Unit One

Chapters 3 and 4

Emission, Propagation and Reception of sound

Prepared and presented by: Mr. Mohamad Seif

OBJECTIVES

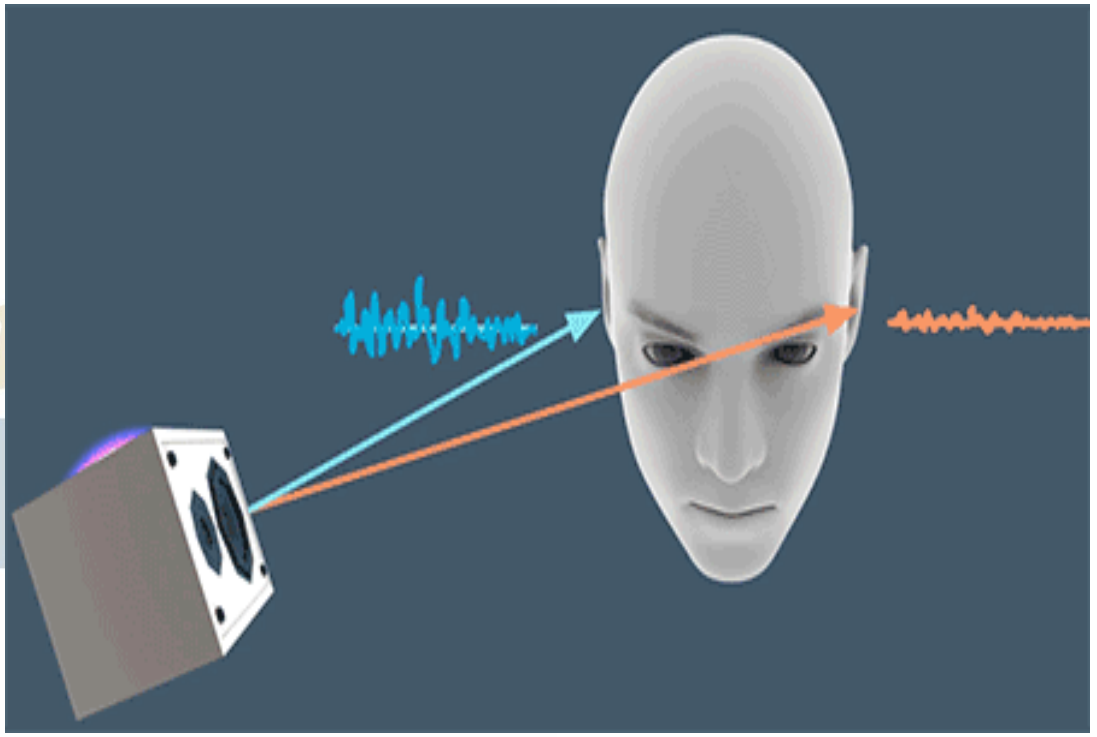
1. Characteristics of sound wave
2. Determine the Mach number
3. Study the Sonic boom

Characteristics of sound wave

What is sound wave?

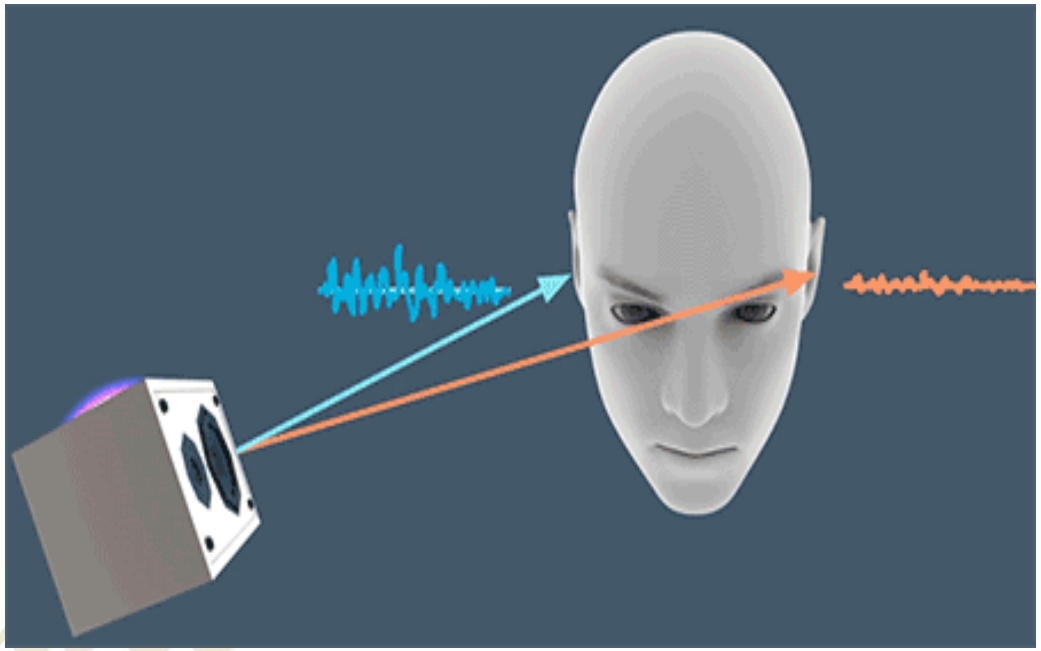
Sound is a vibration that propagates as an acoustic wave, through a transmission medium such as a gas, liquid or solid.

When an object vibrates, it causes the surrounding air molecules to vibrate, initiating a chain reaction of sound wave vibrations throughout the medium.



Characteristics of sound wave

Sound wave is a mechanical and longitudinal wave.



Sound wave propagates faster in solids, then liquids then gas

- **It has a speed of around 340 m/s in air and 1500 m/s in water.**
- $V_{solid} > V_{liquid} > V_{gas}$
- **Human beings can hear a sound of frequency ranging between:** $20\ Hz \leq f \leq 20000\ Hz$

Characteristics of sound wave

In gases, the speed of sound increases with the temperature and the density of the gas.

In air the speed of sound is given by the following expression

$$V = V_0\sqrt{1+\frac{T}{273^\circ}}$$

- V_0: speed of sound in air at 0 ℃, where $V_0 = 331\text{m}/s$.
- T: temperature of air in degree Celsius (℃)

Characteristics of sound wave

Application 1:

The speed of sound in air depends on the temperature T of the medium and given by: $V = 331.3\sqrt{1 + \frac{T}{273.15}}$, where T in degree Celsius (℃)

1) **Calculate the speed of sound at 0 ℃ and at 40℃.**
2) **Indicate how the speed changes with temperature.**
3) **Determine the temperature at which the speed becomes double that at 0 ℃.**

Characteristics of sound wave

1) Calculate the speed of sound at 0 ℃ and at 40℃.

$$V = 331.3\sqrt{1 + \frac{T}{273.15}} \rightarrow V = 331.3\sqrt{1 + \frac{0}{273.15}}$$

$$V = 331.3\sqrt{1 + 0} \rightarrow V = 331.3m/s$$

$$V = 331.3\sqrt{1 + \frac{T}{273.15}} \rightarrow V = 331.3\sqrt{1 + \frac{40}{273.15}}$$

$$V = 331.3\sqrt{1 + 0.146} \rightarrow V = 354.6m/s$$

Characteristics of sound wave

2) Indicate how the speed changes with temperature.

When the temperature was 0 °C, the speed of sound was 331.3m/s

But when the temperature become 40 °C, the speed become $354.6m/s$.

Therefore, as the temperature increases the speed of sound increase too

Characteristics of sound wave

3) Determine the temperature at which the speed becomes double that at 0 ℃.

The speed at 0 ℃ is 331.3m/s

Now the speed is doubled then: $V = 2 \times 331.3 = 662.6 m/s$

$$V = 331.3\sqrt{1 + \frac{T}{273.15}} \Rightarrow 662.6 = 331.3\sqrt{1 + \frac{T}{273.15}}$$

$$\frac{662.6}{331.3} = \sqrt{1 + \frac{T}{273.15}} \Rightarrow 2 = \sqrt{1 + \frac{T}{273.15}}$$

Characteristics of sound wave

$$2 = \sqrt{1 + \frac{T}{273.15}}$$

Square both sides

$$(2)^2 = \left(\sqrt{1 + \frac{T}{273.15}}\right)^2 \Rightarrow 4 = 1 + \frac{T}{273.15}$$

$$4 - 1 = \frac{T}{273.15} \Rightarrow 3 = \frac{T}{273.15}$$

$$T = 819.45℃$$

Mach muber

Mach number (M):

Mach is a number used to represent the speed of a plane when it is traveling close to or above the speed of sound

$$M = \frac{speed\ of\ plane}{speed\ of\ sound}$$

- **If M<1: the speed is subsonic.**
- **If M=1: the plane flies at mach 1.**
- **If M>1: the speed is supersonic**

Breaking the sound barrier (Sonic boom)

