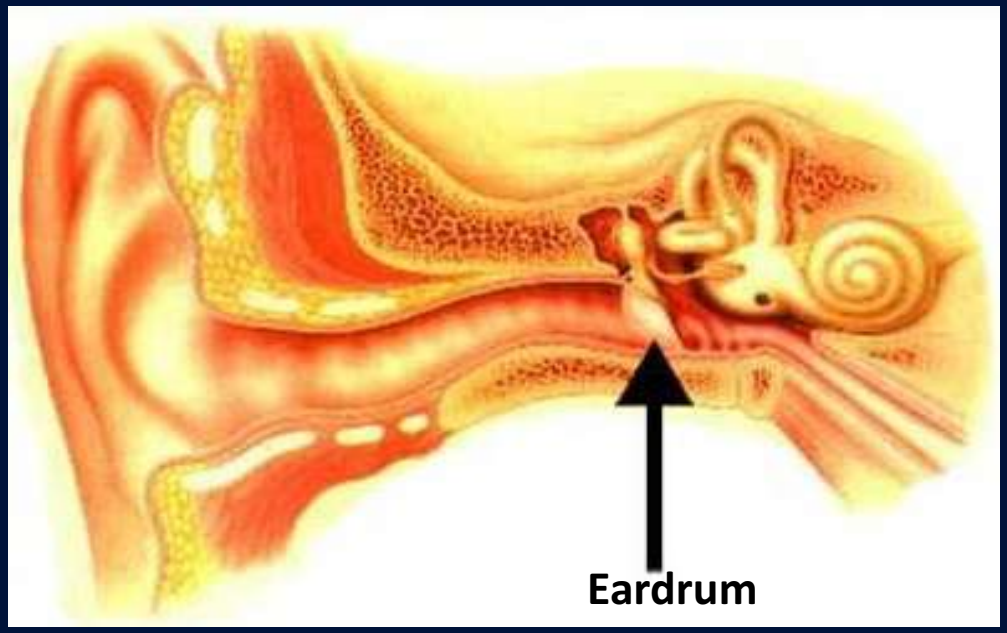
$4\pi r^2$



Sound intensity is expressed in terms of watts per square centimeter or per square meter.

Introduction

10^{-12} →

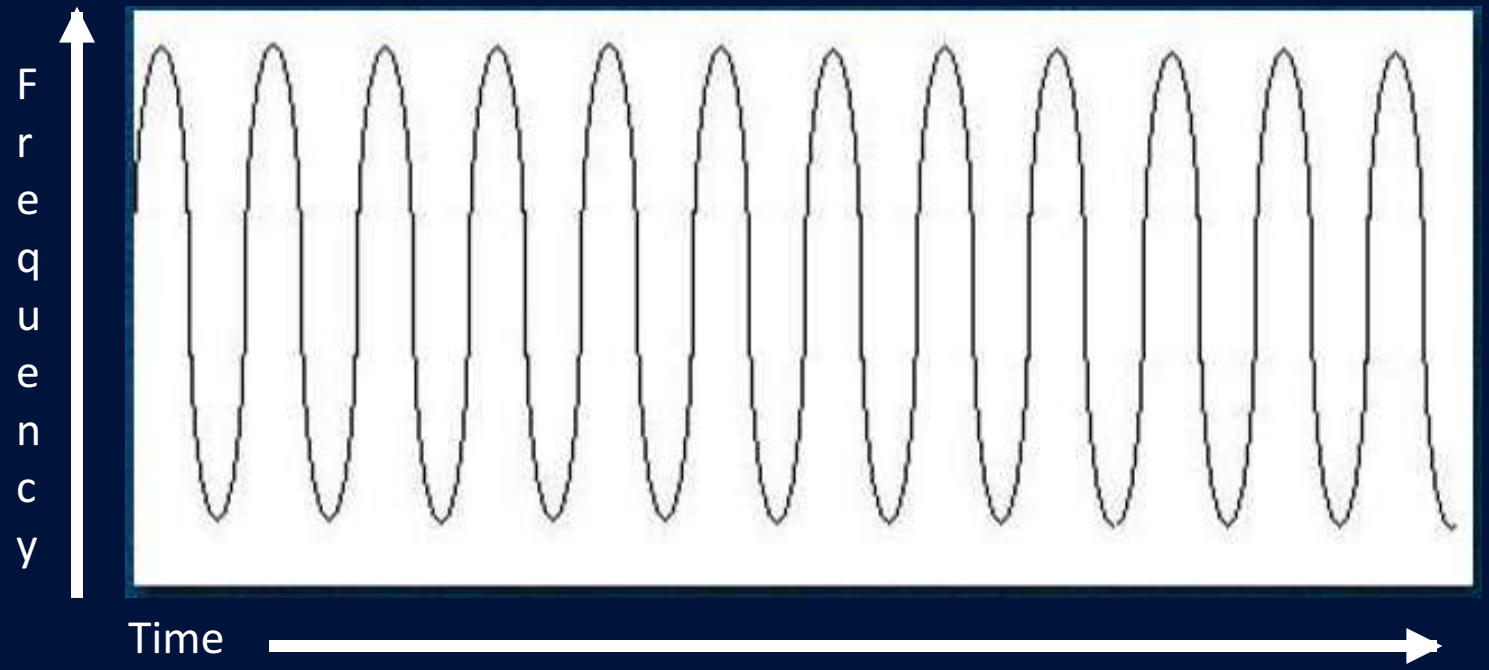


In order for a human to hear it, sound must hit the eardrum with an intensity of at least 10^{-12} watts per square meter.

Introduction

Anything less than 10^{-12} w/psm will not deflect the eardrum sufficiently for the sound to be heard.

