Measurement of Speed of Sound

Objective

To determine the speed of sound in air using the concept of resonance and to compare it with its theoretical value.

Apparatus

- Kundt's tube
- Speaker
- Function generator
- Support blocks
- Measurement scale
- Styrofoam balls

Introduction

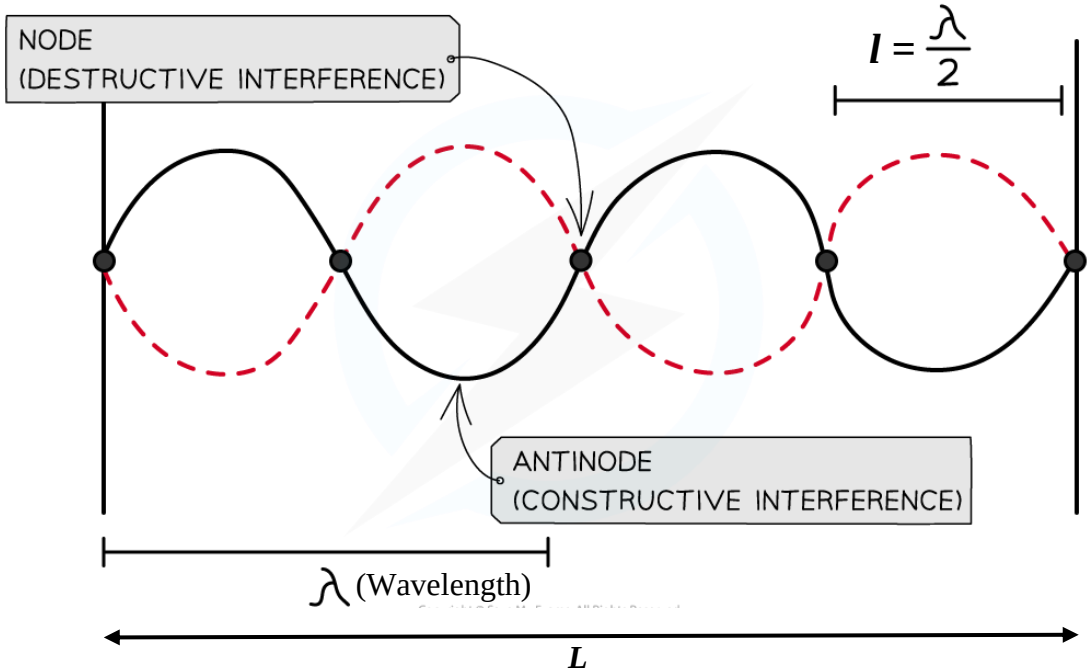
Sound is energy. It is the kinetic energy of atoms or molecules (particles) in motion in a periodic manner. All sound is produced by a vibrating membrane of some sort; for our purposes let's assume the source is a loudspeaker. When the electrical current in the coil of the loudspeaker forces it to move forward, the air load in front of it is compressed. Since the currents in a speaker are sinusoidal, the speaker will quickly be pulled back from its extended position. This creates a partial vacuum in the air load. The sinusoidal current usually carries interesting information (speech, music, etc.), and the motion of the speaker, and therefore the air load, tracks the current. The air load on the speaker forces the mass of air in front of it to move, and so the chain of compressions and rarefactions spreads out from the loudspeaker to the listener. This chain is called a longitudinal wave, and it is completely analogous to a sinusoidal (like a water) wave. The difference in pressure between the compressions and the rarefactions is the amplitude A (called loudness in music), and the number of waves produced each second is called the frequency f (pitch). The reciprocal of waves per second would therefore be seconds per wave; this is called period, T, obviously a specific time interval.

