7b SOUND

Content

- Sound waves
- Speed of sound
- Echo
- Ultrasound

Learning Outcomes

Candidates should be able to:

(a) Describe the production of sound by vibrating sources

(b) Describe the longitudinal nature of sound waves in terms of the processes of compression and rarefaction

(c) Explain that a medium is required in order to transmit sound waves and that the speed of sound differs in air, liquids and solids

(d) State the approximate range of audible frequencies

(e) Describe a direct method for the determination of the speed of sound in air and make necessary calculations.

(f) Relate loudness of a sound wave to its amplitude and pitch to its frequency

(g) Describe how the reflection of sound may produce an echo, and how this may be used for measuring distances

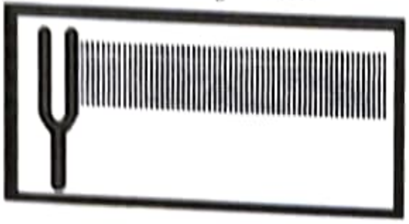
(h) Define *ultrasound* and describe one use of ultrasound, e.g. cleaning, quality control and pre-natal scanning.

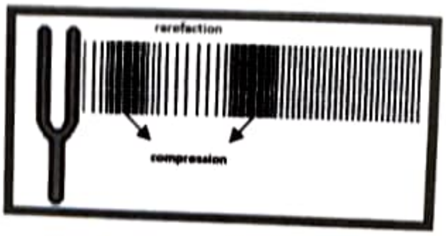
[Explain reverberation and the effect of reverberation time on room acoustics.]+
[Describe the use of a microphone and a cathode ray oscilloscope (C.R.O.)]+

8.8 Sound waves

Longitudinal waves

Sound waves are longitudinal waves. They propagate energy from one point to another, *without transporting matter*.





Sound waves are produced by the **vibration** of objects. When a tuning fork is struck, the two prongs vibrate with repeated inward-outward motions. These motions result in repeated **pushing** and **pulling** of the surrounding air layers. A series of **compressions** and **rarefactions** results and travels outwards.

Example 1

A sound wave travels in air from left to right. P and Q are two air molecules separated by a distance of one wavelength along the direction of propagation of the wave.

What are the instantaneous directions of motion of P and Q ?

Solution:

This figure represents the given wave at a small time interval later.

Comparing positions,

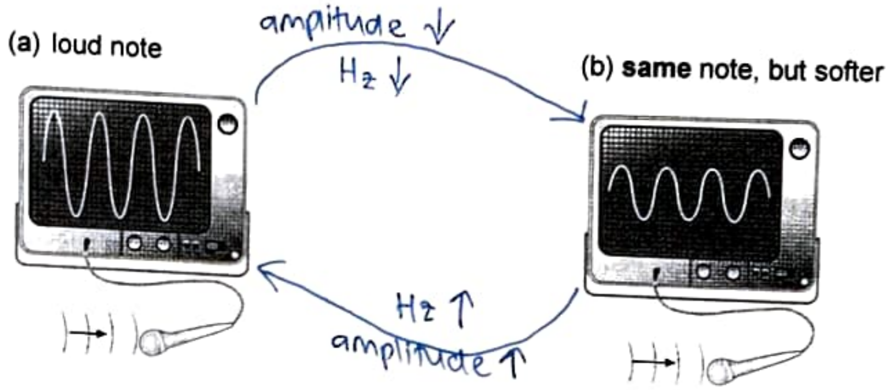
instantaneous direction of motion of Q is left.

Since P and Q are one wavelength apart,

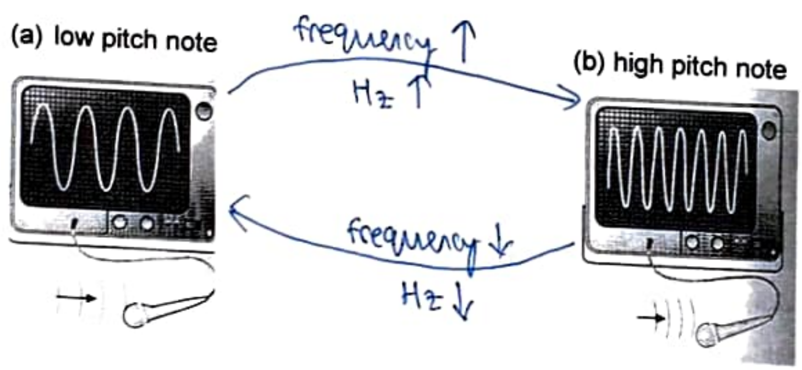
instantaneous direction of motion of P is left.