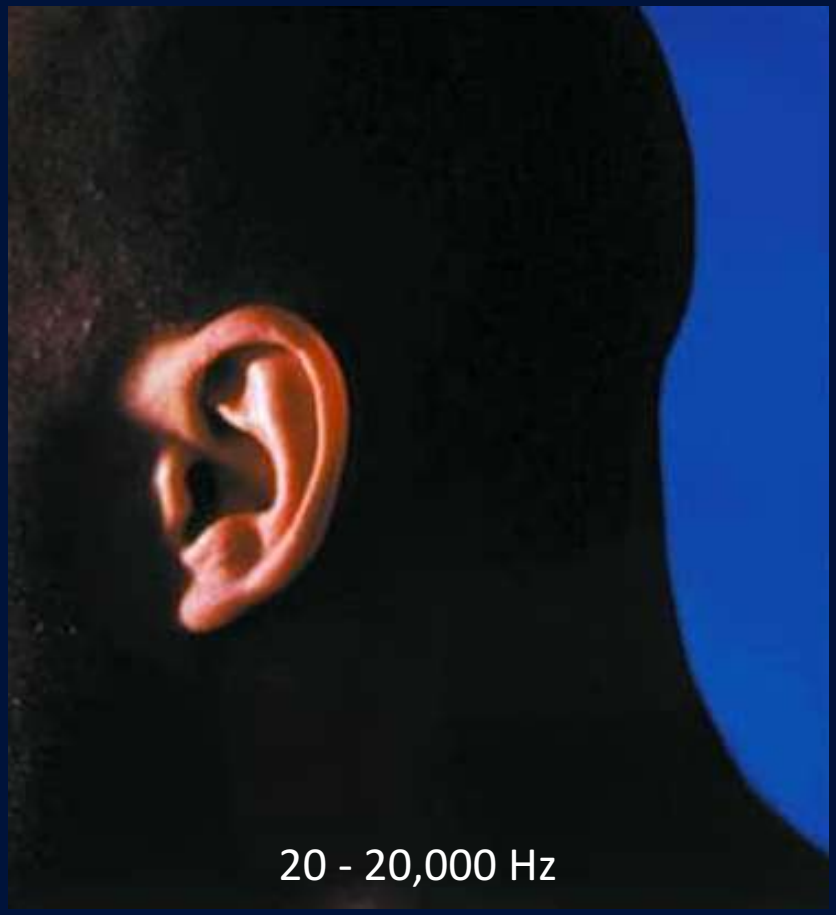
Introduction



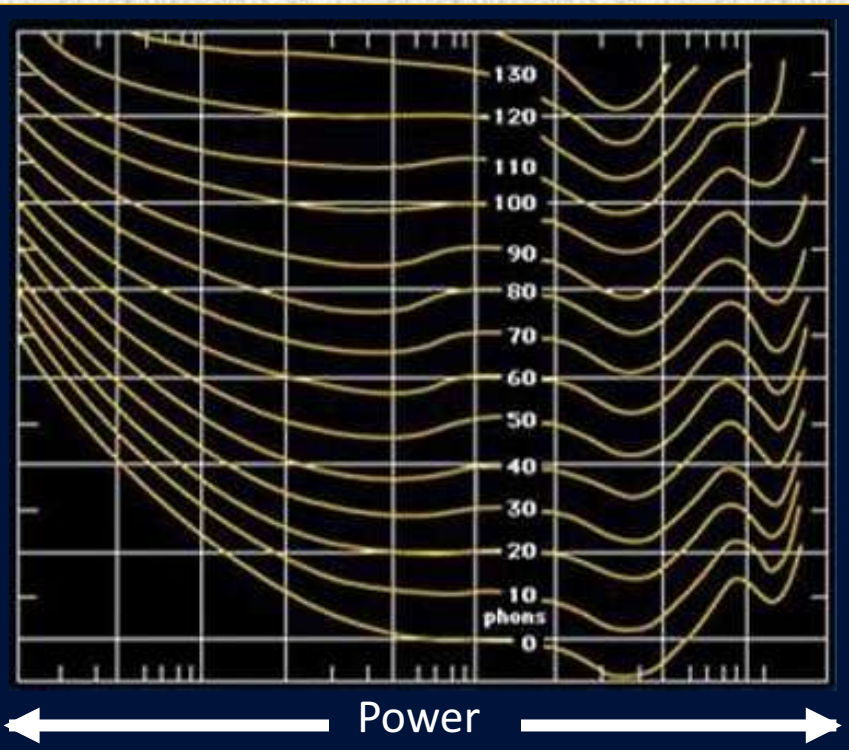
A human's ability to hear a sound also depends on the frequency of the sound, or the number of times per second that a sound wave passes by.

Introduction

The so-called audible frequency range for the human ear is 20 to 20,000 Hz.



Introduction



Sounds in the extreme high and low ends of this frequency range require more power per unit area to be heard than do sounds in the mid-range.

