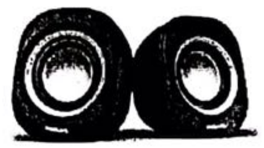
O Level Physics Syllabus Content for CAIE 2019-22 Exams

CHAPTER 16:

SOUND

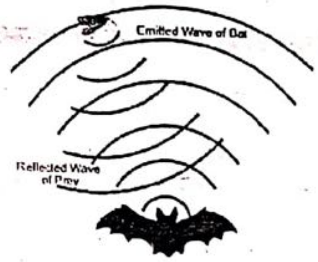


Syllabus Content

16.1 Sound waves

16.2 Speed of sound

16.3 Ultrasound



Learning outcomes

Candidates should be able to:

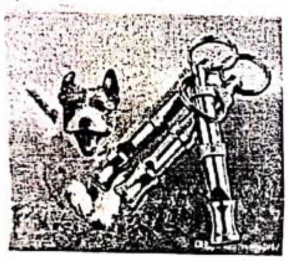
(a) Describe the production of sound by vibrating sources.

(b) Describe the longitudinal nature of sound waves and describe compression and rarefaction.

(c) State the approximate range of audible frequencies for the healthy human ear as 20 Hz to 20 000 Hz.

(d) Explain why a medium is required in order to transmit sound waves and describe an experiment to demonstrate this.

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



(f) State the order of magnitude of the speeds of sound in air, liquids and solids.

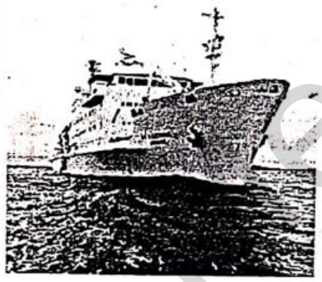
(g) Explain how the loudness and pitch of sound waves relate to amplitude and frequency.

(h) Describe how the reflection of sound may produce an echo.

(i) Describe how the shape of a sound wave as demonstrated by an oscilloscope is affected by the quality (timbre) of the sound wave.

(j) Define *ultrasound*.

(k) Describe the uses of ultrasound in cleaning, quality control and pre-natal scanning.



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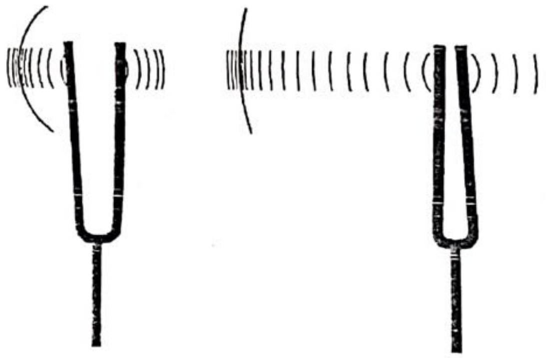
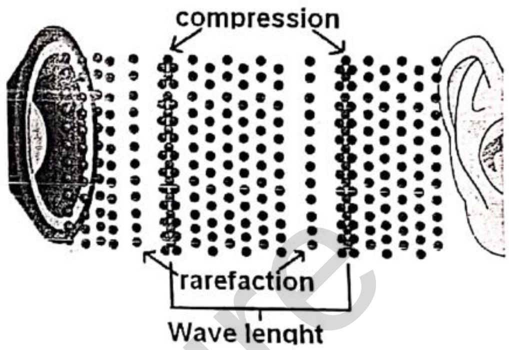
SOUND

1. Sound is produced by vibrations of objects, like vibrations of a stretched string, an air column, a tuning fork, etc.



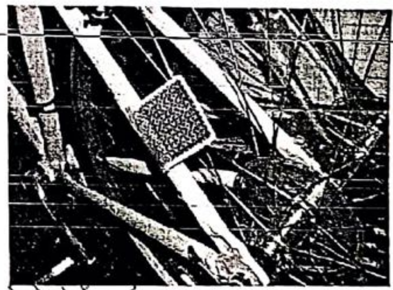


2. The sound travels in the form of longitudinal waves. The wave consists of a series of compressions, C followed alternately by rarefactions, R.

The compression is a region where the molecules of the medium are very close to each other and the pressure is higher than normal pressure.

The rarefaction is a region where the molecules are farther away from each other and the pressure is lower than the normal pressure.

3. The Wavelength of sound is the distance between two successive compressions or two successive rarefactions.
4. Audible Sound has a frequency between 20 and 20 000 Hz.



Frequencies less than 20 Hz. (infra sound) cannot be heard, Frequencies greater than 20 000 Hz. (ultra sound) cannot be heard. When a flexible metal strip presses against the teeth of a rotating toothed wheel as shown; the frequency of the sound produced can be calculated by:

Frequency = no. of teeth x no. of revolutions per second.