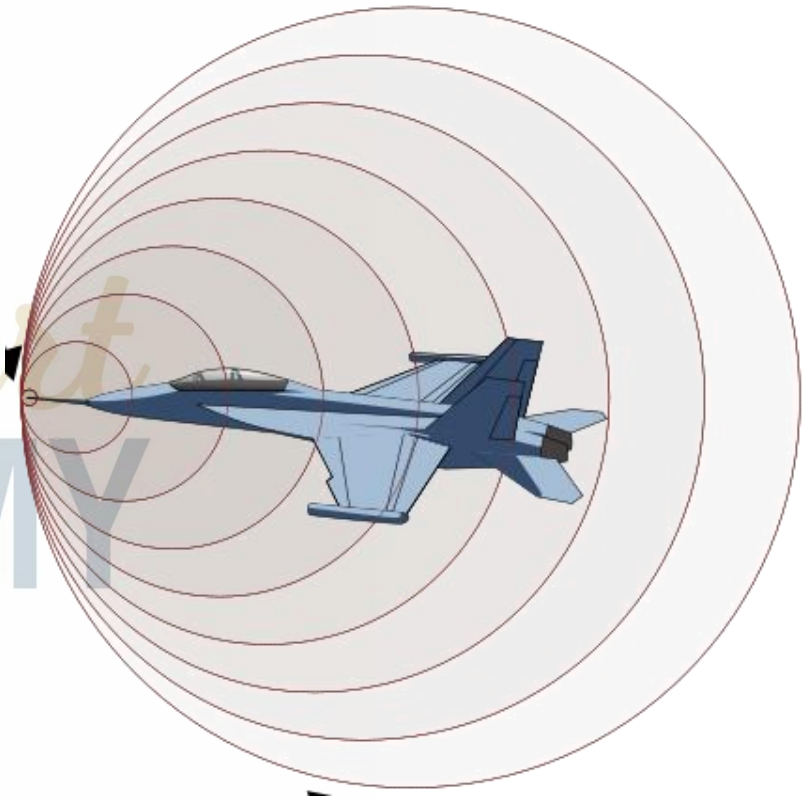
Breaking the sound barrier happens when an object moves faster than the speed of sound in air, which is about 343m/s.

When this occurs, a shock wave forms, creating a loud sonic boom

Breaking the sound barrier (Sonic boom)

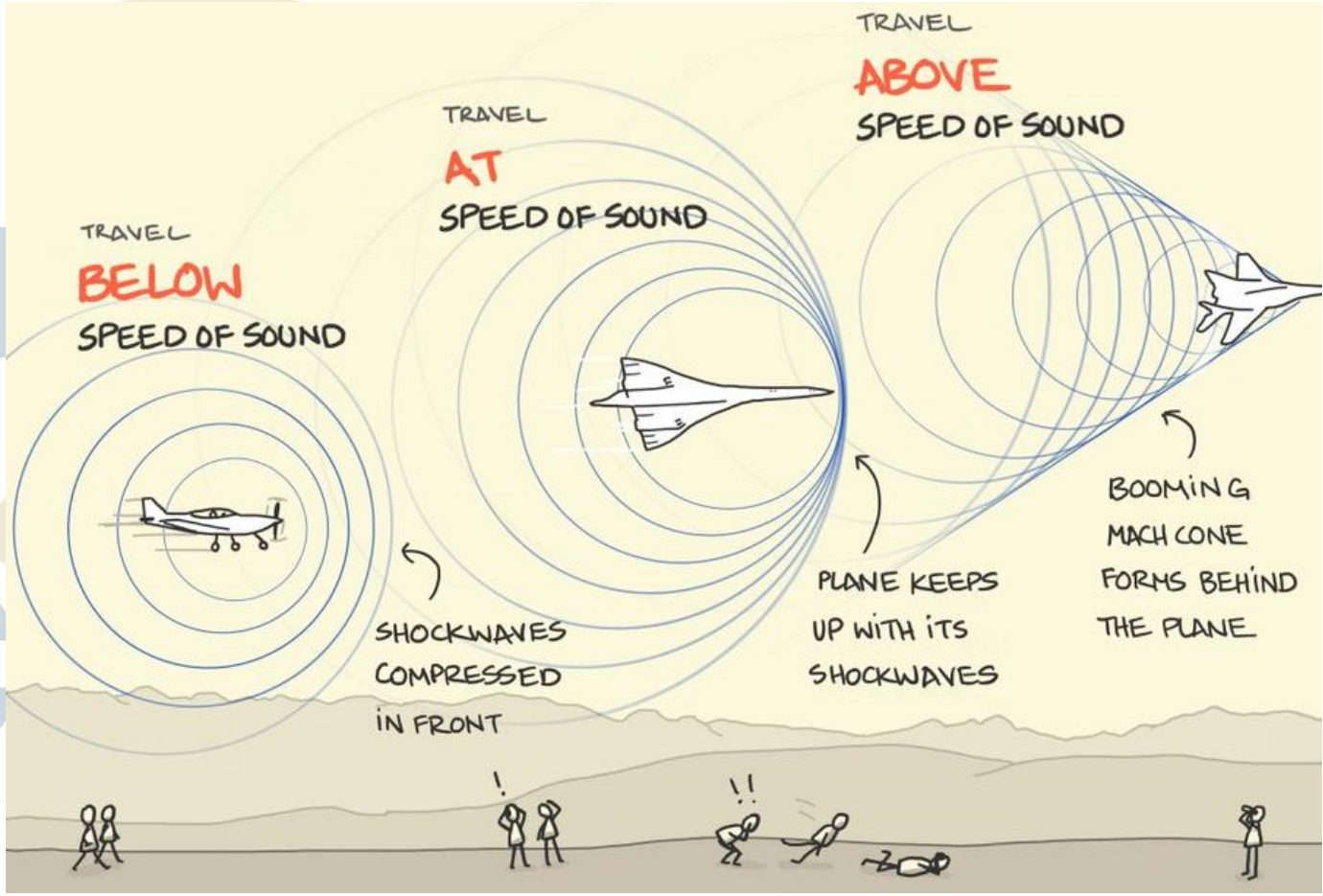
As the plane increases its speed, the emitted sound waves are compressed together until they merge together to form a single wave when the plane flies at Mach=1

This wave forms a region of high pressure or a sound barrier.



Breaking the sound barrier (Sonic boom)

When the speed of the plane increases and exceeds the local speed of sound (M>1), the plane breaks the sound barrier.



Breaking the sound barrier (Sonic boom)

Application 2:

In a certain medium the local speed of sound is 335m/s

1) **A plane is flying at Mach 3. Calculate the speed of the plane in Km/h.**

2) **Now the plane is flying at 670m/s**
   a) **Calculate the Mach number of the plane.**
   b) **Specify if the sonic boom occurs or not?**

Breaking the sound barrier (Sonic boom)

In a certain medium the local speed of sound is 335m/s

1) **A plane is flying at Mach 3. Calculate the speed of the plane in Km/h.**

$$M = \frac{V_{plane}}{V_{sound}} \Rightarrow 3 = \frac{V_{plane}}{335} \Rightarrow V_{plane} = 10053 m/s$$

$$V_{plane} = 1005 \times 3.6 \Rightarrow V_{plane} = 3618 Km/h$$

Breaking the sound barrier (Sonic boom)

2) Now the plane is flying at 670m/s

a) Calculate the Mach number of the plane.

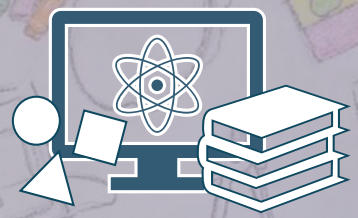
$$M = \frac{V_{plane}}{V_{sound}} \Rightarrow M = \frac{670}{335} \Rightarrow M = 2$$

b) Specify if the sonic boom occurs or not?

Since the speed of the plane is greater than the speed of the sound, then the speed of the plane is supersonic

Therefore, the plane breaks the sound barrier and then the sonic boom occurs.