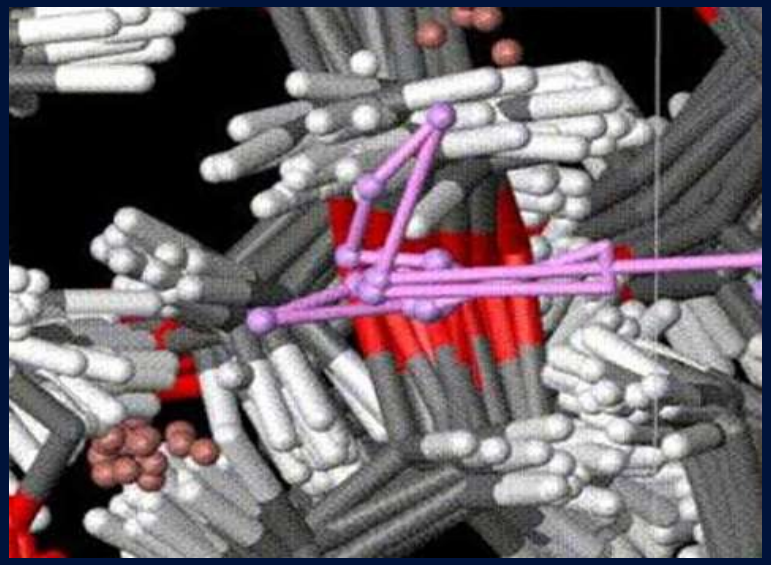
Check On Learning Questions

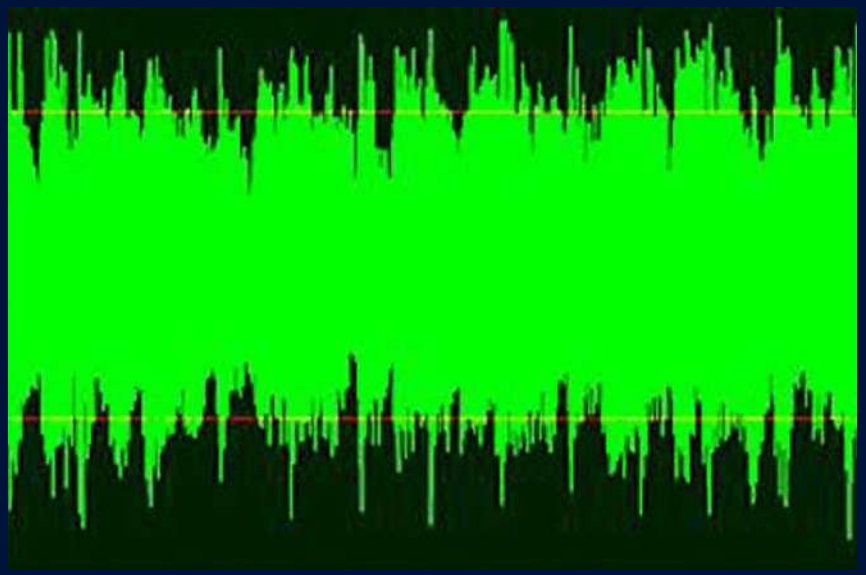
CPS Lesson

Question

3 - 4

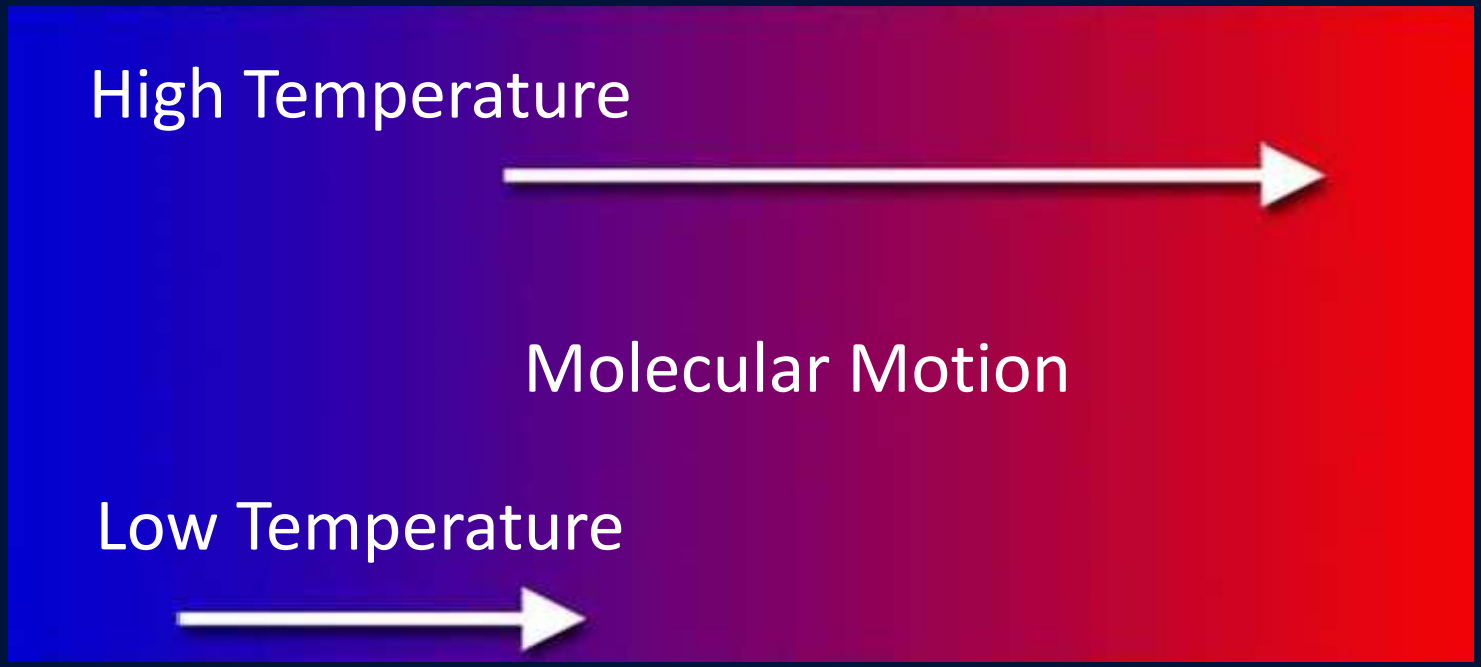
The Physics of Sound





Because sound is a material wave the denser the medium, the better sound will travel through it.

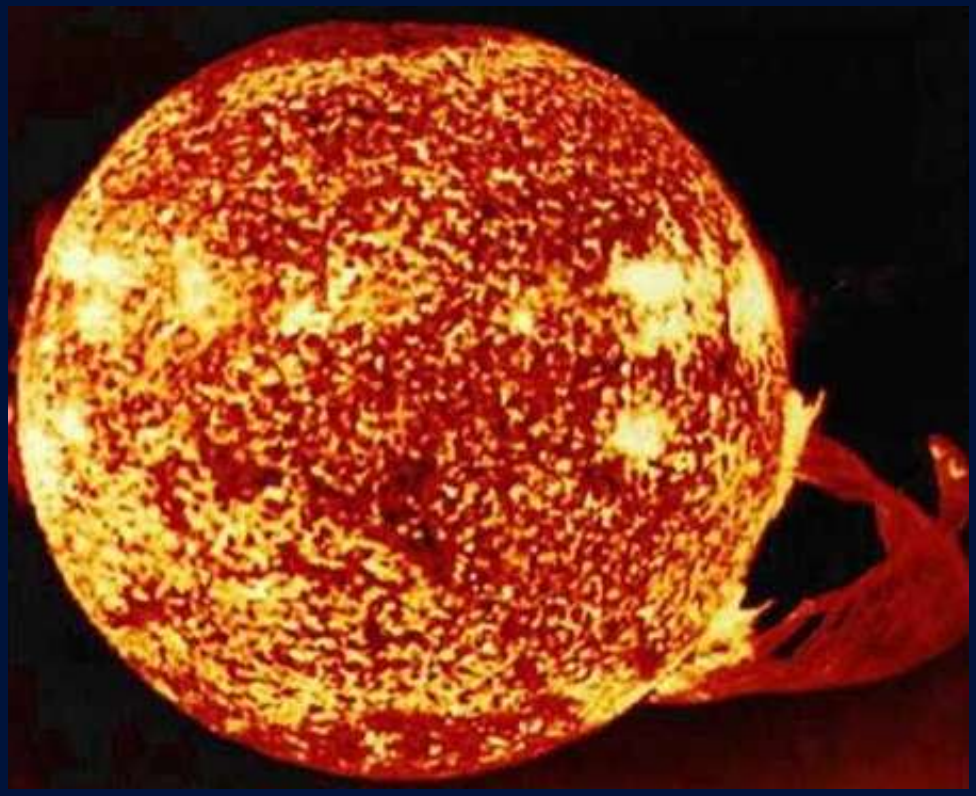
The Physics of Sound



Because of the increase in molecular motion within a material as temperature increases, the temperature of the medium also affects sound transmission.

