Module 16
Sound: Its Origin and Properties

What this module is about

Can you ever imagine the world without sound or without music? Don't you think that life would be so dull without sound? Sound makes life interesting. Music gives life to things. It can be used to express various emotions. **Sound and Music!**

In this module you will learn many things about Physics, particularly about sound. This module includes four (4) lessons such as:

- **Lesson 1 - The Nature and Properties of Sound**
- **Lesson 2 - The Behavior of Sound**
- **Lesson 3 - Resonance**
- **Lesson 4 - The Application of Sound**

Read, enjoy, and discover the secrets of Physics!

What you are expected to learn

After going through this module, you are expected to:

1. compare the transmission of sound through air with its transmission through solids, liquids, and a vacuum;
2. discuss the factors that affect the speed of sound;
3. explain how sound waves are produced, transmitted and propagated;
4. discuss how information is transmitted and received in terms of energy transfer and transformation in a telephone; and
5. recognize the contributions of Graham Bell, Maxwell, Hertz and Marconi in the development of telecommunications.

How to learn from this module

Here's a simple guide for you in going about the module.

1. Read and follow the instructions very carefully.
2. Take the pretest. It is a simple multiple-choice test provided at the start to determine how much you know about the content of this module.
3. Check your answers against the answer key provided at the last page of the module.
4. Be very honest in taking the test so you know how much knowledge you already have about the topic.
5. Perform all the activities, as these will help you have a better understanding of the topic.
6. Take the self-tests at the end of each lesson to determine how much you remember about the lesson.
7. Finally, take the post-test at the end of this module.

Good Luck and have fun!

What to do before (Pretest)

Direction: Choose the letter of the best answer. Write your answer on a separate sheet of paper.

1. Which of the following produce sound?
    a. soft objects
    b. radio stations
    c. vibrating objects
    d. objects under pressure

2. Compared to the speed of light, sound travels _______________.
    a. faster.
    b. slower.
    c. at the same speed.
    d. There is not enough information to compare the two.

3. Which of the following would be most likely to transmit sound the best?
    a. steel in cabinet
    b. water in the ocean
    c. air in your classroom
    d. water in a swimming pool

4. Resonance occurs when you _________________.
    a. push an object.
    b. vibrate an object.
    c. hit an object with a hammer.
    d. force the object to vibrate at its natural frequency.

5. Beats can be heard when two tuning forks ______________.
    a. are sounded together
    b. have the same frequency and are sounded together
    c. have almost the same frequency and are sounded together
    d. All of the above

6. An echo occurs when ______________.
    a. sound is reflected from a distant surface.
    b. sound is transmitted through a surface.
    c. the sound waves are very large.
    d. All of the above

7. What is the main reason why you can hear noises a long distance away over water at night?
    a. There are fewer other noises at night.
    b. Water conducts sound better at night.
    c. Sound bounces off water better at night
    d. Sound waves are bent towards the cool air over the water.

8. A sound wave is a _______________.
    a. shock wave.
    b. standing wave.
    c. transverse wave.
    d. longitudinal wave.

9. The speed of sound wave depends on ______________.
    a. pitch.
    b. loudness.
    c. temperature.
    d. None of the above

10. Sound waves cannot travel in ______________.
    a. air
    b. water
    c. steel
    d. vacuum

B. Write “**A**” if the statement is TRUE and “**B**” if the statement is FALSE.

11. A pulse of compressed air that is part of a sound wave is called refraction.
12. When an object is forced to vibrate at its natural frequency, resonance occurs.
13. Beats occur when two tuning forks at slightly different frequencies are sounded together.
14. Sound can travel through solids, liquids, and gases and even in a vacuum.
15. In order for sound from a speaker to reach a listener, air near the speaker must move to the listener.
16. Almost everything that exists has a natural frequency.
17. Even steel bridge can collapse because of resonance.
18. The word “pitch” refers to the period of a sound wave.
19. If you strike a tuning fork and hold it on a table, the sound becomes relatively loud.
20. When an object is disturbed slightly and then left alone, it vibrates at its natural frequency.
21. When an object is forced to vibrate at its natural frequency, its vibration amplitude gets very large.
22. Interference patterns are produced when two sources of waves are placed side by side.
23. Two speakers can be set side-by-side so there are some places in front of them where there is no sound.
24. Repeated echo is known as reverberations.
25. Sound can also exhibit refraction.

Key to answers on page 30

Lesson 1 The Nature and Properties of Sound

When we speak or make any sound, we tend to feel that our vocal cords vibrate. Conversely, no vibrations are felt when no sound is produced. This means that sounds are caused by vibrations. Vibrations of molecules refer to the to-and-fro oscillation of molecules as a disturbance that travels through a medium. This vibratory motion produces a sensation that reaches our ears and is interpreted by our brain. Sound waves are examples of **longitudinal waves**. They are also known as mechanical waves since sound waves need medium in order to propagate. Sound waves can travel in air. When they come in contact with our eardrums, the vibrations of the air force our eardrums to vibrate which is perceived and interpreted by our brain.

Terms to Remember

Longitudinal Wave
- *Wave whose motion is parallel to the motion of the medium or the particles*

Mechanical wave
- *Wave that needs a medium in order to propagate*

Vacuum
- *A space without matter*

Can sound waves also travel in other media like solids and liquids?

What you will do

Activity 1.1

Place your ear against one end of a tabletop. Ask a friend to gently tap the other end of the table with a pencil or a ruler. What happens? Then ask your friend to gently tap the other end of the table but this time make sure that your ear is above the other end of the table. What happens? On which situation did you encounter louder and more pronounced sound? On which situation did you encounter the sound earlier?

Slight tapping on the table can produce sound that can be heard clearly on the other end of the table. This shows that sound waves can also travel through wood or solid. Sound is more pronounced in solids than in the air. This also means that sound is heard louder when it propagates in solids than in air

Read This…

Liquids, on the other hand, are better conductors of sound than gases. If two bodies are struck together underwater, the sound heard by a person who is underwater is louder than when heard with air as the medium. As you can see, sound is transmitted differently in different media. Liquid particles are close to each other than the particles in the gases, so sound waves are transmitted easier in liquids. Between liquids and solids, the particles of solids are even closer together than the liquid molecules; therefore, sound travels even faster in solids than in liquids. Since different media transmit sound differently, sound travels at different speeds in different materials. Since solid is the best transmitter of sound, **sound travels fastest in solids and slowest in gases.**

Sound cannot travel in a vacuum. Remember that sound is a mechanical wave which needs a medium in order to propagate. If there is no matter, there is no sound. In the outer space, sound would not be transmitted.