The End



Be Smart Academy

Unit One

Chapters 3 and 4

Emission, Propagation and Reception of sound

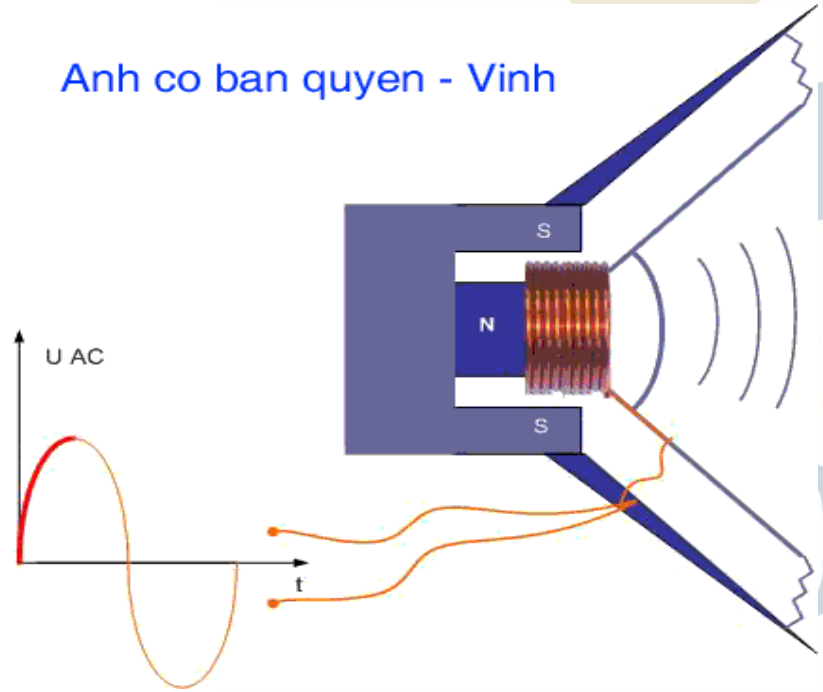
Prepared and presented by: Mr. Mohamad Seif

OBJECTIVES

1. Identify the Emitter of sound wave
2. Study the function of loudspeaker

Emitter of sound wave

A sound emitter transforms mechanical energy or electrical energy into sound energy such as loudspeaker, tuning fork ..



Electrodynamic loudspeaker

Tuning fork

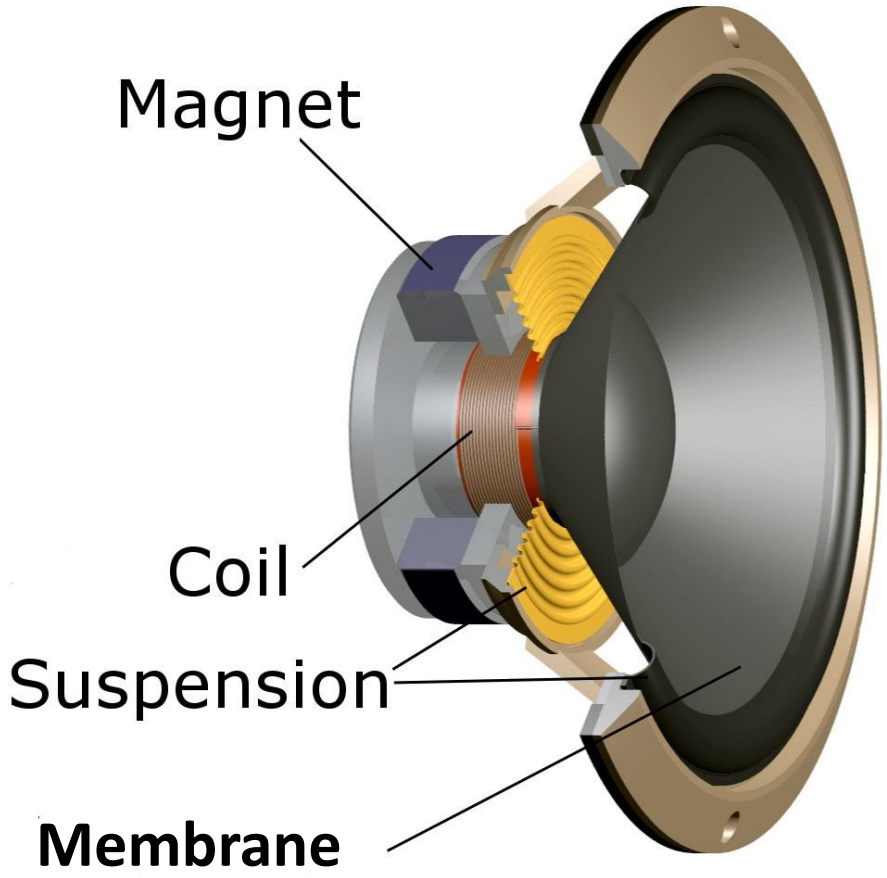
Function of loudspeaker

Main parts of Electrodynamic loudspeaker

It is called an electroacoustic device; it transforms electric energy into sound energy

The main parts of the loudspeaker are:

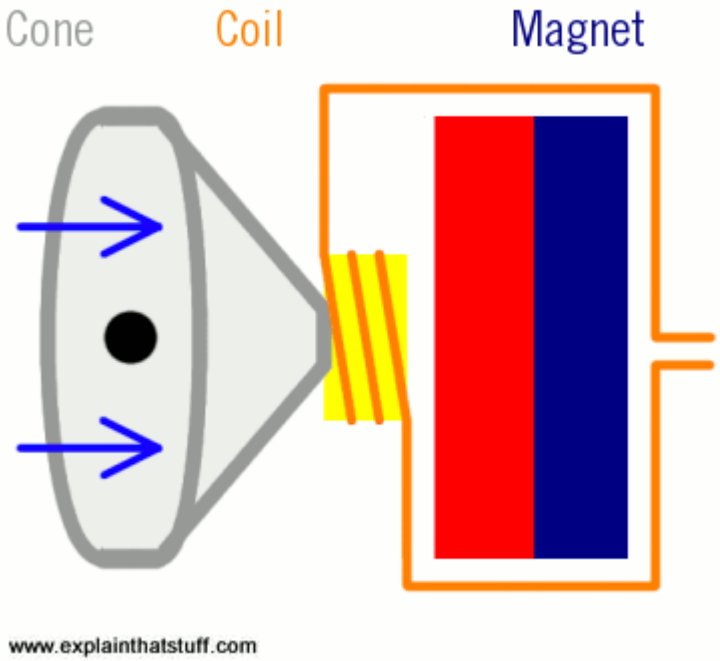
1. **Magnet**
2. **Coil**
3. **Membrane**
4. **Suspension**



Function of loudspeaker

Functioning of loudspeaker

1. The loudspeaker receives alternating electric current.
2. The current traverses the coil.
3. The coil being traversed by a current and placed in an external magnetic field
4. The coil then submitted to an electromagnetic force (called Laplace's force).

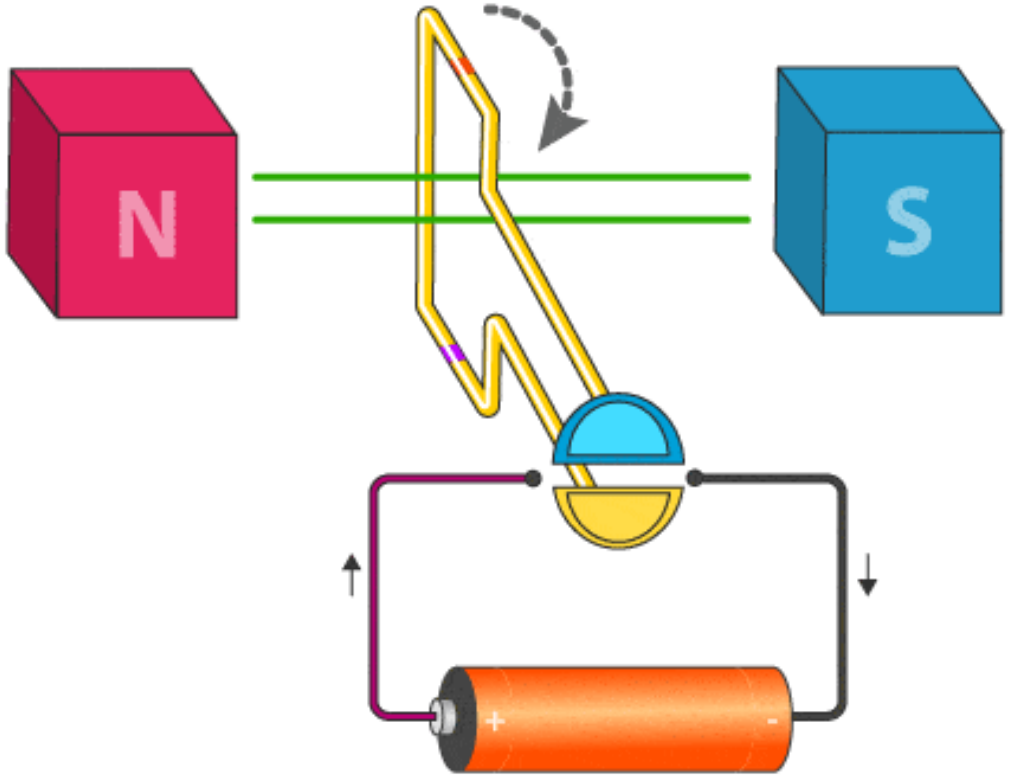


Function of loudspeaker

Functioning of loudspeaker

5. Since the current is AC hence the force has an opposite direction in each half period (left and right).

6. Due to the force, the coil vibrates longitudinally hence the membrane vibrates and the particles of air vibrate; Sound is produced.