The Physics of Sound

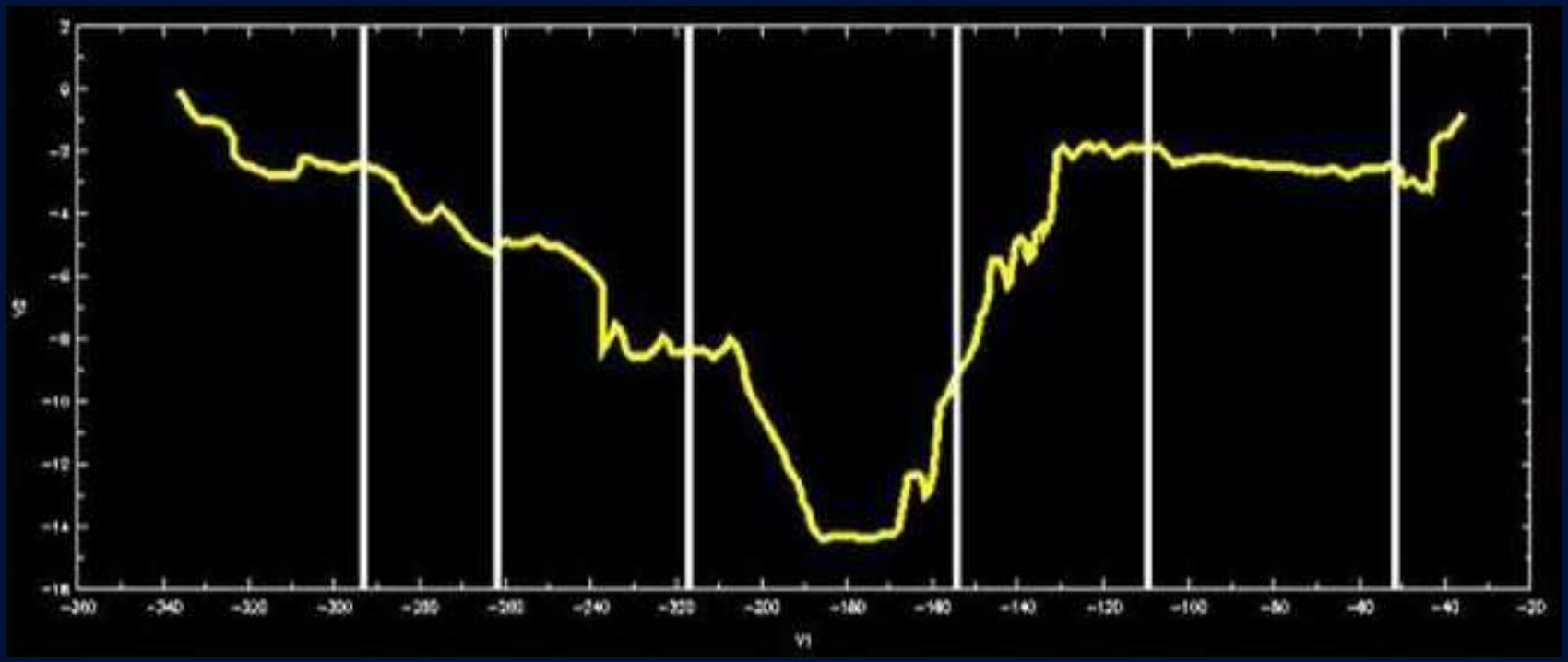
Sound travels better within a given material if its temperature is higher as opposed to when its temperature is lower.



The Physics of Sound

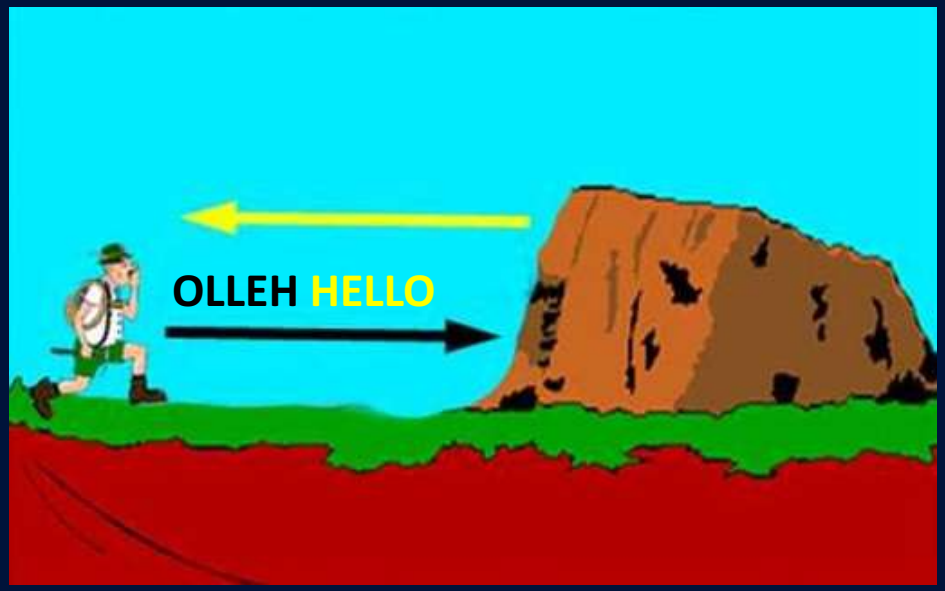
Material	Speed of Sound (m/s)
Air at 0 °C	331
Air at 20 °C	344
Air at 100 °C	390
Kerosene at 25 °C	1324
Water at 25 °C	1498
Wood (oak)	3850
Steel	5200

The Physics of Sound



Sound waves have the same general behavior as other types of waves.

The Physics of Sound



Sound waves can be reflected by media having a greater density than the medium they originate in, as for example, when a sound wave traveling through air hits the side of a mountain.