What you will do
Activity 1.2

1. Which would best transmit sound: steel, water, or gas? _____________

2. If you are in space, are you capable of listening to another spaceship approaching you? Why or why not? ____________________________

Key to answers on page 31

The Speed of Sound

Fig. 1.1 Lightning

Did you know that lightning and thunder occur at the same time? However, we often see lightning much earlier than the corresponding thunder unless, of course, we are at the source. This is because the speed of light ($c = 3 \times 10^8$ m/s) is much faster than the speed of sound.

The speed of sound in dry air at 0^oC is about 331.5 m/s. However, the speed of sound in air is not constant. It is basically affected by three (3) different factors, which are the atmospheric pressure, relative humidity and atmospheric temperature. At higher atmospheric pressure sound waves travel faster. This means that in Baguio where the atmospheric pressure is relatively lower than at sea level, sound is transmitted slowly as compared to how it is transmitted at sea level where the atmospheric pressure is relatively higher. **Relative humidity** also affects the speed of sound in air. The higher the relative humidity, the faster the sound is transmitted. This is due to the fact that at higher relative humidity there is more water vapor in the atmosphere which makes the particles in the atmosphere a little closer than at low relative humidity. Thus, transmission of sound is better in humid air than in dry air.

The table below shows the speed of sound in different materials.

Table 1.1 Speed of sound in different materials

Materials	**Speed of Sound** V (m/s)
Air (0^oC)	331
He (0^oC)	1005
H (20^oC)	1300
Water	1440
Seawater	1560
Iron and Steel	5000
Aluminum	5100
Hard wood	4000

Hotter areas transmit sound better than cooler areas. For every degree of rise in air temperature above 0^oC, the speed of sound in air increases by 0.6 m/s. In symbols;

$$v = [331.5 + 0.6(T)] \text{ m/s}$$

where:

v = speed of sound in air at a particular temperature
T = temperature of the atmosphere

Example 1

At an atmospheric temperature of 40^oC, what is the speed of sound in air?

$v = [331.5 + 0.6(T)]$ m/s
$v = [331.5 + 0.6 (40)]$
$v =$ **355.5 m/s**

This is slightly faster than the speed of sound in dry air at 0^oC which is only about 331.5 m/s.

Frequency and Pitch

What you will do

Activity 1.3 Frequency and pitch

I. Objective:

To determine the factors that affect pitch.

II. Materials:

Guitar, guitar pick

III. Procedure:

1. Strum each guitar string without holding the frets. (String #0 is the lowermost string while string #6 is the uppermost string. Record all your observations in the table provided.

IV. Data and Results:

String #	Pitch (High or Low)
0	
1	
2	
3	
4	
5	
6	

V. Guide Questions:

1. Which string vibrates the most when strummed?
2. Which string vibrates the least when strummed?
3. Which string has the highest frequency?
4. Which string has the highest pitch?
5. Which has the lowest frequency?
6. Which string has the lowest pitch?
7. How would you relate pitch and frequency?

Key to answers on page 31

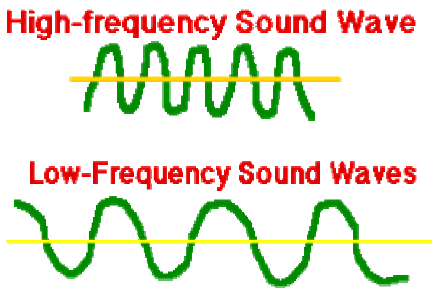

Fig. 1. 2 Pitch and Frequency

The highness or lowness of sound is known as the **pitch** of a sound or a musical note. It is determined by its frequency. A high pitch corresponds to a high frequency while a low pitch corresponds to a low frequency.

Did you know that…

The human ear and the animal ear are very sensitive sound detectors. The ear is a part of the peripheral auditory system. It is divided into three major parts: the outer ear, the middle ear and the inner ear.

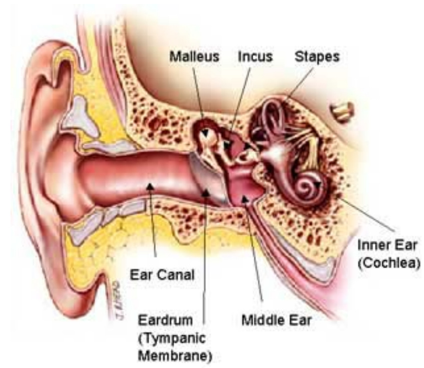

Fig. 1. 3 The Human Ear

The outer ear called the *pinna* collects the sound waves and focuses them into the ear canal. This canal transmits the sound waves to the eardrum.

On the other end of the ear canal is the eardrum membrane or the *tympanum*. This part separates the outer and the middle ears physically so that air pressure is controlled and will not rapidly equalize between the two. Air vibrations set the eardrum membrane in motion that causes the three smallest bones (*hammer, anvil and stirrup*) to move. These three bones convert the small-amplitude vibration of the eardrum into large-amplitude oscillations and transfer them to the inner ear through the oval window. Behind such oval window is a snail-shell shaped liquid –filled organ called the *cochlea.* The large-amplitude oscillations create waves that travel in liquid. These sounds are converted into electrical impulses, which are sent to the brain by the auditory nerve. The brain, then, relates these sounds to previous experiences and interprets these signals as words, music or noise.

The response of the human ear is limited to a range of frequencies about 20 Hz to about 20, 000 Hz. These frequencies are referred to as audio frequencies or sonic frequencies. Generally, as one grows older, the upper limit of audible frequencies drop.

Vibrational frequencies beyond 20 000 Hz are called **ultrasonic frequencies** while extremely low frequencies are known as **infrasonic frequencies**. The human ear is not capable of detecting ultrasonic or infrasonic waves. Some animals like dogs however, can hear sounds as high as 50 000 Hz while bats can detect sounds as high as 100 000 Hz.