Pitch and loudness of sound

The loudness of sound (how soft or loud a sound is) depends on the amplitude of the sound wave. A sound wave with a larger amplitude contains more energy and is therefore louder in volume.



The pitch of sound (how low or high a sound is) depends on the frequency of the sound wave. A sound wave of higher frequency (shorter wavelength) produces a higher pitch note.



Example 3

When a guitar string is plucked harder, which of the properties of the note produced will change?

(I) frequency
(II) loudness
(III) quality
(IV) velocity of propagation of sound

A I, II and III only
B I, II and IV only
C II only
D II and IV only

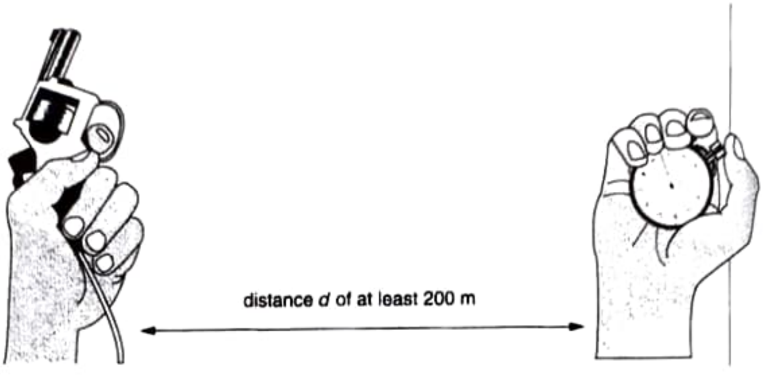
8.9 Speed of sound

Direct method for determination of speed of sound in air (measuring time taken for sound to travel a known distance)

Apparatus: one starting pistol, one measuring tape, one stopwatch

Assumption: Time taken for light to travel the distance is negligible as light travels at a very high speed.

Procedure:



Observers A and B are positioned in an open field at a distance *d* (more than 200 m) apart. When A fires a starting pistol, B starts the stopwatch upon seeing the flash of the pistol and stops the stopwatch on hearing the gun shot. The time interval *t* is recorded. This is the time taken for the sound to travel the distance *d*.

$$\text{speed of sound in air} = \frac{\text{Distance}}{\text{Time taken}}$$

$$v = \frac{d}{t}$$

To reduce errors from possible wind effects, the experiment is repeated by getting B to fire the starting pistol, and A to record the time. The speed of sound can then be calculated by taking into consideration the speed and direction of wind.

Example 4

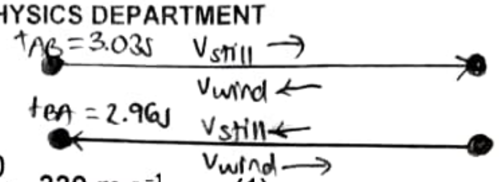
Two observers, A and B, are 1.00 km apart. There is a steady wind blowing from B to A. When a starting pistol is fired at A, the time interval between the flash seen and the sound heard by B is 3.03 s. When a starting pistol is fired at B, the time interval between the flash seen and the sound heard by A is 2.96 s.

(a) Calculate

(i) the speed of sound in *still* air,

(ii) the speed of wind in the direction BA.

(b) Explain what will happen to the speed of sound in *moving* air if the wind is blowing at an angle θ to the direction BA.



Solution:

(a)

$$v_{still} - v_{wind} = \frac{1000}{3.03} = 330 \text{ m s}^{-1} \quad \text{--(1)}$$

$$v_{still} + v_{wind} = \frac{1000}{2.96} = 338 \text{ m s}^{-1} \quad \text{--(2)}$$

$(1) + (2)$:

$$2v_{still} = 668 \text{ m s}^{-1}$$

$$v_{still} = 334 \text{ m s}^{-1}$$

$(2) - (1)$:

$$2v_{wind} = 8.00 \text{ m s}^{-1}$$

$$v_{wind} = 4.00 \text{ m s}^{-1}$$

(b) Amount of wind blowing in direction BA will be smaller.
Speed of sound (from B to A) in moving air will be slower than before.
Speed of sound (from A to B) in moving air will be faster than before.