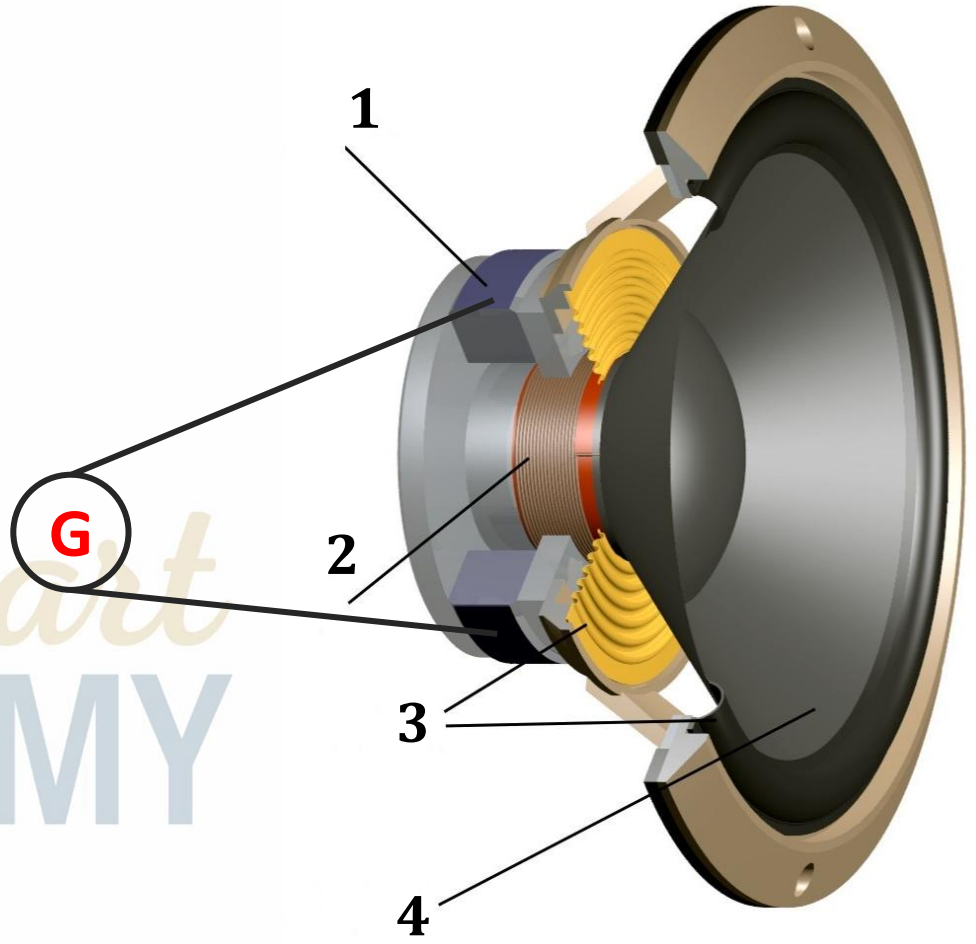


Function of loudspeaker

Application 3:

The adjacent figure shows a loudspeaker connected to a generator (G).

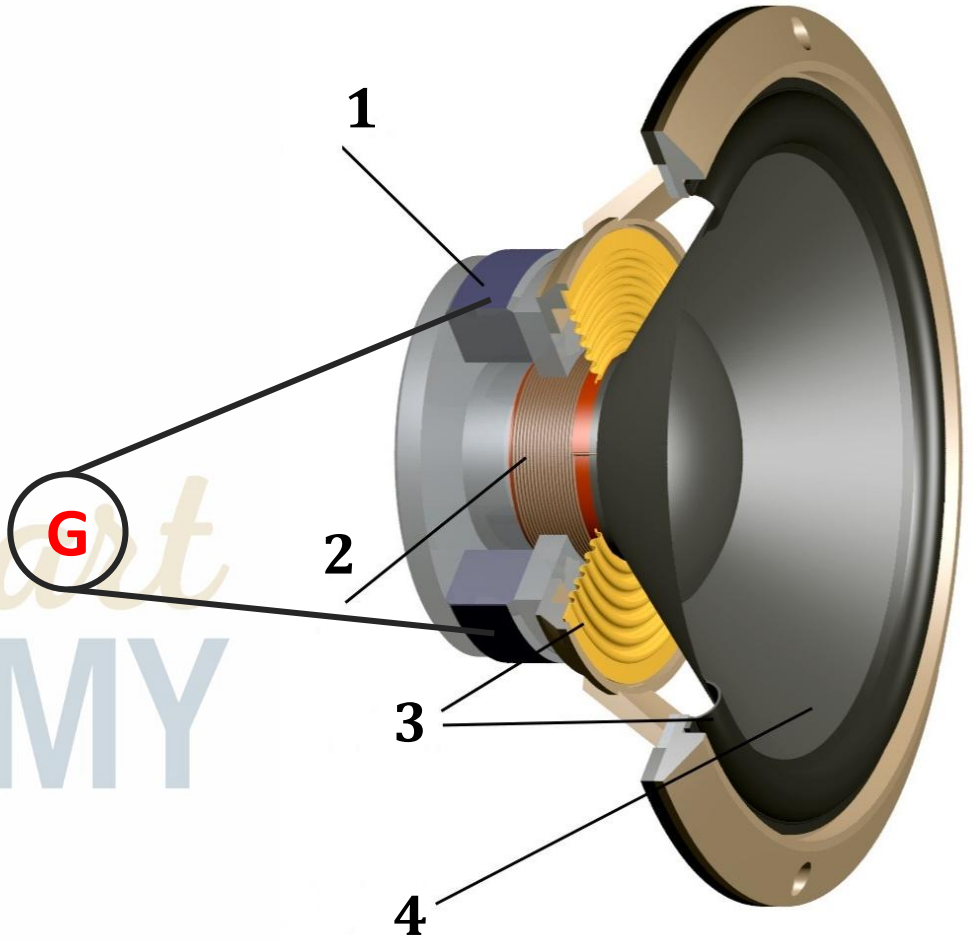
1) **Name the elements 1, 2, 3, and 4.**
2) **The generator (G) delivers an AC voltage of frequency f=440Hz. What is the frequency of the sound produced by loud speaker?**



Function of loudspeaker

1) Name the elements 1, 2, 3, and 4.

- Element 1: the magnet
- Element 2: the coil
- Element 3: the suspension
- Element 4: the membrane



Emitter of sound wave

2) The generator (G) delivers an AC voltage of frequency f= 440Hz. What is the frequency of the sound produced by loud speaker?

The frequency of the sound produced by loud speaker is same of the source.

$$f_{sound} = f_G = 440Hz$$

Emitter of sound wave

Application 4:

A loudspeaker carries a sinusoidal alternating current of frequency 500Hz.

1) **Describe briefly the motion of the membrane of the loudspeaker.**
2) **Calculate the speed of the emitted sound if its wavelength is 0.66m.**
3) **Does the loudspeaker emits sound when it carries a constant current of value I=0.01A. Justify**

Emitter of sound wave

1) Describe briefly the motion of the membrane of the loudspeaker.

When the loudspeaker is connected to a generator supplying an AC voltage, a current traverses the coil.

The coil then submitted to an electromagnetic force (called Laplace's force).

Since the current is AC hence the force has an opposite direction in each half period (left and right).

Due to the force, the coil vibrates longitudinally hence the membrane vibrates and the particles of air vibrate; Sound is produced.

Emitter of sound wave

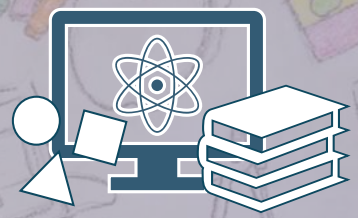
2) Calculate the speed of the emitted sound if its wavelength is 0.66m.

$v = \lambda \times f$ ➡ $v = 0.66 \times 500$ ➡ $v = 330 m/s$

3) Does the loudspeaker emits sound when it carries a constant current of value I=0.01A. Justify

When the loudspeaker carries a constant current, it does not emits sound, since the membrane deflect in one direction (no vibration)