Ultrasonic waves are very helpful to physicians. They often use ultrasonic waves to probe human internal organs instead of using x-rays, which can destroy human tissue. Most OB-Gynecologists use ultrasonic waves to examine the uterus of a pregnant woman to obtain information concerning the growth of the fetus. Nowadays, ultrasonic technology is of three categories: 2-dimensional, 3-dimensional, and 4-dimensional categories. In the 3 – and 4-dimensional ultrasonic technologies, the features of the fetus are very clearly captured.

Figure 1. 4 Ultrasound Machine

Ultrasonic waves can also be used as rodent and insect exterminators. The very loud ultrasonic sources in a building will usually drive the rodents away or disorient cockroaches causing them to die from the induced erratic behavior.

Loudness and Intensity

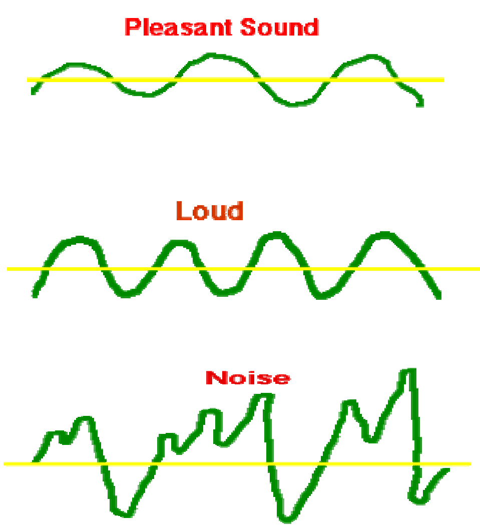

Fig. 1. 5 Wave forms of different sounds

Sound waves like any other waves carry different amounts of energy. The amount of energy a sound wave carries is known as **intensity** of the sound. Take a look at figure 1.5. High amplitude sounds usually carry large energy and have higher intensity while low amplitude sounds carry lesser amount of energy and have lower intensity. The intensity of sound is proportional to the square of the amplitude of a sound wave. **Sound intensity** is objective and is measured by various instruments like the oscilloscope. On the other hand, the subjective judgment of a person on the intensity of the sound is called loudness. **Loudness** is a psychological sensation that differs for different people. Loudness is subjective but is still related to the intensity of sound. In fact, despite the subjective variations, loudness varies nearly logarithmically with intensity. A logarithmic scale is used to describe sound intensity, which roughly corresponds to loudness. The unit of intensity level for sound is the decibel (dB), which was named after *Alexander Graham Bell* who invented the telephone. On the decibel scale, an increase of 10 dB means that sound intensity is increased by a factor of 10. A sound of 10 dB is 10 times as loud as 0 dB sound is 100 times more intense than the 40 dB level.

Fig. 1.6 Father and Son on guitar

Take a look at the picture of a father and son who interpret the loudness of a sound differently. The son considers the rock music a soft music while the father considers it a loud sound. The father may even interpret the sound as a distorted sound, which is known as noise. Noise is a wave that is not pleasing to the senses.

Table 1.2. Shows some common sources of sound.

Source of sound	Level (dB)
Jet engine, 30 m away	140
Threshold of pain	120
Amplified rock music	115
Old subway train	100
Average factory	90
Busy street traffic	70
Normal conversation	60
Library	40
Close whisper	20
Normal breathing	10
Threshold of hearing	0

What you will do

Self-Test 1.1

Choose the letter of the best answer. Write your answer on a separate sheet.

1. What happens to the wavelength of a sound wave if both the frequency and the velocity of sound are reduced to one-half?
    a. It is halved.
    b. It does not change.
    c. It becomes twice as large.
    d. It is reduced to one fourth.

2. Sound waves travel faster in water than in air because water has a greater ___________.
    a. density.
    b. elasticity.
    c. number of molecules.
    d. volume.

3. A high frequency sound has _____________.
    a. low pitch.
    b. high pitch.
    c. low energy.
    d. a and c

4. The part of the ear where sound energy is converted to electrical impulses and sent to the brain as nerve pulses is the _____________.
    a. tympanum
    b. cochlea
    c. ear canal
    d. auditory nerve

5. Sound waves travel fastest in _____________.
    a. vacuum.
    b. air.
    c. liquids.
    d. solids.

6. On which area will we not be able to hear any sound?
    a. a theater
    b. a closed room
    c. in the outer space
    d. in a spaceship

7. Compared to a thin string of the same length and tightness a thick string produces sounds of ____________.
    a. the same pitch
    b. lower pitch
    c. higher pitch
    d. lower then higher pitch

8. When is sound transmitted faster?
    a. during winter
    b. during summer
    c. There is no relation between season and sound transmission
    d. There is not enough information to say

9. A sound wave is a _____________.
   a. longitudinal wave
   b. transverse wave
   c. standing wave
   d. shock wave

10. Which of the following is NOT capable of transmitting sound?
   a. air
   b. water
   c. steel
   d. a vacuum

Key to answers on page 31

Lesson 2 The Behavior of Sound Waves

Have you ever experienced shouting inside a cave or even inside your bathroom? What did you notice? Chances are you also heard what you just said. It is like someone just repeated what you have said. This is called **reflection** of sound. Sound bounces back whenever it strikes a barrier. This reflected sound is also known as **echo.** Sometimes, reflection happens repeatedly and you would encounter repetitions of what you have said. This repeated echo is called **reverberation**.

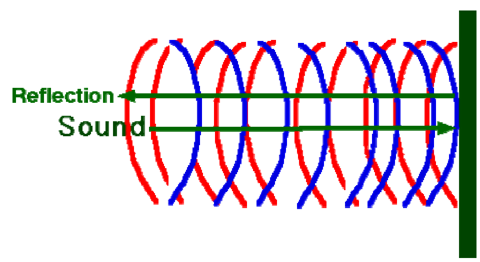

Fig. 2.1. Reflection of Sound

Echoes occur when a reflected sound wave reaches the ear more than 0.1 second after the original sound wave was heard. However, if the elapsed time between the arrival of the two sounds is more than 0.1 second, then the sensation of the first will have died out. In such a case, the second sound wave is perceived as a second sound.