5. Velocity of sound = frequency x wavelength $V = f \times \lambda$

The velocity of sound depends on the medium in which it is passing:

Speed of sound in Air (at 0°C)	=	330 m/s
Speed of sound in water	=	1400 m/s
Speed of sound in solids	=	4000 to 6000 m/s

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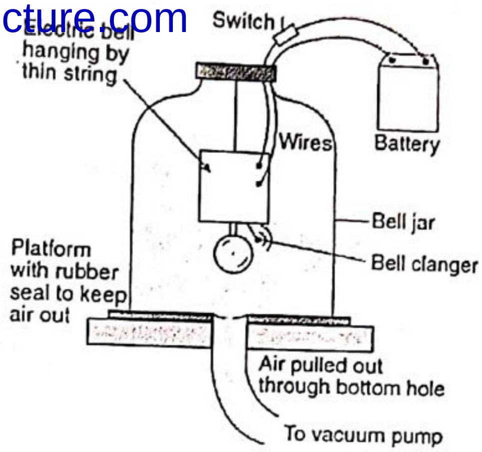
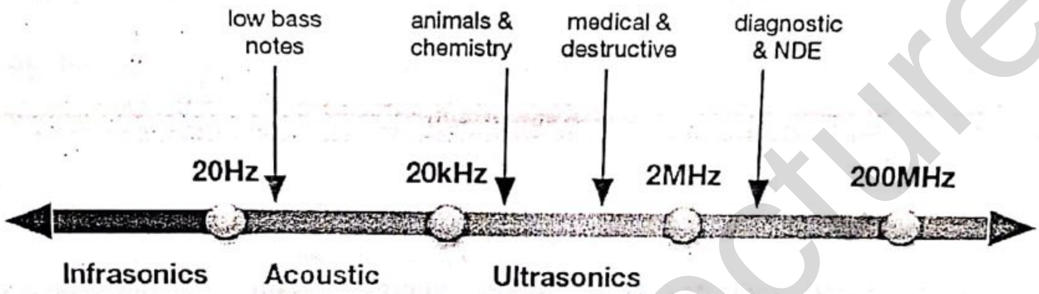
Sound is fastest in solids and has least speed in gases. In air, the speed of sound increases as the temperature rises, but the pressure does not affect it.



6. Sound cannot travel in vacuum, sound waves require a material medium whether it is a gas, a liquid, or a solid. When the air is pumped out of a glass jar containing a ringing bell, the sound disappears gradually though the bell can still be working. (Light can travel in vacuum but sound cannot).

Types of Sounds

Ultrasound range diagram



Ultrasound and Infrasound

Sound waves with a frequency *too low* for the human ear to hear are called **infrasound**.

Sound waves with a frequency *too high* for the human ear are called **ultrasound**

Animals such as whales, elephants and hippopotamus use infrasound to communicate over distances.

Animals such as dogs, bats, birds and insects can hear ultrasound.

Factor affecting speed of sound

1. Atmospheric pressure
2. Relative humidity
3. Atmospheric temperature
4. High atmospheric pressure, relative humidity and atmospheric temperature lead to faster moving sound.

Reflection of Sound

An echo is hearing a reflected sound a short time after hearing the original sound.

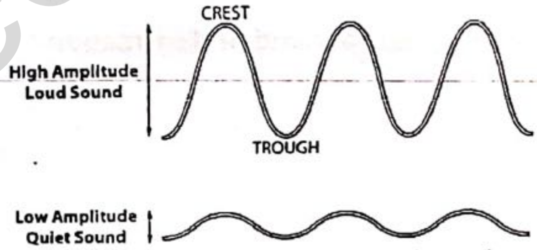
In order to hear an echo; the distance between the source of sound and the reflecting wall must be greater than 17 m (or a separation of at least 0.1 sec.)

Sound waves are reflected well from hard flat walls and cliffs and obey the laws of reflection. Soft materials like foam or sponge are bad reflectors of sound (they are absorbers of sound).

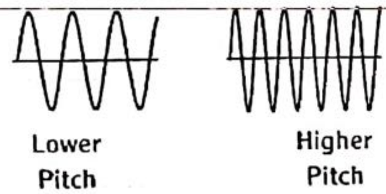
Properties of Sound

a) Loudness indicates the sound energy reaching the ear and it increases by increasing the amplitude of the vibrating source. The louder sound has greater amplitude.

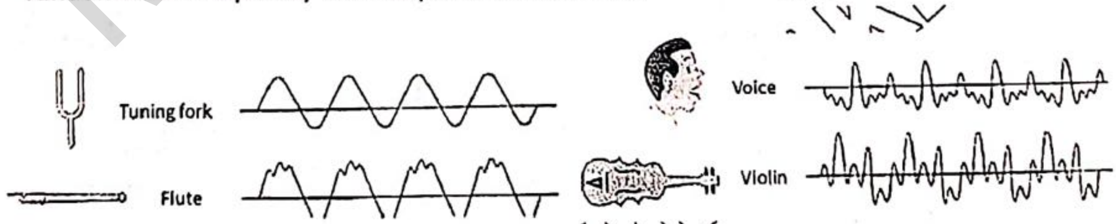
Amplitude of Sound Waves



b) Pitch of a note indicates the sharpness of sound and depends on the frequency of the sound wave. A high frequency note has a high pitch, and a low frequency note has a low pitch.



c) Timbre also known as tone quality, timbre is the quality of a musical note, sound or tone that distinguishes different types of sound production. It depends on fundamental frequency and shape of sound wave.

