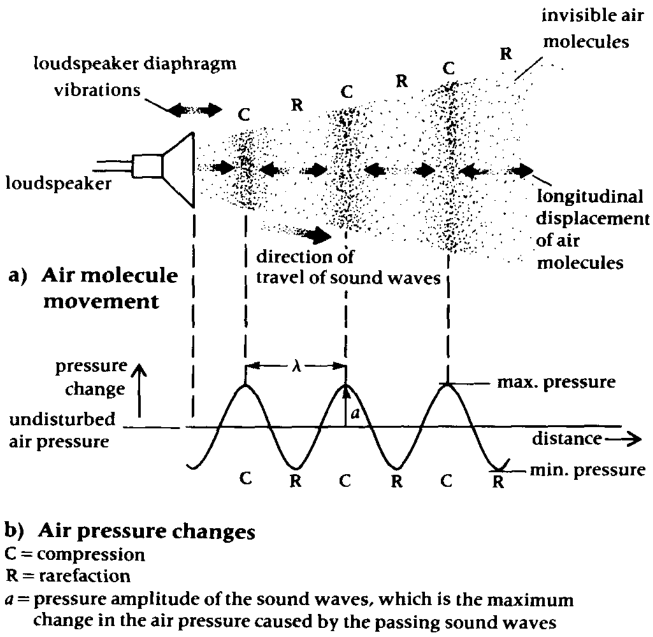
Hwa Chong Institution (High School) Name : ________________________ ( )
PHYSICS Notes Class:_________
Topic: Sound waves Date:_________

1. What is the nature of sound?
Sound is a form of energy that is transmitted as a wave. Sound is an example of a longitudinal wave.
What happens when a sound wave travels through air?
The figure shows how sound waves from a loudspeaker produce compressions and rarefactions of the air molecules. Where the air molecules bunched together, a region of compression is produced where the air pressure is higher. In between the compressions are rarefactions where the number of molecules is reduced and the air pressure is lower.

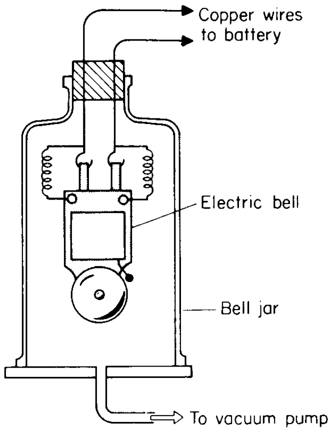
The distance between two successive compressions (or rarefactions) is the wavelength of the longitudinal sound wave.



2. For sound to be transmitted, the following are necessary:
a) A source, the vibrating object which produces the sound.
The majority of musical instruments produce notes either by the vibration of stretched strings or by the vibration of air in pipes. These vibrations cause the air in the neighbourhood to vibrate also, and this disturbance of the air travels out in the form of a longitudinal wave.

b) A medium to transmit the sound.
Sound waves cannot travel through a vacuum. An experiment using the following apparatus can be carried out to show this effect. For further details, read text.

c) A receiver (e.g. the ear, or a microphone) to receive the sound.



3. Sound can travel through solids and liquids. The table gives a comparison of the speed of sound in three different medium.

Medium	Speed of sound (m/s)
steel	5000
water	1500
air	330

4. Comparison of sound waves and electromagnetic waves.

a) Common properties

Both sound waves and e.m. waves exhibit the following wave properties:

- reflection;
- refraction.

b) Differences between sound waves and e.m. waves

Sound waves	Electromagnetic waves
longitudinal waves	transverse waves
340 m/s	3.0×10^8 m/s
cannot travel through a vacuum	can travel through a vacuum

5. Audibility

A normal, healthy individual has a hearing range between 20 Hz to 20 kHz (i.e. 20,000 Hz).

6. Measuring the speed of sound in air

a) Direct method

Apparatus:

- stopwatch
- starting pistol
- measuring tape

Diagram:

Procedure:

- observer **A** stands at one end of an open field with a starting pistol, while observer **B** stands at the other end with a stopwatch
- the distance between them is measured accurately with a measuring tape
- observer **B** starts the stopwatch on seeing the puff of smoke from the pistol, and stops it on hearing the sound
- the performance is repeated to eliminate any wind effects

Calculation:

- the average time is taken
- the speed of sound in air is found by taking distance/average time

Accuracy:

- since sound travels at 340 m/s, a stopwatch is not likely to be accurate enough
- a millisecond timer is preferable, or choose the echo method

b) Echo method

Apparatus:

- a large wall that is smooth, vertical and hard
- measuring tape
- stopwatch

Diagram:

Procedure:

- observer **A** stands at a measured distance of about 50 m in front of a wall and gives a clap (when the echo is heard, the sound has travelled 100 m)
- observer **B** holds the stopwatch
- observer **A** claps at such a rate that the returning echo coincides with the next clap, with the result that only one sound is heard
- observer **B** note the time (t) taken for a fixed number of claps (n)

Calculation:

$$\textbf{speed of sound} = \frac{2d}{\left(\frac{t}{n}\right)} = \frac{2nd}{t}$$

Accuracy:

- carry out the experiment for a large number of claps
- this will lengthen the timing and reduce human reaction timing error

Ex.1: In an experiment to determine the speed of sound in air, a student bangs two blocks of wood together when standing 125 m away from a high wall. The student hears the echo from the wall within one second of banging the blocks together. When he bangs the blocks repeatedly at a certain regular rate, he can no longer hear the echoes.

a) Explain why he cannot hear the echoes when he bangs the blocks at a particular rate.