Reverberation, on the other hand, often occurs in a small room with height, width and length of approximately 17 meters each or less. The effect of a particular sound wave upon the brain lasts for more than a tiny fraction of a second. In fact, the human brain keeps a sound for up to 0.1 second. If the reflected sound wave reaches the ear within 0.1 second of the initial sound, then the person perceives the sound as a prolonged sound, that is, **reverberation.**

What you will do

Self-Test 2.1

What might be the reason why the walls of movie houses are designed to be rough?

Key to answers on page 31

Reflection of sound waves in auditoriums and concert halls do not always lead to unpleasant sound results, especially if the reflections are designed right. Smooth walls have a tendency to direct sound waves in a specific direction. In this case, the use of smooth walls in auditoriums will cause the spectator to receive a large amount of sound from one location along the wall. This would result to only one path by which the sound wave could travel from the speakers to the listener. This results to a dull presentation. On the other hand, rough walls tend to diffuse sound and reflect it in a variety of directions. This would allow the spectators to perceive sound from every part of the room, making it seem lively and full. For this reason, auditoriums, concert halls and movie house designers prefer constructing rough walls rather than smooth walls.

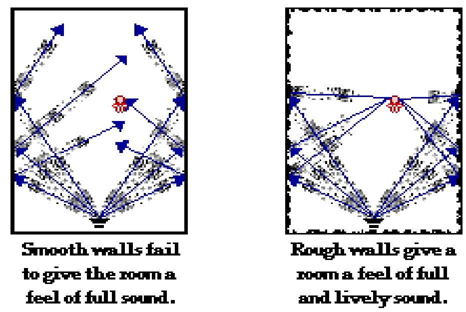

Fig. 2.2 Reflection of Sound

Did you know that reflected sound waves are used in determining ocean depth and the altitude of airplanes? Sound wave is usually sent out under water from a ship. This wave is reflected by the ocean basin back to the ship where a receiver inside the ship detects it. The depth of the ocean may be determined through the elapsed time the sound waves have traveled and the velocity of the sound in water. Airplanes, on the other hand, make use of **sonic altimeter** as a ranging device in determining airplane altitudes. This device consists of a sound emitter and a recorder that measures the time interval between the emission of sound and the reception of echo (reflected sound). The product of the time interval and the speed of sound at a given temperature divided by 2 (since the sound would travel downwards and then upwards back to the plane) is equal to the airplane's altitude.

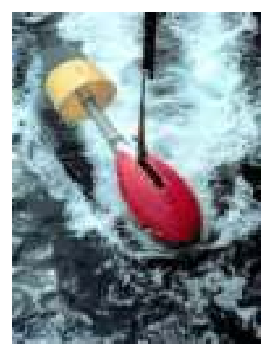

Fig. 2.3 Sound Ranging

Refraction

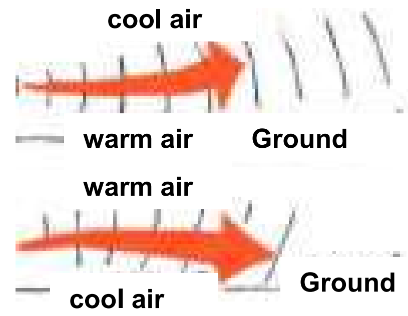

Fig. 2.4 Sound Refraction

You have probably experienced calling out to a friend, but he/she fails to hear you. This phenomenon happens when sound encounters another medium of different density other than air. Sound tends to bend or change its velocity in such a case. This is known as **refraction of sound waves.**

Refraction of waves involves a change in the direction of waves as they pass from one medium to another. Refraction of sound waves is very evident in situations in which sound waves pass through a medium with gradually changing properties. Sound waves travel slower in cooler air than in warmer air. This means that on a clear sunny day, when the earth's surface is hot, the air immediately above the surface is hotter than the layer of air above it. This results to sound traveling faster within the earth's surface. On the other hand, on a clear night, the earth's surface seems cooler. The layer of air immediately above it is also cooler. In such a case, the air closer to the ground is cooler than the layer of air above it. As a result sound would be traveling faster at the higher layer and is refracted (bent) towards the earth's surface.

Diffraction

What you will do

Activity 2.1 Diffraction

Go inside your room and close all the doors and windows. Then, ask your friend who is outside your room to start talking. Can you hear your friend's voice?

Now, while your friend is still talking open your door very slowly. Be sure that there will only be a very small opening on your door. Now, can you hear him/her in every corner of your room?

Key to answers on page 31

Diffraction is a property of wave that involves a change in direction of waves as they pass through an opening or around a barrier in their path. This phenomenon is commonly observed around the corners or through door openings, allowing us to hear others who are speaking to us from an adjacent room. Many forest-dwelling animals take advantage of the diffraction property of long-wavelength sound waves. Owls are capable of communicating across long distances through their long-wavelength boots that are capable of diffracting sound around the forest trees.

Interference and Beats

Interference happens or occurs when two (2) waves overlap or meet. The points of overlap can either be a **node (N) or** an **anti-node (AN)** point. A node is a part of overlapping waves that has very low energy (low amplitude) while an anti-node is the part of overlapping waves that carries the largest amount of energy (maximum amplitude)

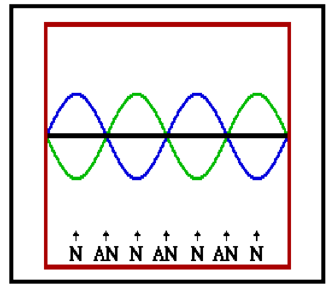

Fig. 2.5 Sound Interference

The waves in figure 2.6 are in-phase since both started as crests. In this case, when the waves overlap they form a wave of greater amplitude. This is known as **constructive interference.** This is also exhibited by sound waves which results to larger amplitude sound waves. Larger amplitude sound waves carry larger energy thus they are perceived to be louder or more intense sound.