The End



Unit One

Chapters 3 and 4

Emission, Propagation and Reception of sound

Prepared and presented by: Mr. Mohamad Seif

OBJECTIVES

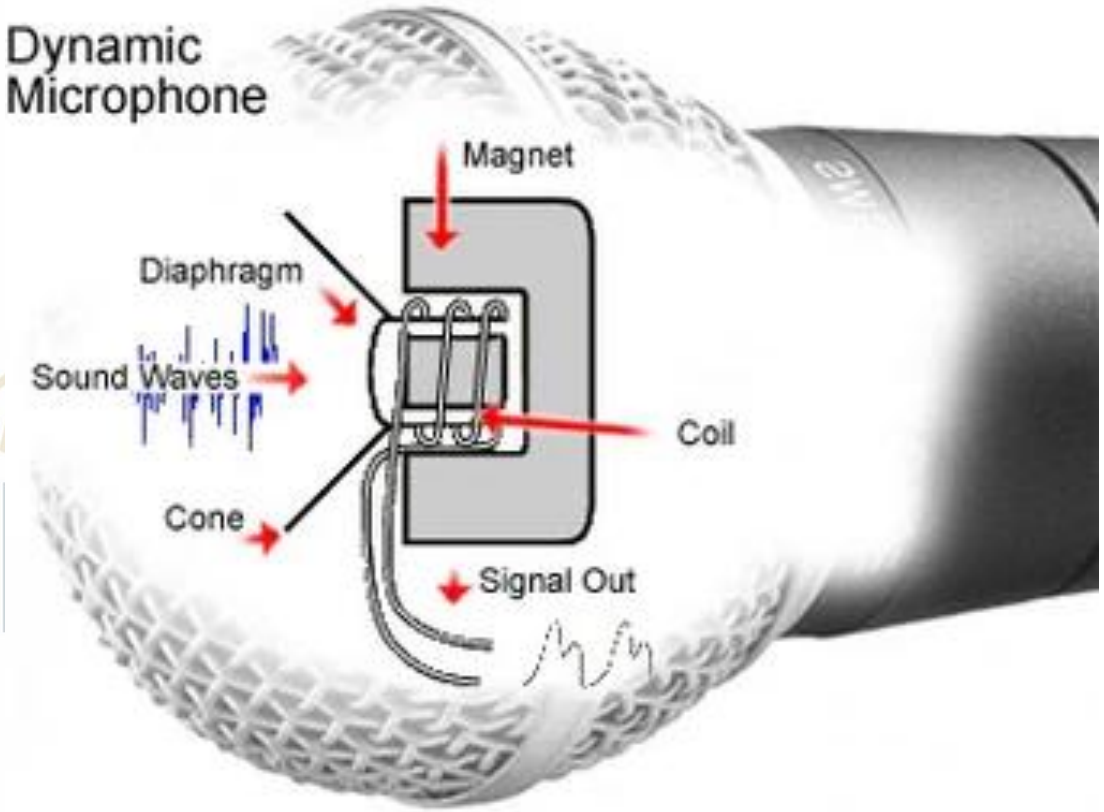
1. Identify the Receiver of sound
2. Study the function of a microphone
3. Audible and inaudible sound

Receiver of sound wave

A sound receiver transforms sound energy (acoustic) into electrical energy, such as Microphone.

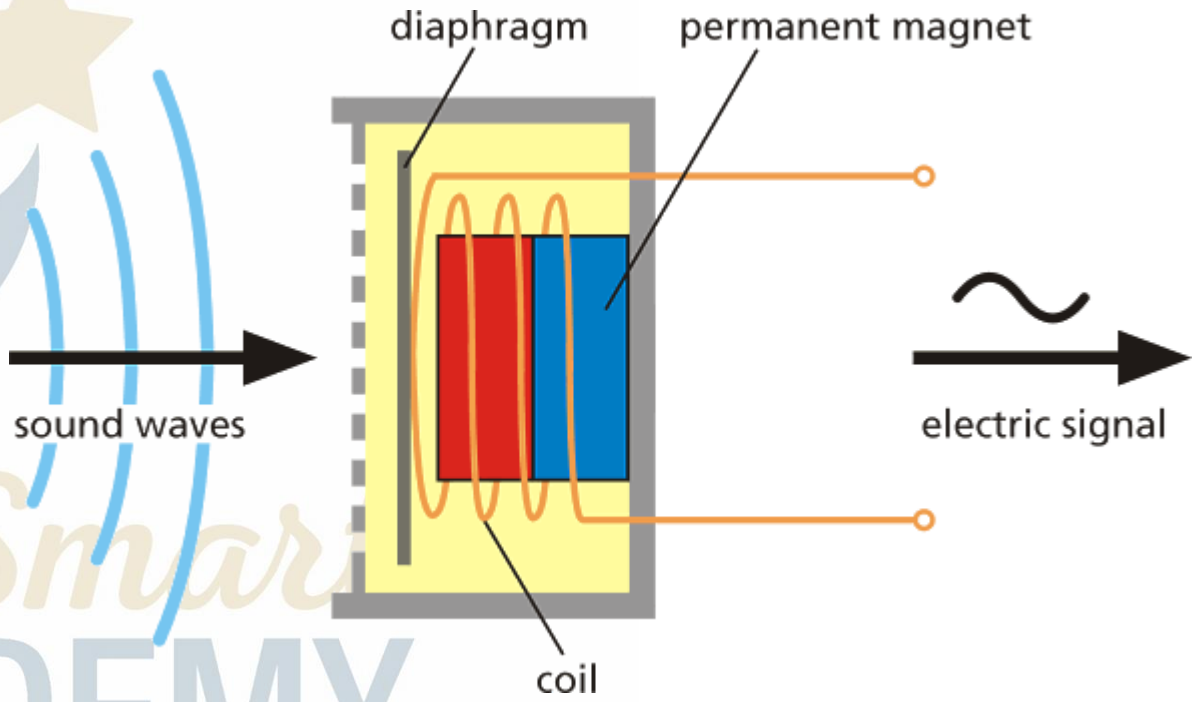
Main parts Microphone:

1. **Magnet.**
2. **Coil.**
3. **Membrane (diaphragm).**



Function of the Microphone:

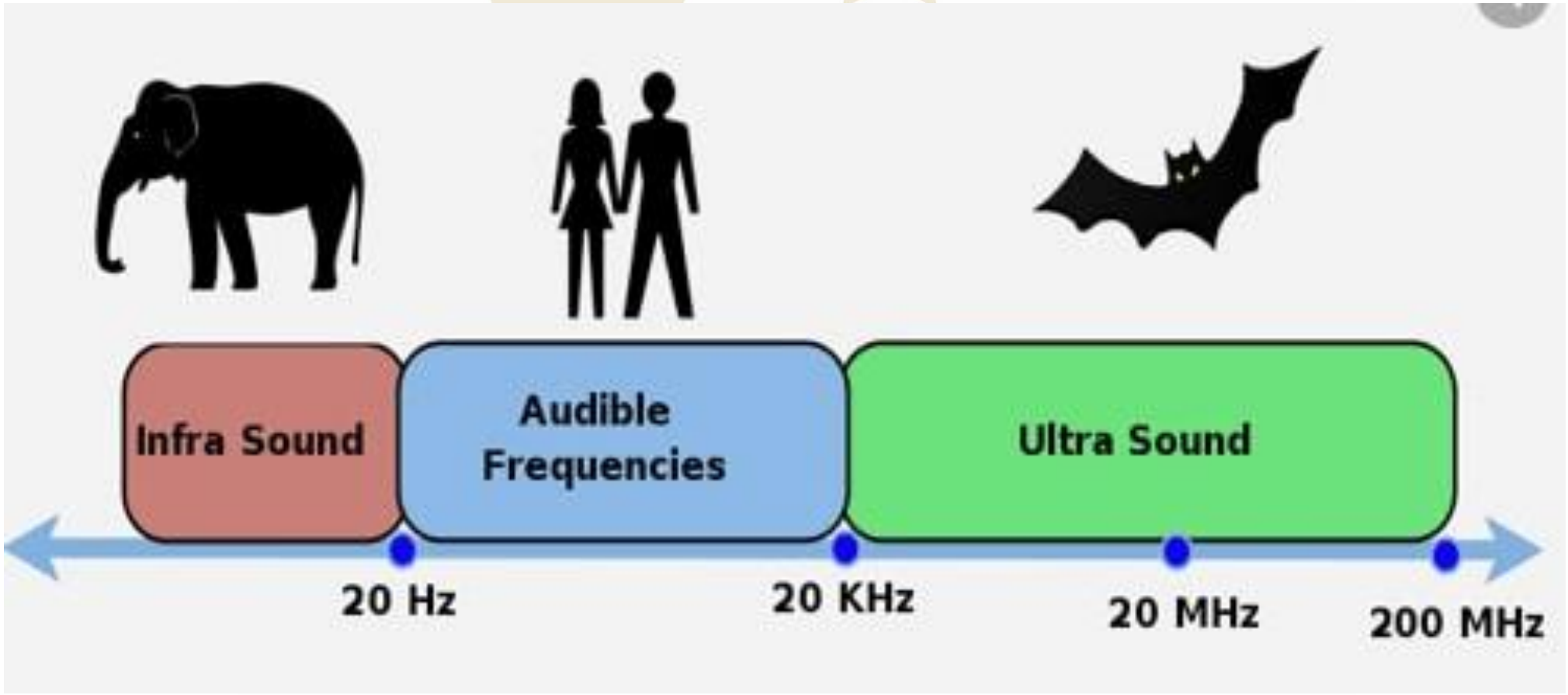
- A sound wave reaches the membrane, hence it vibrates and the coil vibrates.
- The vibration of the coil placed in a magnetic field leads to a creation of a current called induced current. (electromagnetic induction)



- If we connect the microphone to an oscilloscope, we observe a sinusoidal wave of same frequency. Sinusoidal alternating current