You perceive sound through a vibrating membrane in your ear called the tympanic membrane, or eardrum. Through a series of bones this vibration is conducted to sensors in your inner ear which send electrical impulses to your brain, and you ‘‘hear’’. The range of pitches you can detect is wide, from 20Hz (a hertz is a wave per second) to 20,000Hz, but you do not hear all frequencies at the same loudness. The ear discriminates against certain frequencies, depending

on age, gender, and general wear and tear on your auditory system. The speed v at which these or any longitudinal travels is dependent on the medium. Generally, waves travel faster in mediums that are less compressible and less dense. There is no exact correlation between compressibility and density, but many of the more incompressible materials are quite dense. Therefore, sound travels at about 1430m/s in water, but at 5000m/s in steel. Temperature affects the qualities of water and steel. The speed of sound in Sea water at 25 degrees Celsius is 1530 m/sec. The influence of temperature on gas is more dramatic. The speed of sound in air at 1ATM is 331m/s at 0° C, but increases 0.606 m/s for every 1° C increase in temperature.

Standing Waves

Standing waves are easily seen when vibrating a string which is tied to a point and pulled into tension. When the tension of the string and the frequency of the vibration is correct, the string appears to stop moving but takes a sine wave shape. The wave reflecting back from the fixed point interferes with the wave coming forward and the two waves add or subtract from one another vibration in the string appears to become stationary. This is a "standing wave' and the 'nodes' and 'antinodes' can very easily be seen. As the tension is changed or if the frequency is changed, the number of 'nodes' changes. A 'node' is where the string vibration amplitude is zero and an 'antinode' is where the string is vibrating with maximum amplitude. The same thing occurs in sound but the 'nodes' and 'antinodes' cannot be seen. However, they can be detected by 'hearing' the vibrations with a microphone or by seeing the vibrations on an oscilloscope.



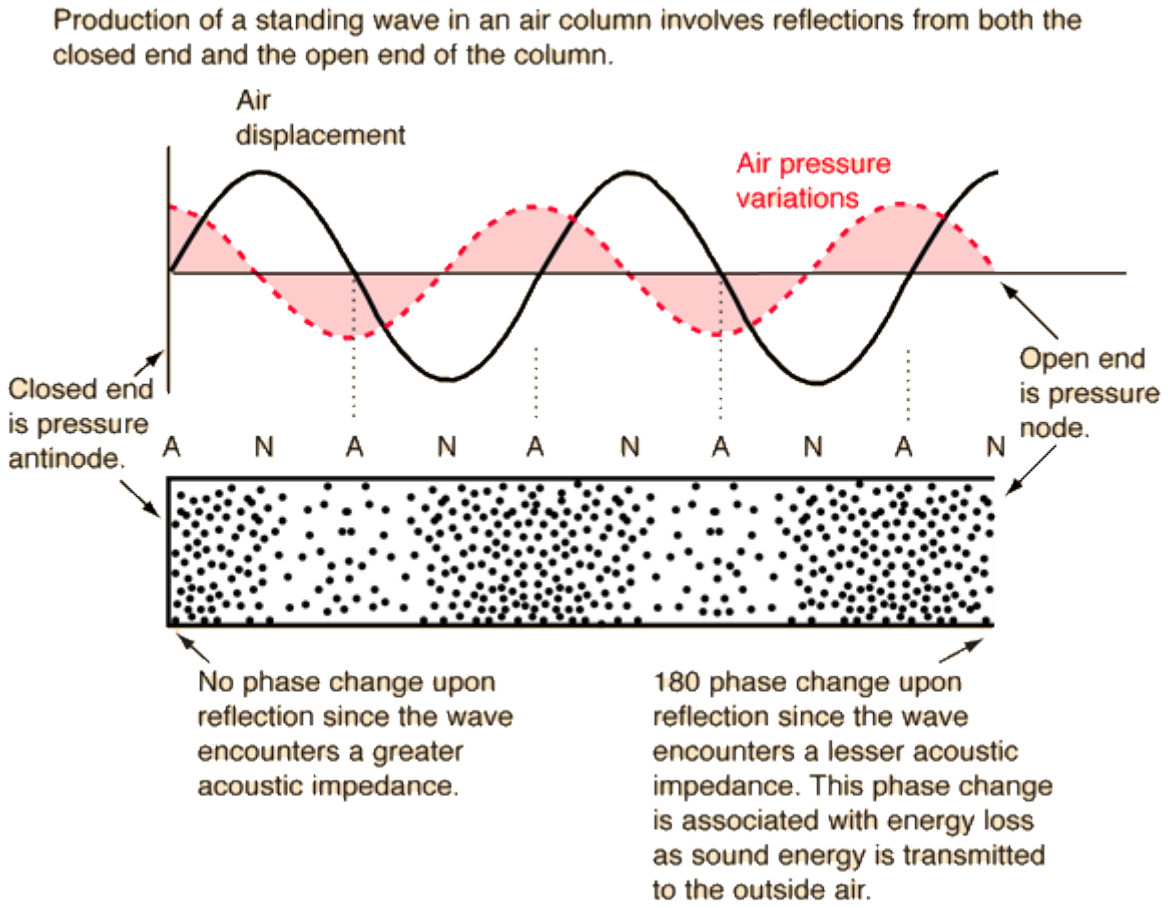
For the calculation of velocity of air through experiment the following relation can be used:

$$Velocity\ of\ sound\ in\ air = V_a = f \times \lambda$$

Where f is frequency and λ is the wavelength. However for calculated values the relation that can be used is:

$$V_a = V_0 \left[1 + \left(\frac{1}{2} \times \alpha \times t\right)\right]$$

The velocity of sound at 0° C is given as V_0, Temperature coeffecient is denoted by α and t is the temperature at which the experiment is being performed (room temp).

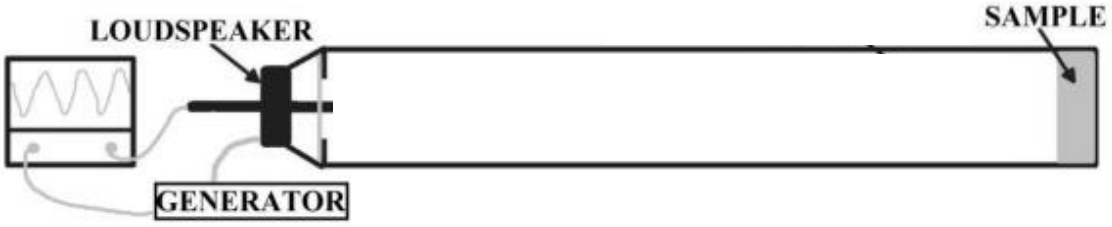


Resonance

When sound reflects from the end of an open or closed tube, the reflected wave will interfere with the original wave multiple times and there is no pattern of addition or destruction of the original wave. When the frequency is set so that the reflected wave synchronizes with the original wave there will be an adding and subtracting from the original wave so that the resulting standing wave will have a much greater vibration and strength than the original wave. This is resonance. The various frequencies that cause resonance depend on the length of the tube.

Procedure

Sound waves generated by audio frequency generator are fed to the Kundt's tube from one end via a speaker. The closed end of the tube serves as the reflecting wall. Standing waves may be generated between the speaker at one end and the tube wall at the other end.



To set up the apparatus following steps are to be followed:

1. Set the tube on a flat surface using support blocks.
2. The tube should be placed parallel to the measuring scale.
3. The tube should be thoroughly cleaned from contaminants.
4. Styrofoam balls are to be placed in the tube.
5. Set the frequency on the function generator.
6. The output of the function generator is to be connected to the speaker.
7. Speaker should be attached tightly at the open end of the tube.
8. Using the measuring scale, the readings such as wavelength of the air column can be noted.

Activity

Change the frequency of the signal from the function generator and note down the readings in the following table. Repeat this step by changing frequency.

Applied Frequency (f)	**No.of Loops Formed in Tube (p)**	**Length of Air Column in Tube (d)**	**Length per Loop** $(l = \frac{d}{p})$	**Wavelength** $\lambda = 2 \times l$	**Velocity of Sound** $V = f \times \lambda$ $(\frac{cm}{sec})$

Harmonic #	Pattern of Standing Waves	#of nodes	#of Anti-Nodes	Wavelength
m=1	 Fundamental, first harmonic, f_1			
m=2	 Second harmonic, f_2			
m=3	 Third harmonic, f_3			
m=4	 Fourth harmonic, f_4			
m=5	 Fifth harmonic, f_5			
m		m-1	m	$\lambda = \frac{2L}{m}$

Lab Exercise and Summary

Summary should cover Introduction, Procedure, Data Analysis and Evaluation.