8.10 Echo

Echoes

Echo is the reflection of sound. The fraction of sound energy reflected from a surface is large if the surface is rigid and smooth; the fraction is smaller if the surface is soft and irregular. Sound reflects from a smooth surface in the same way light does – it obeys the law of reflection. Sound energy that is not reflected is transmitted or absorbed.

Reverberations

Optional

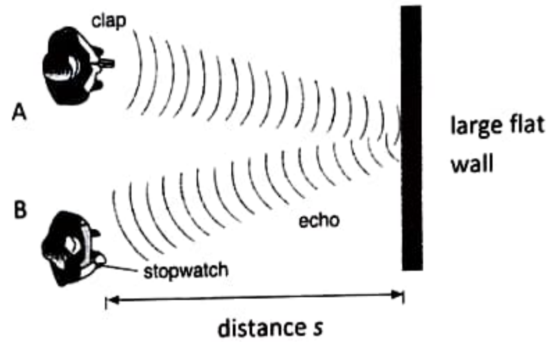
- When there are multiple reflections of sound, reverberation occurs. A balance must be found between reverberation and absorption in the design of an auditorium or concert hall. This study of sound properties is known as acoustics.

Indirect method for determination of speed of sound in air (using echo to find distances and speed of sound)

Apparatus: Two blocks of wood for clapping, one stopwatch, one measuring tape

Assumption: Speed of sound does not change when sound waves are reflected.

Procedure:



Observers A and B stand at equal distances from a large flat wall. Measure and record the distance s between the observers and the wall with a measuring tape. Observer A first claps the two blocks of wood to produce a loud sound. He continues to clap every time an echo is heard (the new clap must coincide with the echo of the previous clap). He makes 51 claps altogether.

Observer B starts the stopwatch at the 1st clap and stops at the 51st clap. The time taken, t_1, between the 1st and 51st clap is recorded. The time interval, t, between successive claps is calculated as

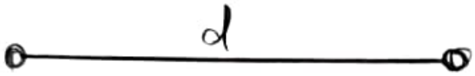
$$t = \frac{t_1}{50}$$

The speed of sound, v, can then be calculated by

$$v = \frac{2 \times \text{distance, } s}{t}$$

Example 5

A man stands in front of a large wall. He claps two pieces of wood together regularly at 0.790 s intervals. The echo of the first clap coincides with the third clap.
If the speed of sound in air is 343 m s^{-1}, calculate the distance between the man and the wall.



Solution:

$$v = \frac{2d}{2(0.790)}$$

$$343 = \frac{2d}{2(0.790)}$$

$$d = 271\text{ m (3 s.f.)}$$

Example 6

A car travels normally towards a cliff at a speed of 45.0 m s^{-1}. It sounds its horn when it is 0.710 km away.
Taking speed of sound to be 343 m s^{-1} in air, calculate the time taken for the driver to hear its echo.

Solution:
let distance travelled by car until hearing echo be x m.

time for car to hear echo = time for sound to travel to wall and back to car

$$\frac{x}{45.0} = \frac{710 + (710 - x)}{343}$$

$$x = 164.69\text{ m}$$

$$t = \frac{164.69}{45.0}$$

$$= 3.66\text{ s (3 s.f.)}$$

8.11 Ultrasound

Ultrasound

The range of audible frequencies for an average human being is between 20 Hz and 20 kHz.