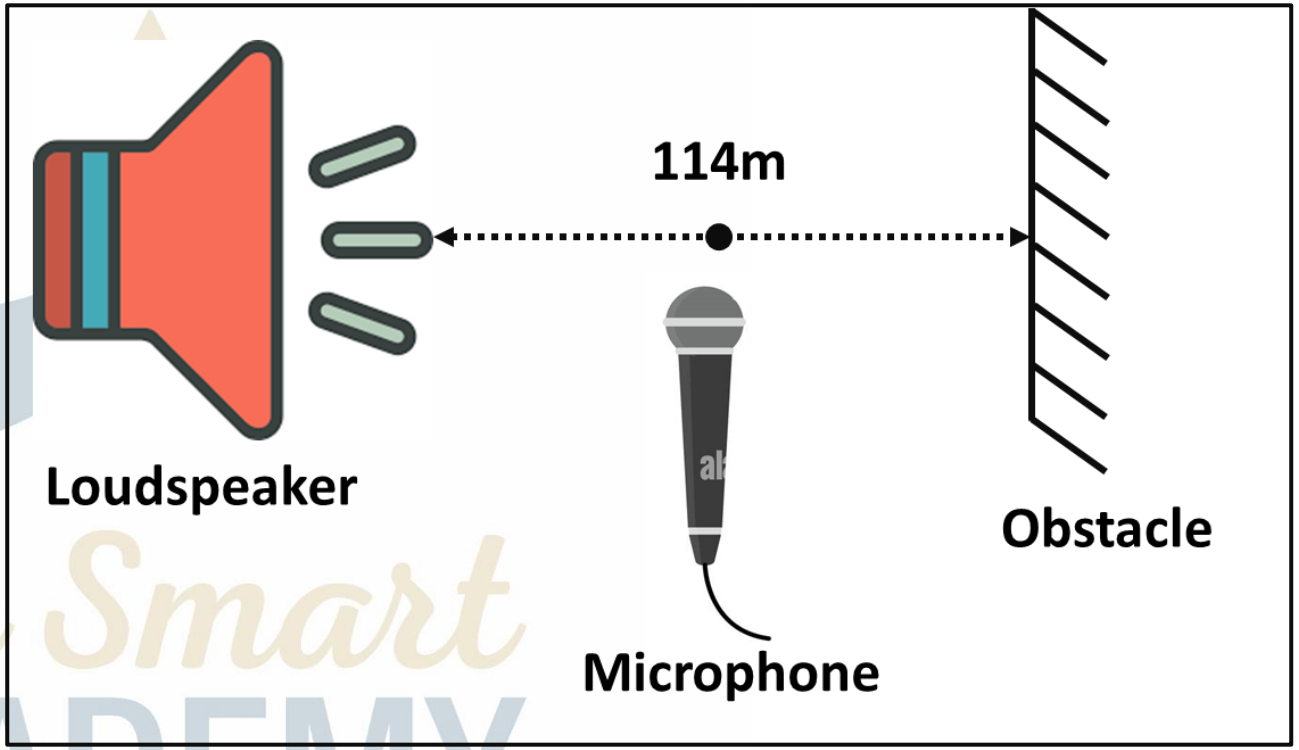
Audible and inaudible sound:

Human beings can hear a sound of frequency ranging between: $20\ Hz \leq f \leq 20000\ Hz$



Application 5:

The adjacent figure includes a sound emitter and a sound receiver.

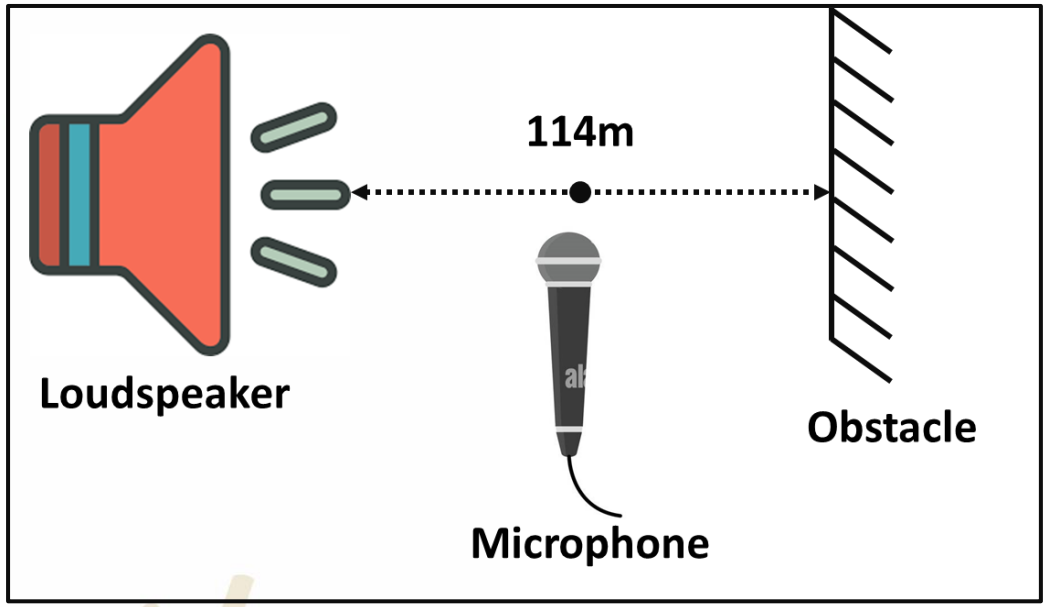


1) **Explain how the microphone functions.**
2) **The emitted sound has a frequency of 3000 Hz. Specify if this sound be audible to the human ear or not?**
3) **Is sound a mechanical or an electromagnetic wave?**

1) Explain how the microphone functions.

When a sound wave of frequency f is transmitted to the microphone through air particles, the membrane set in vibration with same frequency.

Therefore, the coil vibrates between the poles of the magnet.



The vibration of the coil placed in a magnetic field leads to a creation of a current called induced current. (electromagnetic induction)

2) **The emitted sound has a frequency of 3000 Hz. Specify if this sound be audible to the human ear or not?**

Human beings can hear a sound of frequency ranging between: $20\ Hz \leq f \leq 20000\ Hz$

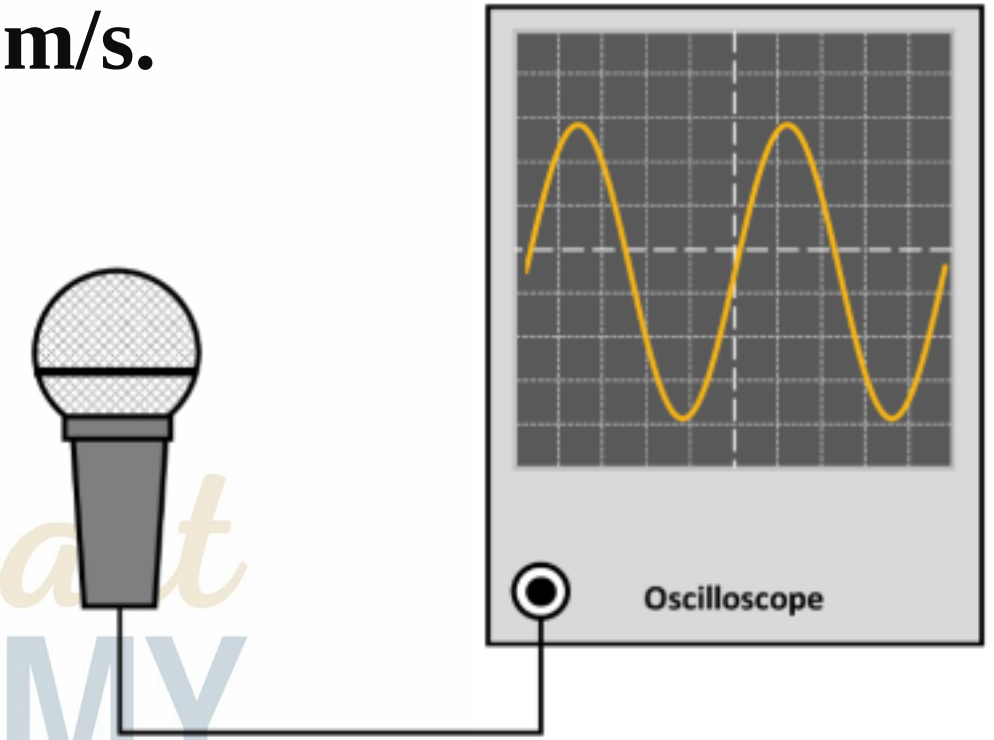
The frequency of the emitted sound is f=3000Hz is in the range of audible frequencies, so its audible to the human ear

3) **Is sound a mechanical or an electromagnetic wave?**

Sound waves are mechanical waves, since it needs medium to propagate and can't propagate in Vaccum.

Application 6:

A dynamic microphone is connected to an oscilloscope whose sensitivities are adjusted as $S_V = 2V/div$ and $S_h = 20ms/div$. The speed of sound is 320m/s.