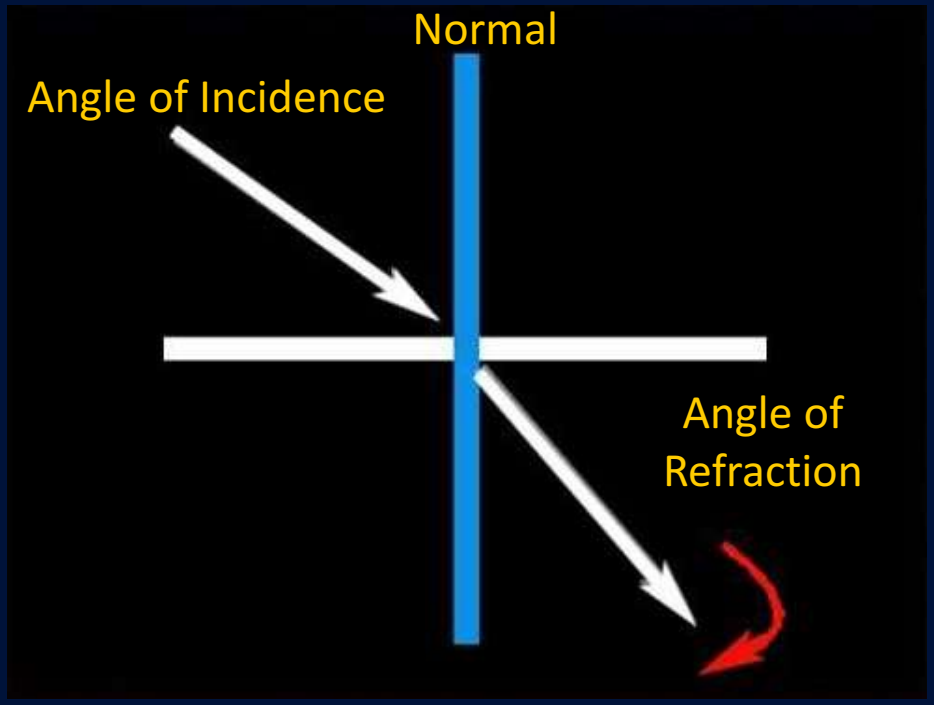
The Physics of Sound

Sound Wave

Echo

The reflected sound is called an echo.

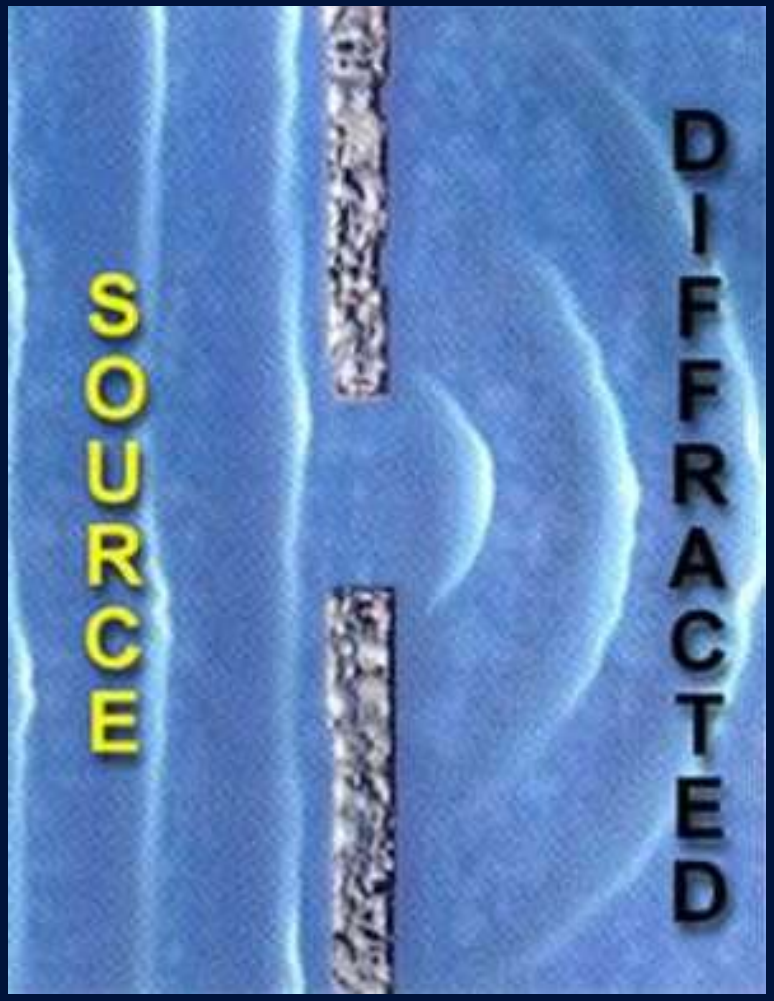
The Physics of Sound



Sound waves can be bent or refracted as they pass from one medium to another, if the densities are not too dissimilar.

The Physics of Sound

Sound waves can also be diffracted, spreading after they pass through a narrow opening.



The Physics of Sound

$$v = f\lambda$$

Sound waves obey the formula $v = f\lambda$, where v is the velocity of the wave, f its frequency, and λ is the wavelength.

Thus, if we know the speed of sound for a given medium, and either the frequency or wavelength, we can easily calculate the unknown quantity.

The Physics of Sound

The distance to an object causing an echo can be found if the speed of sound is known for the medium using this formula:

$$\text{Distance} = \text{Rate} \times \text{Time}$$

For example, if the speed of sound in air were 344 m/s, and it took 4 seconds for an echo to return to a source, then the one-way distance would be:

$$(4 \text{ sec} \div 2) \times 344 \text{ m/s} = 688 \text{ meters}$$

Check On Learning Questions

CPS Lesson

Question

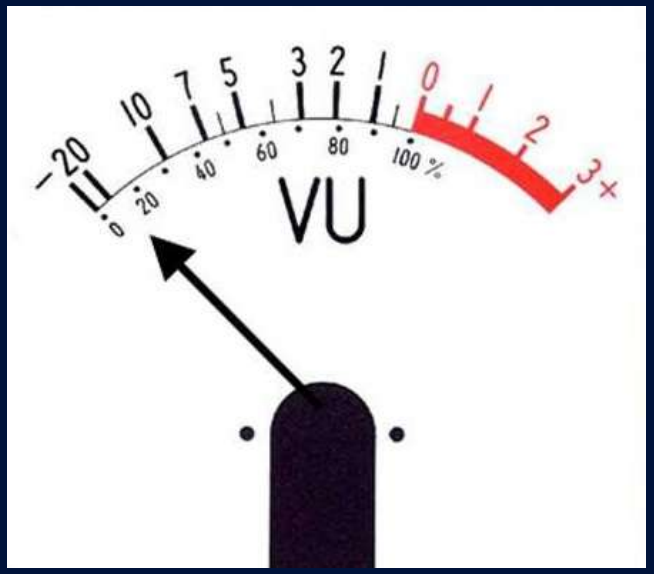
5 - 6

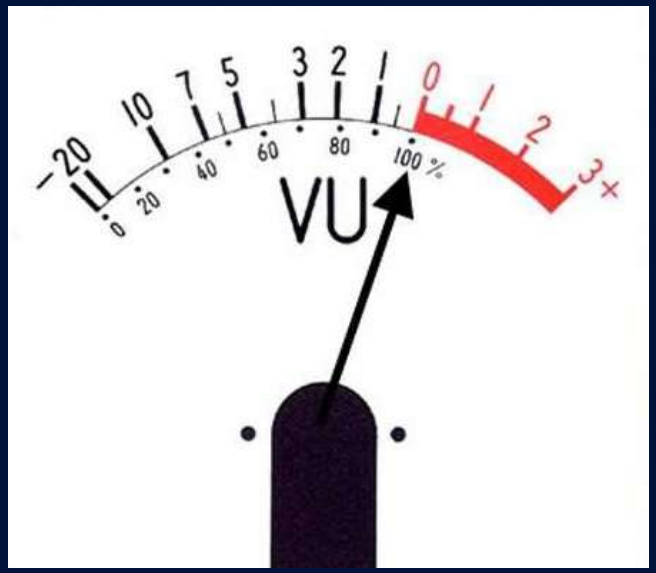
The Physics of Sound

Another way to measure sound is by relative intensity or noise level, calculated in units called decibels.

The Physics of Sound

A sound having 0 decibels is equal in intensity to the lowest that can be heard, 10^{-12} watts per square meter.





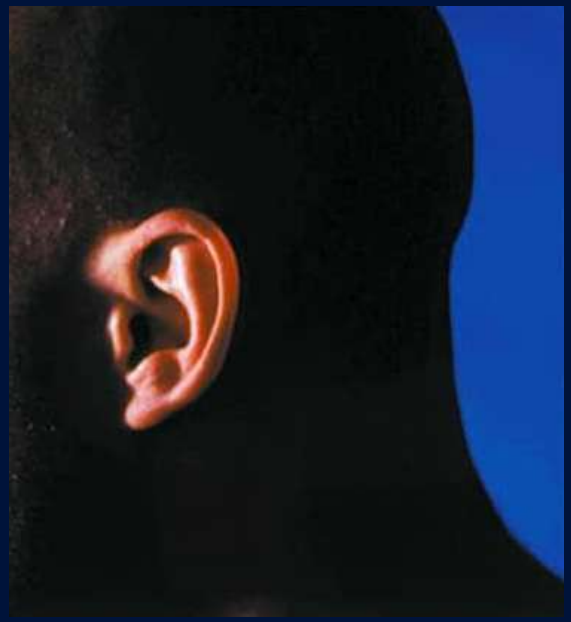
On the decibel scale a sound of 100 decibels would be 10^{10} times as intense as a sound of 0 decibels.

The Physics of Sound

A sound of 120 decibels is the loudest sound that the ear can stand without pain as the eardrum begins to tear.

Sound decibel levels that are negative indicate a sound that is too faint to be heard without amplification, as for example, distant fish sounds in the ocean.

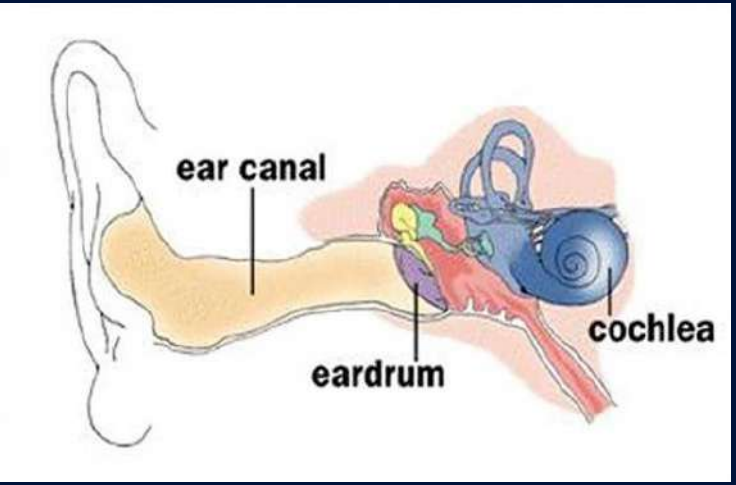
The Physics of Sound

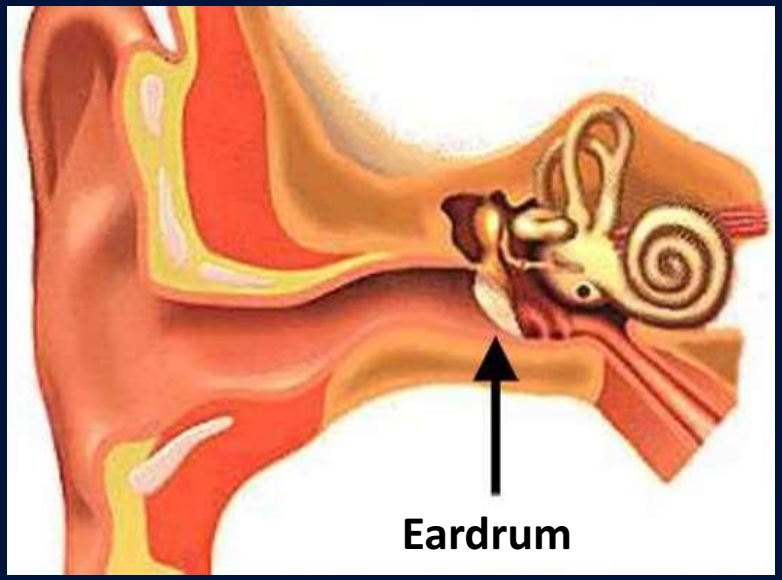


Without a human ear to hear a sound wave, there would be no sound, only noise.

The Physics of Sound

Sound waves are gathered and funneled by the outer ear into an opening through the skull called the ear canal.





At the inner end of the ear canal is a very thin, sensitive membrane called the eardrum.