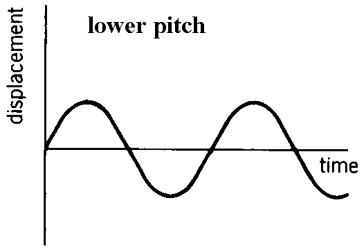
b) The lowest rate of banging for which the echoes cannot be heard is 81 bangs per minute, inclusive. Calculate a value for the speed of sound in air.

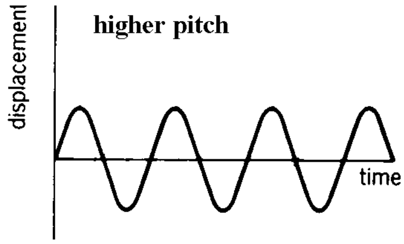
Ex.2: In a simple experiment to determine the speed of sound, an observer with a stopwatch stands on a flat stretch of sand and an assistant standing at a measured distance of 800 m fires a pistol. The observer starts his stopwatch when he sees the flash of the pistol and stops it when he hears the sound of the shot. The time intervals obtained for three experiments are: 2.2, 2.3, 2.1 s. Calculate a value for the speed of sound in air.

7. Characteristics of sound

a) Pitch

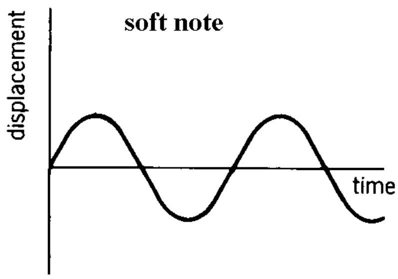
The pitch of a note is determined by its frequency.

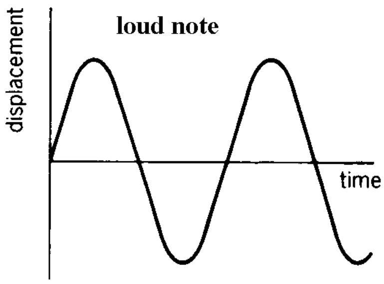




b) Loudness

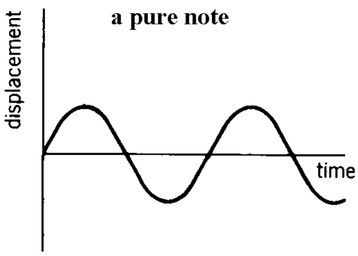
The loudness of a note depends upon the amplitude of the wave that produces it. The greater the amplitude, the louder is the note because more energy is used to produce a larger amplitude.

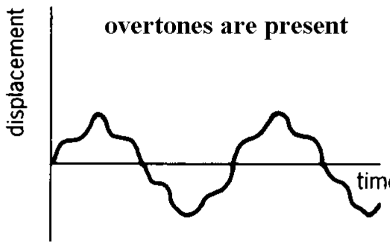




c) Quality (or Timbre)

The quality or timbre is the richness of the sound, and depends upon the number of overtones present, i.e. the quality of a note is determined by the overtones.





Note:

- the pitch and loudness of sounds have no effect on the velocity of sound in air
- changes of pressure also have no effect on the velocity of sound in air
- but, the velocity of sound in air increases with temperature

8. Ultrasound

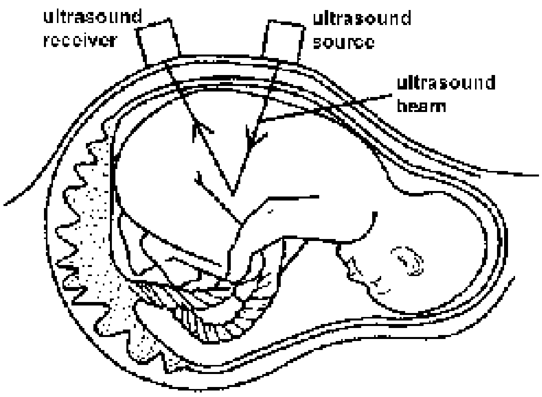
a) Definition

Sound with frequencies above the upper limit of human audible frequency range is known as ultrasound. Generally, **ultrasonic frequencies are found in the region above 20 kHz**.

b) Applications of ultrasound

1. Ultrasound in medical diagnosis

Used to obtain images of the internal parts of the body. Commonly used in pre-natal examination to examine the development of the foetus.
Ultrasound pulses are sent into the body by means of a transmitter. Reflections or echoes are received from any surfaces within the body which have either a different density or a different structure or elasticity. By noting the time interval, the depth of the reflecting surface within the body may be known. The reflections in different directions can be used to build up an image of something inside.



The following website simulates the use of ultrasound imaging as a technique used to "see" the inside of an object: http://electronics.howstuffworks.com/ultrasound4.htm

The advantage of using ultrasound rather than X-rays is that ultrasound is safer. X-rays are known to damage cells by ionisation. Ultrasound can be used continuously to watch the movement of an unborn baby or a person's heart without any injury or risk to the patient. Ultrasound can detect some differences between soft tissues in the body which X-rays cannot. In this way, it is sometimes able to find tumours or lumps inside the body.

2. Ultrasound in cleaning

The transmission of high energy ultrasound may result in the creation of cavitation bubbles. Cavitation bubbles are created at sites of rarefaction. These cavitation bubbles may displace contaminant from surfaces. This effect also allows fresh chemicals to come into contact with the contaminant remaining on the surface to be removed.
Ultrasonic cleaning is especially effective in the cleaning of irregular surfaces or internal cavities and passageways.

Read more about the theory of ultrasonic cleaning in "Ultrasonic Cleaning: Theory and Application" at: http://ultrasonicmachines.com/about-ultrasonics/how-does-ultrasonic-cleaning-work/ also: https://www.youtube.com/watch?v=ydrCPtU2atU

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