1) **Name the basic parts of microphone.**

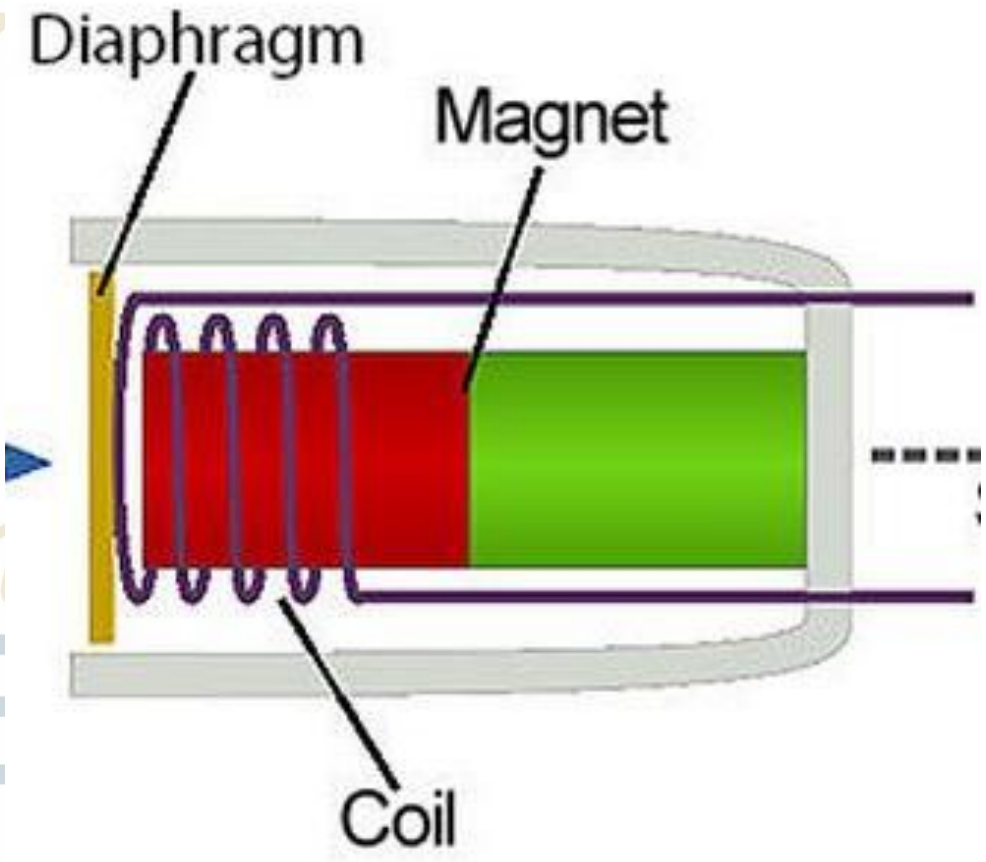
2) **Determine the frequency of the obtained oscillogram. Deduce the frequency of the sound wave captured by the microphone.**

3) **Calculate the wavelength of the corresponding wave**

1) **Name the basic parts of microphone.**

Main parts Microphone are:

- **Magnet.**
- **Coil.**
- **Membrane (diaphragm).**

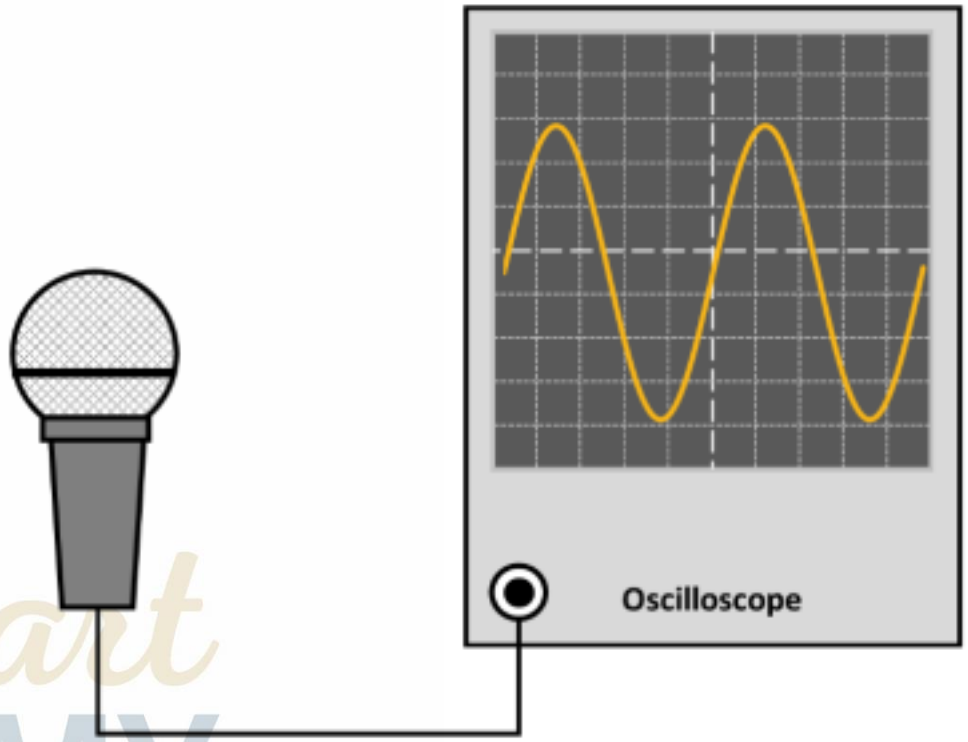


2) **Determine the frequency of the obtained oscillogram. Deduce the frequency of the sound wave captured by the microphone.**

$$T = S_h \times x = 20ms\ /\ div \times 5div$$

$$T = 100ms$$

$$f = \frac{1}{T} = \frac{1}{100 \times 10^{-3}} = 10Hz$$



$$f_{sound} = f_{oscillogram} = 10Hz$$

3) **Calculate the wavelength of the corresponding wave.**

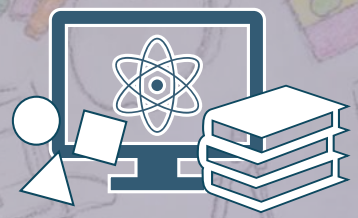
$$v = \lambda \times f$$

$$\lambda = \frac{v}{f}$$

$$\lambda = \frac{320}{10}$$

$$\lambda = 32m$$

The End



Unit One

Chapters 3 and 4

Emission, Propagation and Reception of sound

Prepared and presented by: Mr. Mohamad Seif

OBJECTIVES

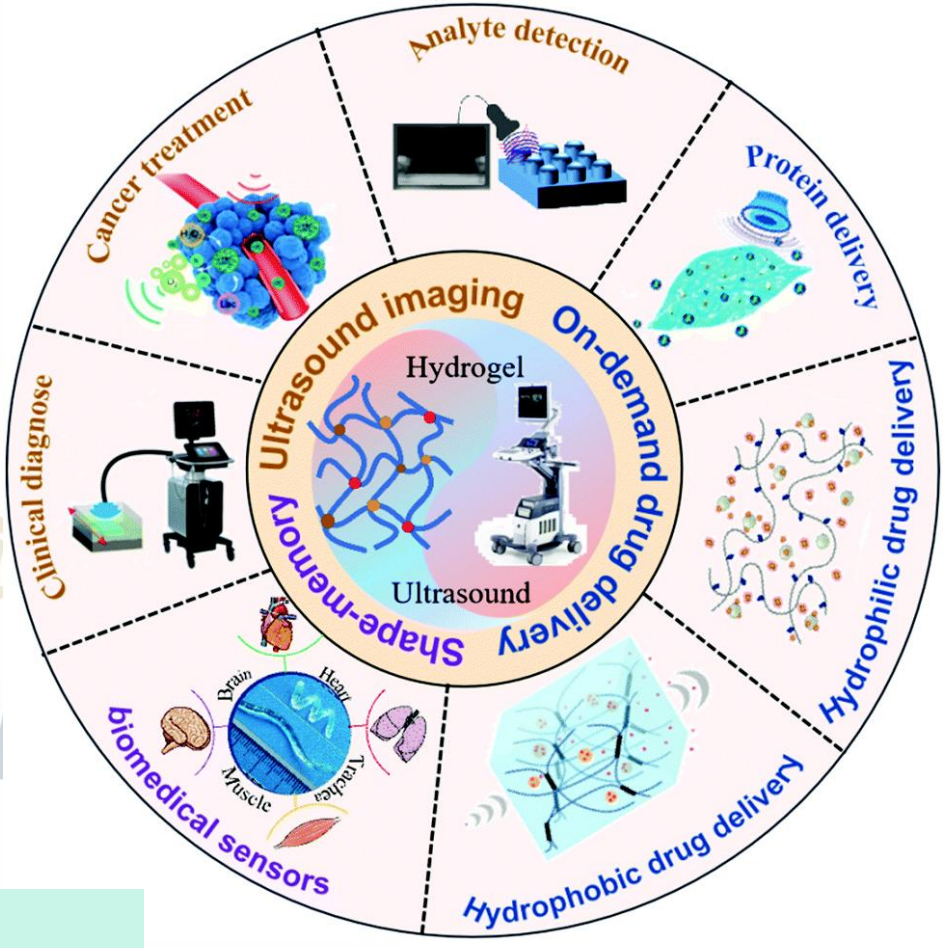
1. Study the applications of Ultrasound

Applications of Ultrasound wave

Ultrasound has physical properties that are similar to those of ordinary sound.