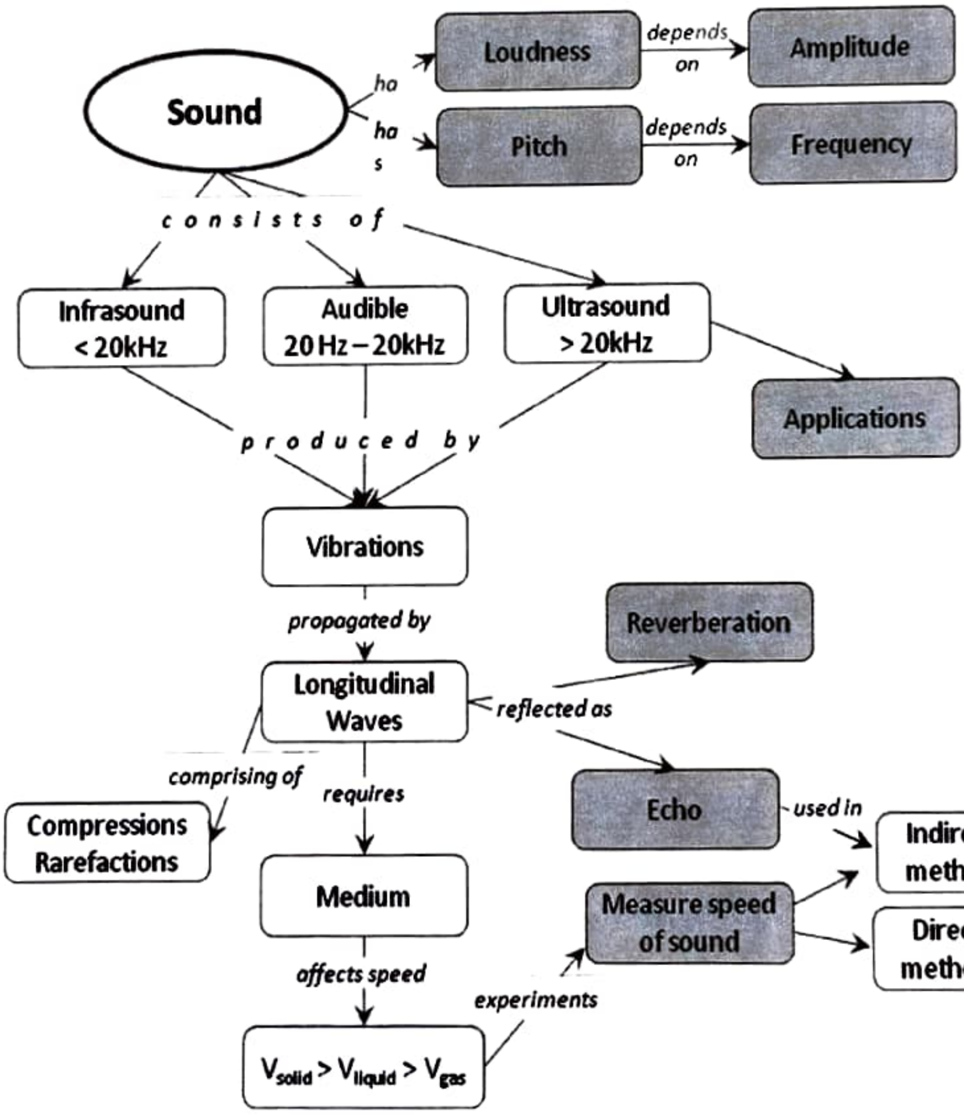
This range decreases as we get older and our ears lose their sensitivity to the extreme ends of the frequency range.

Sounds above the upper hearing limit of 20 kHz are called **ultrasound.**

Although we cannot hear ultrasound, it is used in applications such as cleaning, quality control and pre-natal scanning.

Sounds below the lower hearing limit of 20 Hz are called **infrasound**.

Concept Map



Bulletin

What Is the LRAD Sound Cannon?

by Roberto Baldwin
extracted from url: http://gizmodo.com/what-is-the-lrad-sound-cannon-5860592

Protests in Ferguson, Missouri have reached a terrifying fever pitch, and the *ludicrously* armed Ferguson Police Department is bringing all its crowd-control weapons to bear, tear gas, stun grenades, rubber bullets, you name it. One of the more controversial of those is the LRAD **Sound** Cannon. So what's the harm in a little noise? Well, a lot, actually.

The LRAD Sound Cannon is an acoustic weapon and communication device...

Developed by the LRAD corporation to broadcast messages and pain-inducing "deterrent" tones over long distances, LRAD devices come in various iterations that produce varying degrees of sound. They can be mounted to a vehicle or handheld. The device produces a sound that can be directed in a beam up to 30-degree wide, and the military-grade LRAD 2000X can transmit voice commands at up to 162dB up to 5.5 miles away.