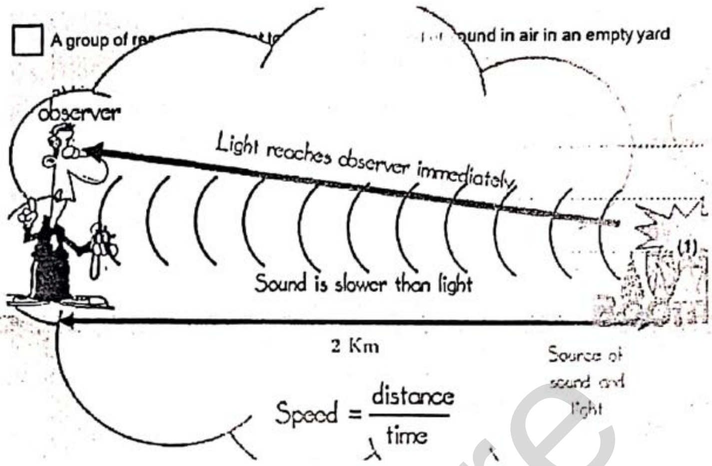


Determination of Speed of Sound in Air

The direct method: Two students stand about one kilometer apart and measure the distance (d) by using a long measuring tape.

1. When one of them fires a gun, the other records the time (t) between seeing the flash and hearing the sound, by using a stopwatch.
2. The speed of sound = $\frac{d}{t}$

- In this experiment, we assume that the time taken by the light to travel this distance is negligible; because the speed of light is much greater than the speed of sound.
- In this experiment, the distance must be very long so that measuring the time would be reasonably accurate.
- One should repeat the experiment several times to get the average of the time.



The Echo Method

1. Stand far away from a high wall and clap two wooden blocks together at a rate such that each clap coincides with the echo of the one before.
2. By counting and timing some 30 echoes, the time (t) taken for one echo is calculated.
3. Measure the distance (d) to the wall, and get the speed of sound by: V $=\frac{2d}{t}$ (notice the "2" in above formula, why it is used?).

Ultrasound

Sound waves with frequencies higher than the upper audible limit of human hearing are called ultrasound. The limit varies from person to person but is approximately 20,000 Hertz. The physical properties of ultrasound are similar to the normal audible sound.

This type of scientific concept is used in many different fields such as navigation, medicine, imaging, cleaning, mixing, communication, testing etc. Even in nature, bats and porpoises use this particular technique for the location of prey and obstacles. In the following section, we shall learn about its applications.

Applications:

Cleaning:

In objects with parts that are difficult to reach, for example, spiral tubes and electronic components, the process of ultrasonic cleaning is used. Here, the object is dipped in a solution of suitable cleaning material and ultrasonic waves are passed into it. As a result of this, high-frequency waves are generated that cause the dirt and grease to detach from the surface.

Detection of cracks:

Ultrasound is used to detect cracks in the metallic components that are used in the construction of high rise structures such as buildings and bridges. They generate and display an ultrasonic waveform that is interpreted by a trained operator, often with the aid of analysis software, to locate and categorize flaws in test pieces. High-frequency sound waves reflect from flaws in predictable ways, producing distinctive echo patterns that can be displayed and recorded by portable instruments. A trained operator identifies specific echo patterns corresponding to the echo response from good parts and from representative flaws. The echo pattern from a test piece may then be compared to the patterns from these calibration standards to determine its condition.

Echocardiography:

In the process of electrocardiography, the ultrasonic waves are used to form an image of the heart using reflection and detection of these waves from various parts.

Ultrasonography:

Medical ultrasound is a diagnostic imaging technique based on it. It is used for the imaging of internal body structures such as muscles, joints and internal organs. Ultrasonic images are known as sonograms. In this process, pulses of ultrasound are sent to the tissue using a probe. The sound echoes off the tissue, where different tissues reflect sound varying in degrees. These echoes are recorded and displayed an image.

Lithotripsy:

Ultrasonic waves are used to break stones in the kidney. High energy sound waves are passed through the body without injuring it and break the stone into small pieces. These small pieces move through the urinary tract and out of the body more easily than a large stone.

SONAR:

SONAR, Sound Navigation, and Ranging is a technique in which sound waves are used to navigate, detect and communicate under the surface of the water.

Echolocation:

Echolocation is the process where sound waves and echoes are used to determine objects in space. Echolocation is used by bats to navigate and find their food in the dark. Bats send out sound waves from their mouth and nose, which then hit the objects in their vicinity producing echoes, which are then received by the bats. The nature of the echo helps them determine the size, the shape and the distance of the object.