Student's Signature: _____ **Date: _____**

LABORATORY SKILLS ASSESMENT (Psychomotor)

Total Marks: 100

Criteria (Max Marks)	Level 1 0% ≤ S < 50%	Level 2 50% ≤ S< 70%	Level 3 70% ≤ S< 90%	Level 4 90%≤ S ≤100%	Score (S)
Procedural Awareness (20)	Selects inappropriate skills and/or strategies required by the task	Selects and applies appropriate skills and/or strategies required by the task with some errors	Selects and applies the appropriate strategies and/or skills specific to the task without significant errors	Selects and applies appropriate strategies and/or skills specific to the task without any error	
Practical Implementation (30)	Makes several critical errors in applying procedural knowledge of Measurement of Speed of Sound	Makes few critical errors in applying procedural knowledge of Measurement of Speed of Sound	Makes some non-critical errors in applying procedural knowledge of Measurement of Speed of Sound	Applies the procedural knowledge of Measurement of Speed of Sound in perfect ways	
Safety (10)	Requires constant reminders to follow safety procedures	Requires some reminders to follow safety procedures	Follows safety procedures with only minimal reminders	Routinely follows safety procedures	
Use of Tool/Equipment (20)	Uses tools, equipment and materials with limited competence	Uses tools, equipment and materials with some competence	Uses tools, equipment and materials with considerable competence	Uses tools, equipment and materials with a high degree of competence	
Participation to Achieve Group Goals (10)	Shows little commitment to group goals and fails to perform assigned roles	Demonstrates commitment to group goals, but has difficulty performing assigned roles	Demonstrates commitment to group goals and carries out assigned roles effectively	Actively helps to identify group goals and works effectively to meet them in all roles assumed	
Interpersonal Skills in Group Work (10)	Rarely interacts positively within a group, even with prompting	Interacts with other group members if prompted	Interacts with all group members spontaneously	Interacts positively with all group members and encourages such interaction in others	
				Marks Obtained	

Instructor's Signature: _____ **Date: _____**

LABORATORY SKILLS ASSESMENT (Affective)

Total Marks: 40

Criteria (Max. Marks)	Level 1 0% ≤ S < 50%	Level 2 50% ≤ S < 70%	Level 3 70% ≤ S < 90%	Level 4 90% ≤ S ≤ 100%	Score (S)
Introduction (5)	Very little background information provided or information is incorrect	Introduction is brief with some minor mistakes	Introduction is nearly complete, missing some minor points	Introduction complete and well-written; provides all necessary background principles for the experiment	
Procedure (5)	Many stages of the procedure are not entered on the lab report.	Many stages of the procedure are entered on the lab report.	The procedure could be more efficiently designed but most stages of the procedure are entered on the lab report.	The procedure is well designed and all stages of the procedure are entered on the lab report.	
Data Record (10)	Data is brief and missing significant pieces of information.	Data provides some significant information and has few critical mistakes.	Data is almost complete but has some minor mistakes.	Data is complete and relevant. Tables with units are provided. Graphs are labeled. All questions are answered correctly.	
Data Analysis (10)	Data is presented in very unclear manner. Error analysis is not included.	Data is presented in ways (charts, tables, graphs) that are not clear enough. Error analysis is included.	Data is presented in ways (charts, tables, graphs) that can be understood and interpreted. Error analysis is included.	Data are presented in ways (charts, tables, graphs) that best facilitate understanding and interpretation. Error analysis is included.	
Report Quality (10)	Report contains many errors.	Report is somewhat organized with some spelling or grammatical errors.	Report is well organized and cohesive but contains some grammatical errors.	Report is well organized and cohesive and contains no grammatical errors. Presentation seems polished.	
				Marks Obtained	

LABORATORY SKILLS ASSESSMENT (Cognitive)

Total Marks: 10

(If any) **Marks Obtained**	

Instructor's Signature: _____ **Date: _____**