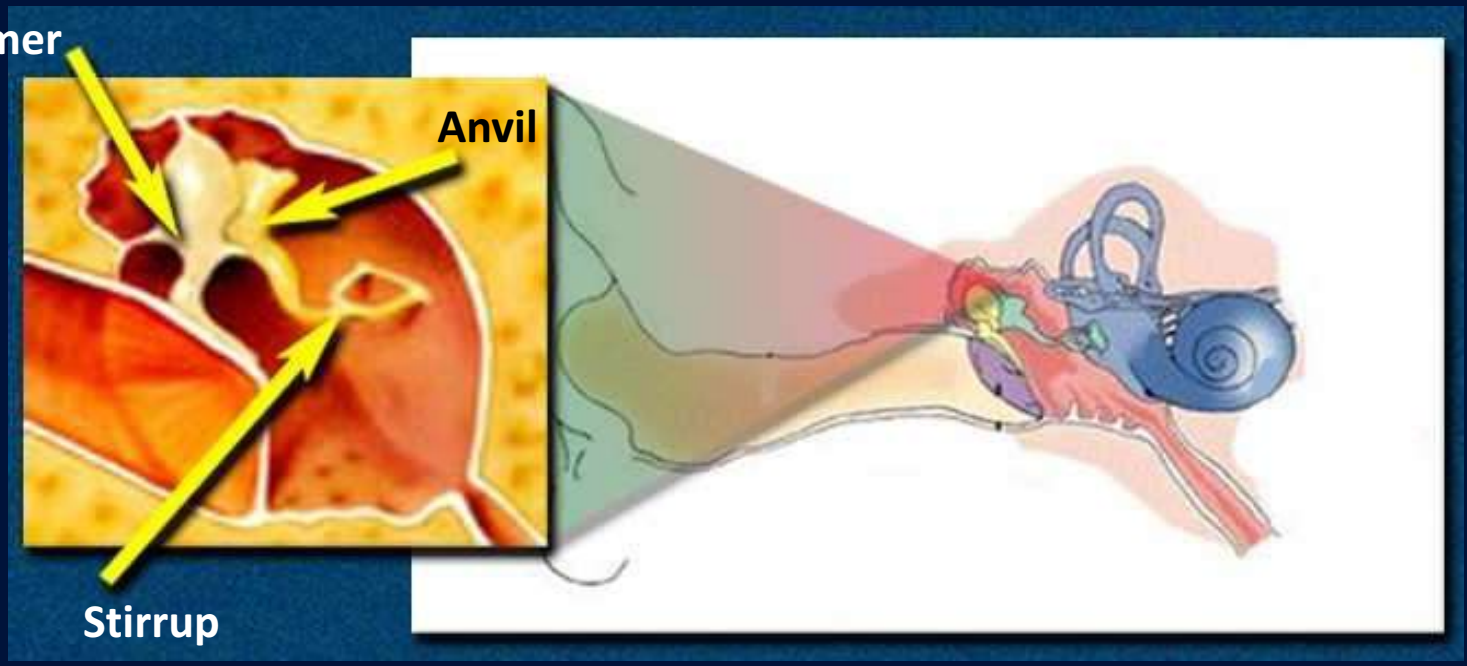
The Physics of Sound

The membrane is so sensitive that it can detect sound intensities of 10^{-12} watts per square meter, equivalent to a pressure of only 2×10^{-5} Newtons (the metric unit of force) per square meter.

The Physics of Sound

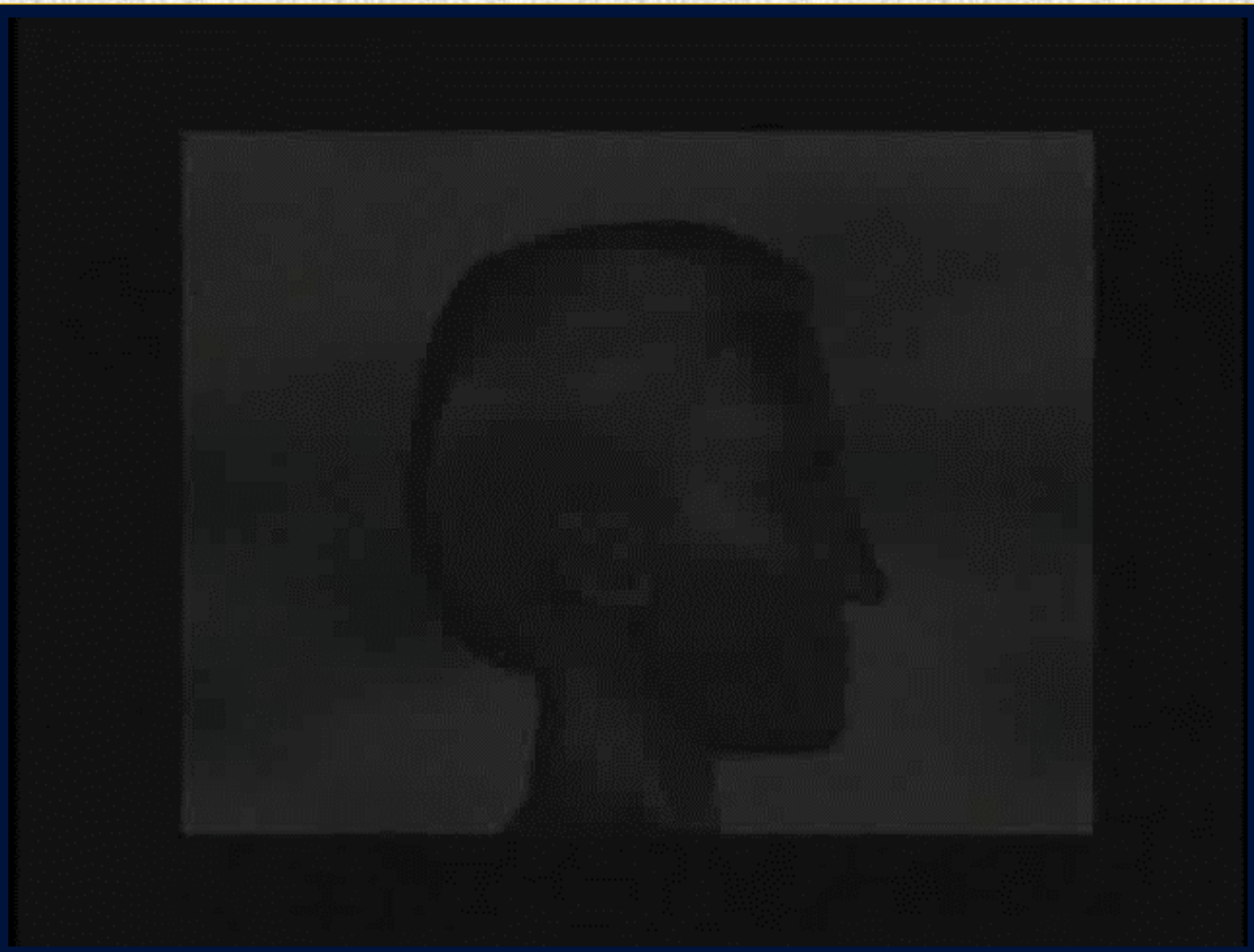
Since the ears are so sensitive, it is obvious that you should be very careful to protect them from loud or highly focused sound, such as that produced by loud music or earphones.