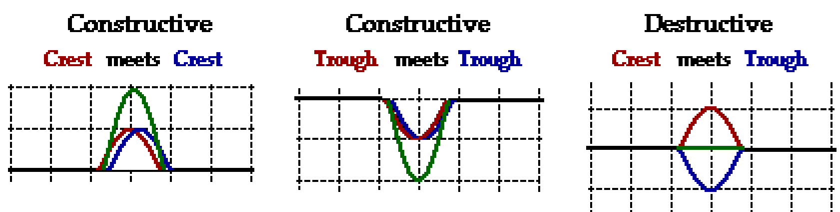

Fig. 2.6 Constructive and Destructive Interference

Out-of-phase waves, on the other hand, overlap and cancel each other. This means that the resulting wave is a lower amplitude wave or no wave at all. This is known as **destructive interference**. In the case of sound waves, lower amplitude waves connote softer sound. These softer sound areas are also known as "dead spots", which are sometimes evident in poorly designed theaters and movie houses.

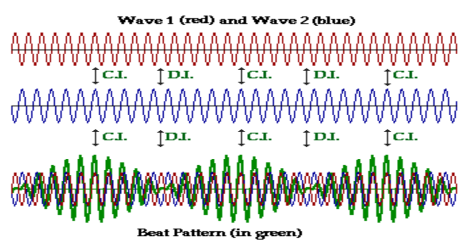

Fig. 2.7 Beats

Beats are special and interesting cases of interference of sound. When two (2) tones of slightly different frequencies are sounded together, a fluctuation in the loudness of the combined sounds is heard. The result is an alternating loud and faint sound.

What you will do
Activity 2.2 Beats

Go to a room with an electric fan. Try to hum at the frequency of the fan. What do you observe?

Beats can occur with any kind of wave and are a practical way of comparing frequencies. To tune a piano, the tuner listens for beats produced between the standard fork and a particular piano string. When the frequencies are identical, the beats disappear.

Doppler Effect

How will you perceive the sound emitted by the siren of an approaching ambulance? Will it be a high pitch sound or a low pitch sound? What about if the ambulance moves away from you?

Doppler Effect is a phenomenon observed when the source of waves is moving with respect to an observer. Take a look at figure 2.8. When the source of wave approaches the observer, there are more emitted waves on the space between the source and the observer. This results to a higher frequency waves. Remember that higher frequency waves result to a higher pitch sound – Weeee! This means that when the ambulance approaches you, you would perceive a higher pitch sound. On the other hand, when the wave source moves away from you (observer), there are only a number of waves perceived by the observer resulting to a low frequency sound. A lower frequency sound connotes a lower pitch. Thus, when the ambulance moves away from you, you perceive a lower pitch sound (WAAAANG!).

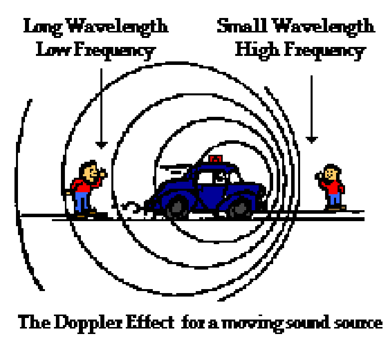

Fig. 2.8. Doppler Effect

When the speed of the source is the same or equal to the speed of the wave it produces, a wave barrier is produced. When the source of wave moves faster than its speed, the crests of the waves overlap at the edges as shown in figure 2.10. The pattern made by such overlapping waves is a V-shaped wave called **bow waves.** Similarly, a super sonic aircraft generates a three-dimensional **shock wave**. Just as

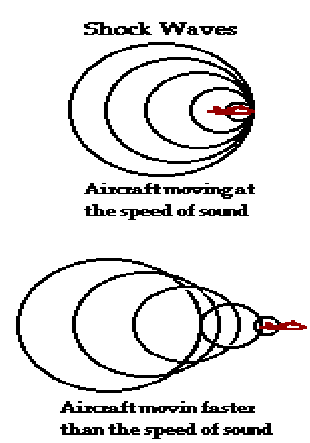

Fig. 2.10. Shock Waves

bow waves are produced by overlapping circles that form V, shock waves are produced by overlapping spheres that form a cone. This conical shell, which sweeps behind a super sonic aircraft, spreads until it reaches the ground. The sound heard by people on the ground as a sharp crack is known as **sonic boom.**

What you will do

Self-Test 2.2

1. Is interference a property of some types of waves only or is it a property of all types of waves?
2. When a wave source moves towards a receiver, does the receiver encounter an increase in wave frequency, wave speed or both?
3. Suppose a piano tuner hears 3 beats per second when listening to the combined sound from her tuning fork and the piano note being tuned. After slightly tightening the string, she hears 2 beats per second. Should she loosen the string or should she further tighten the string? Why?

Key to answers on page 31

Lesson 3 Resonance

Natural Frequency

What you will do

Activity 3.1 Natural Frequency

Gather the following materials: softball or a tennis ball, ball pen, and a nail. Drop the objects one at a time on the floor. Observe how each one sounds. Then with a friend drop the same set of objects one at a time. Blindfold a friend and ask him or her to guess the objects that you dropped

Guide Questions:

1. Did the sounds produced by the objects differ?
2. Did they have the same pitch?
3. What might be the reason why they exhibit different sounds?

Key to answers on page 32

When different objects made of different materials are dropped on the floor, they exhibit distinctly different sounds because objects vibrate differently when they strike the floor. The ability of the material to vibrate depends on the material's elasticity and the shape of the material. The set of frequency on which the material vibrates when disturbed is known as **natural frequency**. It is also described as one at which minimum energy is required to produce forced vibration. Most materials have distinct elasticity and vibrate at one or more **natural frequencies.**

What you will do

Activity 3.2 Forced Vibration

Hold both ends of a loosened guitar string. Let your friend strum or disturb the string. Then listen to the sound produced.

Get a guitar. Connect the guitar string to the sounding board (wooden part of the guitar). Strum or disturb the string.

Guide Question:

How did the sound of the loosened string compare to the sound made by the string connected to the sounding board?

Key to answers on page 32

Sounding boards are important in stringed instruments. Without them, the sound produced would be barely audible. The sounding board increases the energy released by this strip thus making the sound more intense. This happens when the vibrating string forces the sounding board to vibrate. This phenomenon is known as **forced vibration.**

Fig. 3.1 Stringed instruments

However, when the frequency of forced vibration on an object matches the object's natural frequency, a large increase in amplitude occurs. This is called resonance. **Resonance** means to resound or sound again. Inelastic materials like clay do not resonate since they are incapable of vibrations. In order for something to resonate, it needs a force to pull it back to its starting position and enough energy to keep it vibrating.

Resonance is not restricted to wave motion. It occurs whenever successive impulses are applied to a vibrating object in rhythm with its natural frequency. English cavalry troops marching across a footbridge in 1931 inadvertently caused the bridge to collapse when they marched in rhythm with the bridge's natural frequency. Since then, troops "break steps" when crossing bridges. In 1940, however, just four months after Tacoma Narrows Bridge in Washington was built, it was destroyed by a 40 mph wind. The mild gale produced a fluctuating force that is said to have resonated with the bridge's natural frequency and has steadily increased the amplitude over several hours until the bridge collapsed.

What you will do

Self-Test 3.1

1. Why do different objects make different sounds when dropped on the floor?
2. Why can a tuning fork or bell be set into resonance while a paper cannot?
3. If the handle of a tuning fork is held solidly against a table, the sound becomes louder. Why?

Key to answers on page 32

Lesson 4 The Application of Sound

You probably have relatives and friends who live far from your place. How do you communicate with them without traveling hundreds of miles? Which of the devices in the figure do you often use when communicating with them?

Nowadays, there are so many devices that can be used to communicate with our loved ones. Letters and telegrams are the older versions of emails and texts messages while cell phones and e-mails are the more convenient versions of the telephones.

Fig. 4.1. Communicating devices

William Sturgeon is a British inventor who exhibited a device that laid the foundation for large-scale electronic communications: the electromagnet. He displayed the power of electromagnet by lifting nine pounds with a seven-ounce piece of iron wrapped with wires through which the current of a single battery was sent.

Five years later, Joseph Henry demonstrated the potential of Sturgeon's device for long distance communication by sending an electronic current over one mile of wire to activate an electromagnet which caused a bell to strike. And so the telegraph was born.

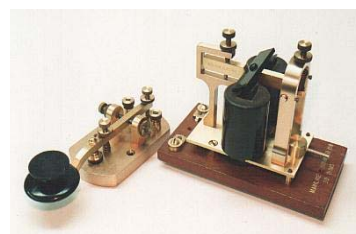

Fig. 4.2 A telegraph

The term "telegraph" comes the Greek word "tele" which means after and "graphos" which mean *write*.

> "What hath God wrought?"

Are you familiar with this phrase? Would you believe that this was the first message sent through a telegraph? Samuel F.B. Morse was the first person who made use of Henry's invention. In 1835 at New York University, he proved that signals could be transmitted by wires. He used pulses of current to deflect an electromagnet. This makes the electromagnet move a marker to produce written codes on a strip of paper. This is known as Morse's code.

In the United States, the operation developed into sending by key and receiving by ear. A trained Morse operator could transmit 40 to 50 words per minute. It became very popular that most Americans relied on it for communication.

Here's a good glimpse of telegraphy timeline.

Timeline of Telegraphy

1810	-	An electro-chemical telegraph was constructed in Germany.
1823	-	In England, Ronalds built a telegraph in his garden.
1827	-	In London, Wheatstone constructed a microphone.
1833	-	In Germany, a telegraph running nearly two miles was constructed.
1837	-	Wheatstone and Cooke sought patent for an electric telegraph in England.
1844	-	Morse's telegraph connected Washington and Baltimore.
1845	-	English channel cable was developed.
1847	-	First use of telegraph as business tool was realized.
1851	-	The Erie railroad depends on the telegraph.
1855	-	Printing telegraph was used in the U.S.
1861	-	Telegraph brought Pony Express to an abrupt end.
1894	-	Marconi invented wireless telegraphy
1933	-	The invention of the "Singing Telegrams"

What you will do

Activity 4.1 Finding Us!

Direction: Hunt the words, terms and names of scientists that are related to telegraphy and sound in the next page. Box the word that you find. The word may be written diagonally, horizontally, vertically or reversed.

Finding Us!

B	T	J	D	M	X	J	E	V	Q	G	Q	J	T	L	V	F	Z	Z	W
M	E	C	H	A	N	I	C	A	L	C	V	G	H	Y	F	P	O	A	L
X	K	U	A	I	N	Y	T	J	U	R	B	K	O	X	F	F	T	A	A
C	G	I	H	L	V	J	E	D	C	P	B	N	M	H	S	S	K	U	A
D	K	F	U	L	Y	Z	L	U	C	I	V	V	A	V	O	P	D	G	M
W	T	P	F	I	S	L	E	X	K	C	T	O	S	N	Z	C	Z	Y	S
M	G	A	X	W	U	X	P	O	K	K	Y	S	Y	G	R	E	N	E	D
V	V	U	I	D	M	J	H	H	K	M	I	S	U	W	R	V	R	T	J
M	V	Q	E	N	R	S	O	L	M	J	T	X	F	O	D	V	O	N	V
I	O	W	L	V	D	D	N	V	H	U	I	T	D	G	C	X	A	P	K
T	H	B	U	A	L	I	E	C	R	V	N	E	Z	A	L	A	E	S	V
Y	E	H	I	J	B	O	F	G	X	E	Z	N	R	N	C	S	F	T	H
B	R	L	O	L	D	Y	E	A	R	M	K	O	G	R	L	U	W	C	Y
W	D	N	E	X	E	O	U	R	X	M	S	H	P	U	S	K	I	U	A
B	R	S	E	G	N	O	U	V	M	F	M	P	P	S	A	M	J	T	H
P	K	R	O	H	R	C	X	M	M	F	F	C	H	Z	I	O	U	J	Z
N	L	D	V	U	I	A	I	U	K	C	J	S	T	D	L	B	C	E	D
N	F	L	F	U	Z	P	P	K	P	U	U	E	E	J	O	S	E	P	H
M	T	S	A	D	K	Y	X	H	B	I	K	C	X	A	A	C	R	V	M
C	I	R	T	C	E	L	E	H	Q	O	R	L	Z	K	V	L	C	B	D

ACOUSTIC	CURRENT	ELECTRIC
ENERGY	HENRY	JOSEPH
MECHANICAL	MOBILE	PHONE
PULSE	STURGEON	TELEGRAPH
TELEPHONE	THOMAS	WATSON
WILLIAM		

Key to answers on page 33

Telephone and Telephone System

Fig. 4.3 A telephone

Kring!!! Kring!!! Kring!!! This is a familiar sound in almost every household in the Philippines. When you want your friends to talk to you, you would wait for the sound Kring!!! Kring!!! Kring!!! For emergency purposes, it is still the sound Kring!!! Kring!!! Kring!!! that matters. When you are waiting for your girlfriend or your boyfriend to talk to you the most important sound is Kring!!! Kring!!! Kring!!! This is the sound emitted by a device known as a telephone. A telephone comes from the Greek word "tele" which means *afar* and "phone" meaning *voice or voiced sound*. It is often described as a device that conveys sound over a distance.