The Physics of Sound



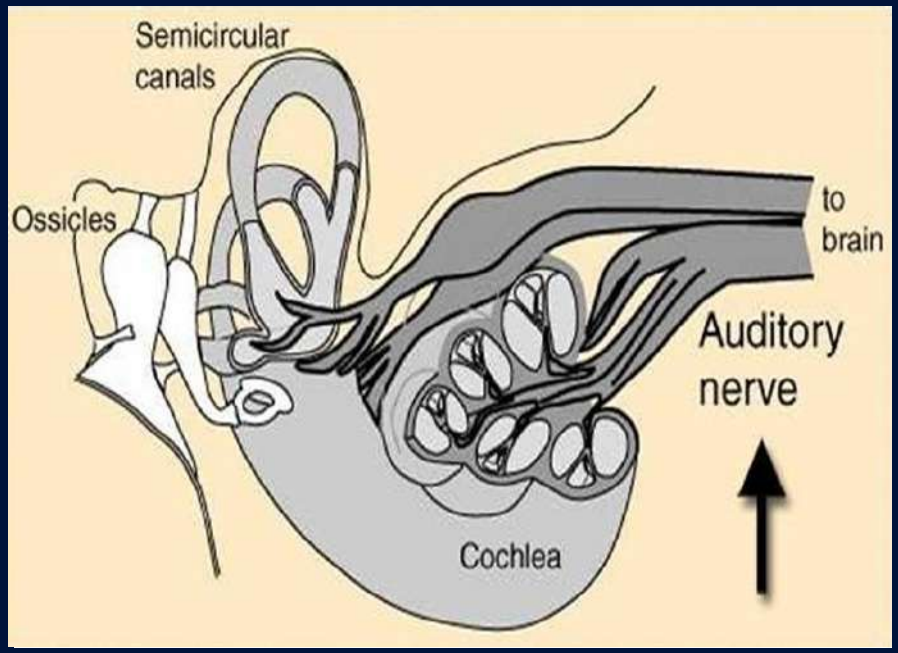
Beyond the eardrum is the middle ear where three delicate bones called the hammer, anvil, and stirrup transmit sound from the eardrum to the inner ear.

The Physiology of Sound



The Physics of Sound

The inner ear is where a liquid-filled structure called the cochlea is located.



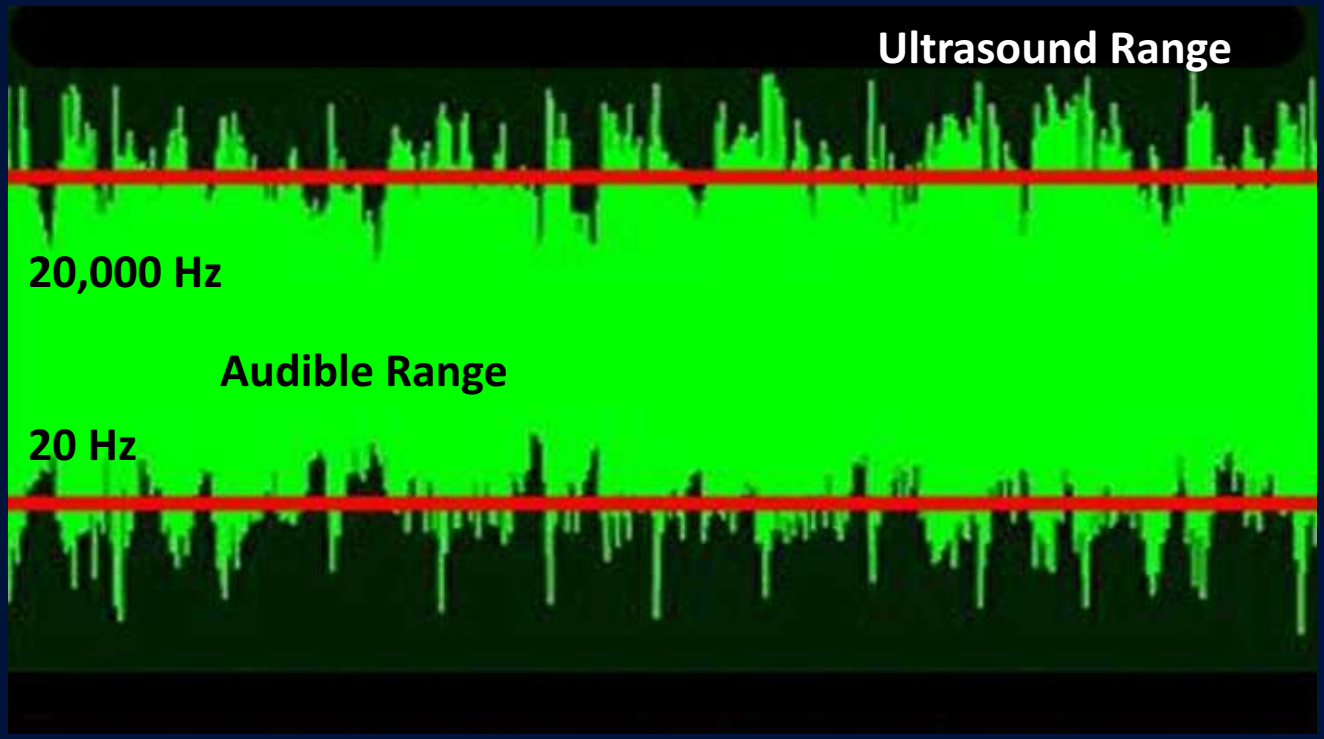
Sound vibrations in the cochlea's liquid are sensed by special cells that translate the mechanical vibrations to electromagnetic nerve impulses.

These impulses travel through the auditory nerve to the brain, where the person interprets them as sound.

The Physics of Sound

Some animals such as bats and dogs have ears that are sensitive to sounds above the 20,000 Hz upper frequency limit that humans can hear.

The Physics of Sound



Sounds above 20,000 Hz are called ultrasound.

The Physics of Sound

Bats use these high intensities to navigate by means of echoes returned from objects around them.

Dog owners may use ultrasonic dog whistles to call their pets.

Review Question

Why should people be careful to protect their eardrums against loud sounds?

1.

2.

3.

(Use CPS "Pick a Student" for this question.)

Closing Questions

CPS Lesson Questions

7 - 8

Questions?