Fig. 4.4 Telephonic Devices

Take a look at the devices on Figures 4.3 and 4.4. These are the string telephone, megaphone and a speaking tube. They might be considered telephonic instruments but they only transmit sound mechanically. Acoustic pressure can be produced when talking. Speaking into a telephone made of can and string, for example, makes the line vibrate causing sound waves to travel from one end of the stretched line to the other.

A telephone, on the other hand, is a device that reproduces sound by electrical means. It consists of a transmitting and a receiving instrument connected by a line or a wire, which conveys the electric current.

What you will do

Self-Test 4.1

List 3 advantages and 3 disadvantages of using a telephone.

Key to answers on page 32

Do you know how the telephone was developed? It was Alexander Graham Bell who invented the telephone. On June 2, 1875, he discovered that he could hear sound over a wire. He further developed his findings and on March 10, 1875, he was able to speak through his telephone to his assistant Thomas A. Watson in the next room. These were his famous first words, "Mr. Watson --- come here --- I want to see you."

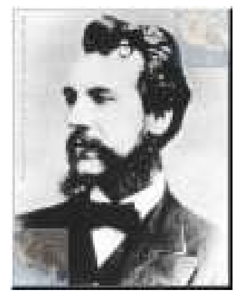

Fig. 4.5 Alexander Graham

But did you know that Bell was not the very first inventor of the telephone? Take a look at this timeline.

Time line of Telephony

1860	-	Philipp Reis developed a "telephon"
1874	-	Alexander Graham Bell discovered the principle of the telephone
1876	-	US Patent No.174, 465, issued on March 3 for "improvements in Telegraphy
1876	-	Elisa Gray applied for a similar patent hours after Bell
1877	-	Thomas Edison received a patent in Britain for the "electro-motograph"
	-	Commercial telephone service began in the US.
1878	-	The workable exchange enabled calls to be switched among any number of subscribers rather than requiring direct line
1879	-	Telephone subscribers began to be designated by numbers rather than names
1880	-	Long distance services were established and grew using metallic circuits.
1888	-	The common battery system developed by Hammad V. Hayes, permitted a central battery to supply all telephones on an exchange
1900	-	The first coin telephone was installed in Hartford, Connecticut
1911	-	American Telephone and Telegraph (AT & T) took control of Western Union Telegraph Company
1918	-	Ten million Bell System telephone were in service
1927	-	Transatlantic service from New York to London became operational, transmitted by radio wave
1946	-	Transmission via coaxial cable was accomplished.
1958	-	All Number Calling (ANC) instituted to handle consumer demands for individual telephone numbers
1960s	-	Videophones became more affordable and practical
1980s	-	Fiber optics technology was developed.

Let's summarize

1. Sound is a longitudinal wave. It is also considered as a mechanical wave.

2. Sound can be transmitted in solid, liquid or gas. It is best transmitted in solids and poorest transmitted in gases.

3. Sound cannot be transmitted in vacuum.

4. Sound is slower than light. It travels only about 331.5 m/s in dry air.

5. The speed of sound depends on temperature. It increases by 0.6 m/s for each degree rise in temperature.

6. High frequency sound connotes high pitch while low frequency sound connotes low pitch.

7. Loudness is a subjective quality of sound. The quantitative description of sound energy is intensity.

8. Sound can exhibit the following properties: reflection (echo and reverberation), refraction, interference and diffraction.

9. Doppler Effect is a phenomenon observed when the source of waves is moving with respect to an observer.

10. The pattern made by such overlapping waves is a V-shaped wave called bow waves. Similarly, a super sonic aircraft generates a three-dimensional shock wave.

11. The own set of frequency on which the material vibrates when disturbed is known as natural frequency.

12. Resonance means to resound or sound again.

13. A term “telegraph” comes from the Greek word “tele” which means after and “graphos” which means write.

14. A telephone is often described as a device that conveys sound over a distance.

Posttest

Direction: Choose the letter of the best answer. Write your answer on a separate sheet of paper

1. A Doppler Effect occurs when a source of sound waves moves ____________.
    a. towards you
    b. away from you
    c. parallel with you
    d. Needs more information to say.

2. An observer on the ground hears a sonic boom which is created by an airplane flying at a speed ______________.
    a. just below the speed of sound
    b. equal to the speed of sound
    c. greater than the speed of sound
    d. much lower than the speed of sound

3. An aircraft that flies faster than the speed of sound is said to be ____________.
    a. subsonic
    b. supersonic
    c. Neither of the above
    d. Need more information to say.

4. The speed of a sound wave depends on ____________.
    a. its frequency
    b. its wavelength
    c. the air temperature
    d. All of the above

5. Sound travels faster in air if the air is _____________.
    a. warm
    b. cold
    c. Neither warm nor cold
    d. Either warm or cold

6. The phenomenon of beats results from sound ____________.
    a. refraction
    b. reflection
    c. interference
    d. All of the above

7. The singer, Caruso, is said to have made a crystal chandelier shatter with his voice. This is a demonstration of ______________.
   a. beats
   b. an echo
   c. resonance
   d. sound refraction

8. When the handle of a tuning fork is held solidly against a table, the sound becomes louder and the length of time the fork vibrates ____________.
   a. becomes longer
   b. becomes shorter
   c. remains the same
   d. becomes slower

9. In which of the following does sound travel fastest?
   a. Ice
   b. Steam
   c. Water
   d. Sound travels at the same speed in each of the above.

10. Inhaling helium increases the pitch of your voice because sound travels ____________.
    a. slower in helium
    b. faster in helium
    c. at the same speed in helium, but the wavelength is shorter
    d. towards you

11. As you get farther and farther from a point source of waves, the wave fronts appear ____________.
    a. louder
    b. flatter
    c. the same as when they were first created
    d. None of the above

12. In which of the following will we encounter a higher pitched sound?
    a. a high-frequency sound
    b. a low frequency sound
    c. frequency is not related to sound.
    d. Not enough information to say

13. An interference pattern is produced when ____________
    a. the crest of two waves meet
    b. the troughs of two waves meet
    c. two or more waves meet
    d. wave passes through two narrow slits

14. When a wave passes through an opening, some of the waves are bent, this phenomenon is called _____________.
    a. reflection
    b. refraction
    c. interference
    d. diffraction

15. Constructive interference occurs when ____________.
    a. two crests meet
    b. a crest and a trough meet
    c. Need more information to say

16. Destructive interference occurs when____________.
    a. two crests meet
    b. a crest and a trough meet
    c. need more information to say

17. Who is the inventor of a telegraph?
    a. William Thomson
    b. William Sturgeon
    c. Joseph Henry
    d. Alexander Graham Bell

18. Morse' code is a communicating system which uses a device known as ____________.
    a. telephone
    b. megaphone
    c. telegraph
    d. cell phone

19. Which the following is the correct description of a telephone?
    a. A device that allows two people from different places to communicate through the transfer of mechanical energy.
    b. A device that allows two people from different places to communicate through the transfer of electrical pulses.
    c. A device that depends on Morse's code for transfer of information
    d. None of the above.

20. If the sounding board were removed out of a music box, it would ____________.
    a. sound the same as usual
    b. not sound at all
    c. make little "plinks" that you could hardly hear.
    d. Need more information to say.

Key to answers on page 34

Key to Answers

Pretest

1. C
2. B
3. A
4. D
5. C
6. A
7. D
8. D
9. C
10. D
11. B
12. A
13. A
14. B
15. B
16. A
17. A
18. B
19. A
20. A
21. A
22. A
23. A
24. A
25. A

Lesson 1

Activity 1.1

1. Slight tapping on the table can produce sound and will be heard at the other end. Sound can be transmitted by solids. Sound is encountered earlier, louder and more pronounced when the ear is placed against the tabletop.

Activity 1.2

1. Steel
2. No. There is no medium to transmit sound in space

Activity 1.3

1. String # 0
2. String # 6
3. String # 0
4. String # 0
5. String # 6
6. String # 6
7. The higher the frequency, the higher the pitch

Self-Test 1.1

1. B
2. A
3. B
4. D
5. D
6. C
7. B
8. B
9. A
10. D

Lesson 2

Self-Test 2.1

1. Rough walls tend to reflect sound in all directions. This means that all corners and places within the hall will be able to hear the sound clearly with rough walls rather than smooth walls.

Self-Test 2.2.

1. Interference is a property that can be exhibited by all kinds and types of waves.
2. Wave frequency

3. She should tighten the string further. The decrease in the beats when she tightens the string produces low frequency pitch. Tightening it would increase its frequency and lessen the beats.

Lesson 3

Activity 3.1.

1. Yes
2. No
3. Different objects consist of molecules vibrating uniquely. This means that the vibration of each object is unique.

Activity 3.2.

1. The loose string will produce a very soft sound while the one connected to the sounding board will have louder sound.

Self-Test 3.1.

1. Objects produce different sounds when dropped on the floor because they have different or distinct natural frequency.
2. Resonance only occurs in elastic materials. Since a paper is inelastic it cannot exhibit resonance.
3. The table becomes a sounding board when the tuning fork forces the table to vibrate.

Lesson 4

Self-Test 4.1.

Advantages

1. Can be used to communicate to people without seeing them or traveling to the place.
2. Can be useful during emergency cases.
3. Helpful to parents when monitoring their children.

Disadvantages

4. Can be used to commit crimes.
5. Can be used to spy on someone.
6. Can be helpful to those who want to make fun of others.

Lesson 4

Activity 4.1

B	T	J	D	M	X	J	E	V	Q	G	Q	J	T	L	V	F	Z	Z	W
M	E	C	H	A	N	I	C	A	L	C	V	G	H	Y	F	P	O	A	L
X	K	U	A	I	N	Y	T	J	U	R	B	K	O	X	F	E	T	A	A
C	G	I	H	L	V	J	E	D	C	P	B	N	M	H	S	S	K	U	A
D	K	F	U	L	Y	Z	L	U	C	I	V	V	A	V	O	P	D	G	M
W	T	P	F	I	S	L	E	X	K	C	T	O	S	N	Z	C	Z	Y	S
M	G	A	X	W	U	X	P	O	K	K	Y	S	Y	G	R	E	N	E	D
V	V	U	I	D	M	J	H	H	K	M	I	S	U	W	R	V	R	T	J
M	V	Q	E	N	R	S	O	L	M	J	T	X	F	O	D	V	O	N	V
I	O	W	L	V	D	D	N	V	H	U	I	T	D	G	C	X	A	P	K
T	H	B	U	A	L	I	E	C	R	V	N	E	Z	A	L	A	E	S	V
Y	E	H	I	J	B	O	F	G	X	E	Z	N	R	N	C	S	F	T	H
B	R	L	O	L	D	Y	E	A	R	M	K	O	G	R	L	U	W	C	Y
W	D	N	E	X	E	O	U	R	X	M	S	H	P	U	S	K	I	U	A
B	R	S	E	G	N	O	U	V	M	F	M	P	P	S	A	M	J	T	H
P	K	R	O	H	R	C	X	M	M	F	F	C	H	Z	I	O	U	J	Z
N	L	D	V	U	I	A	I	U	K	C	J	S	T	D	L	B	C	E	D
N	F	L	F	U	Z	P	P	K	P	U	U	E	E	J	O	S	E	P	H
M	T	S	A	D	K	Y	X	H	B	I	K	C	X	A	A	C	R	V	M
C	I	R	T	C	E	L	E	H	Q	O	R	L	Z	K	V	L	C	B	D

Posttest

1. C
2. C
3. B
4. D
5. A
6. C
7. C
8. A
9. A
10. C
11. B
12. A
13. C
14. D
15. A
16. B
17. C
18. C
19. B
20. C

-End of Module-

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