Ultrasound with a frequency more than (20kHz) or (20,000Hz), can be used in many domains such as:

- **Medicine, communication, navigation, testing, cleaning.**
- **Detection, ranging, and mixing, among other things.**



We will study some of these applications.

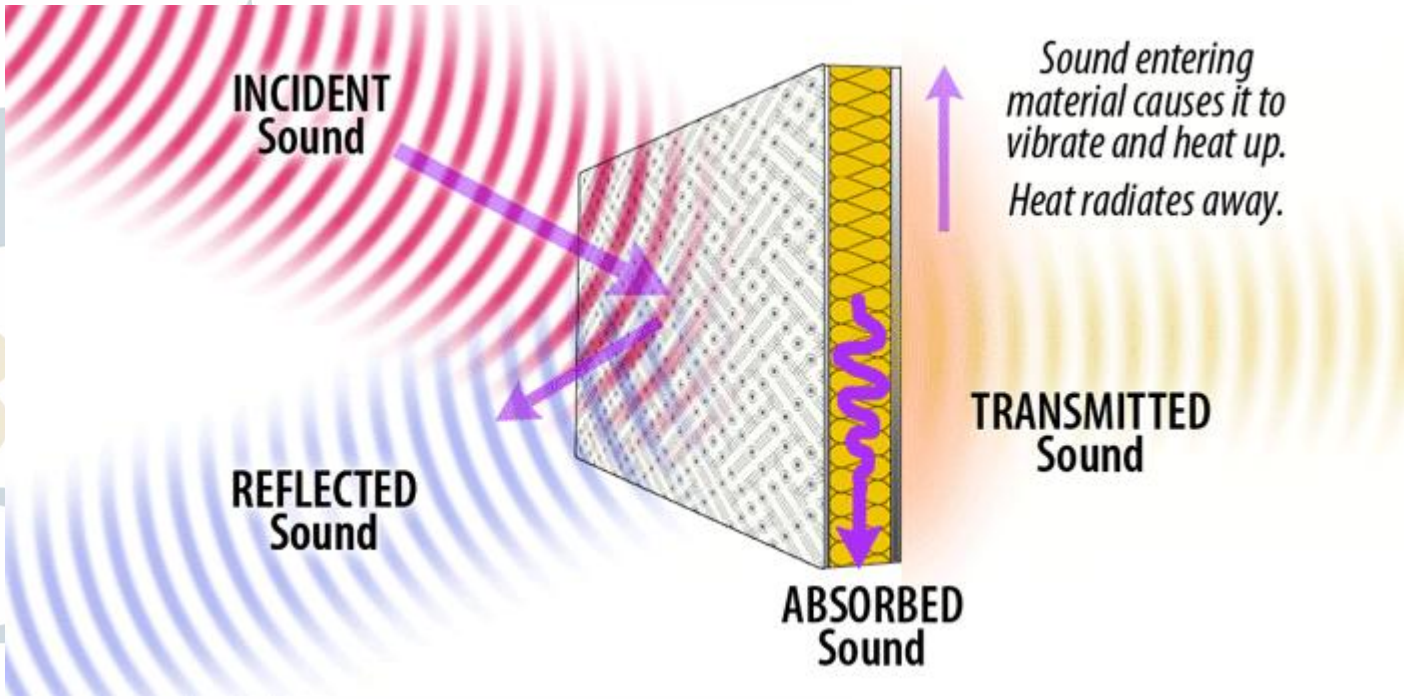
Applications of Ultrasound wave

1) Echo –sounding:

Echo –sounding is a technique is based on using the echo of ultrasound.

a) Sonar

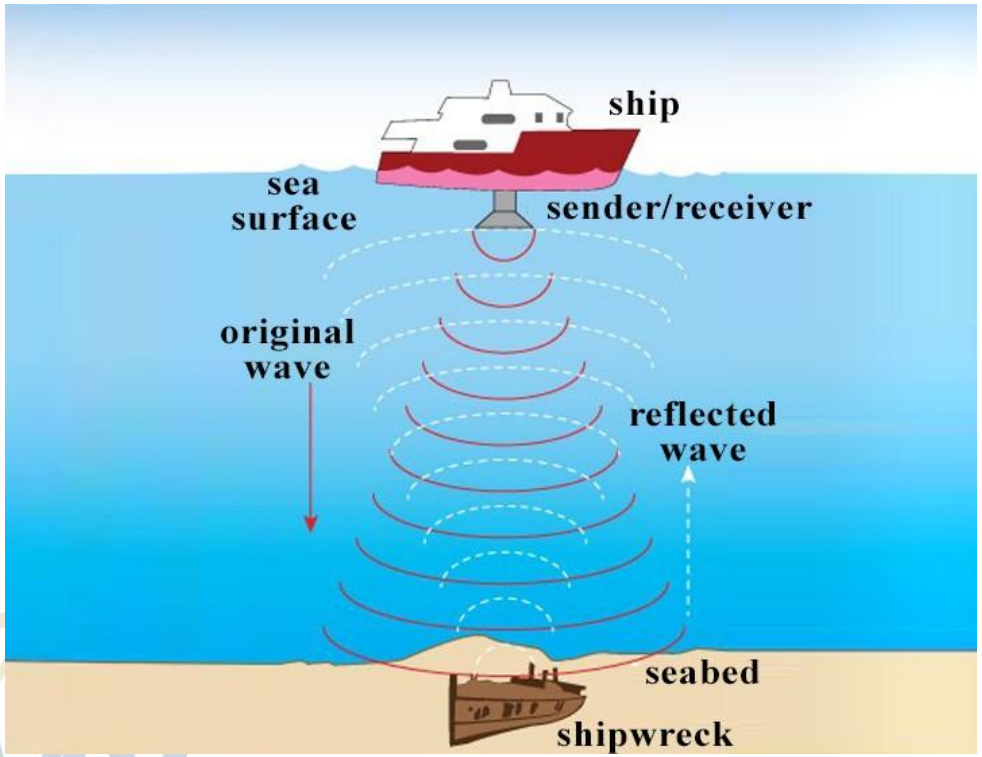
b) Sonography



Applications of Ultrasound wave

a) Sonar

Sonar is a technique that uses the echo of the sound waves to determine the depth of water to sense obstacles, fish and whales,…



The depth is determined by:

$$d = \frac{V\Delta t}{2}$$

Δt is the time separating the emission of the sound and the reception of its echo.

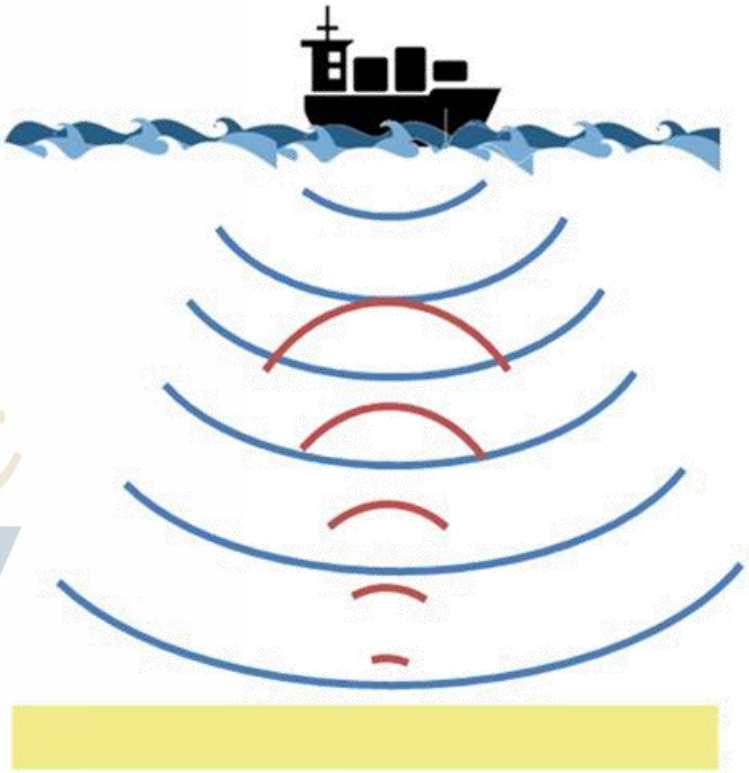
V is the speed of ultra sound in water which is about 1500m/s

Applications of Ultrasound wave

Application 7:

A sonar is an instrument used in order to measure the depth of the ocean.

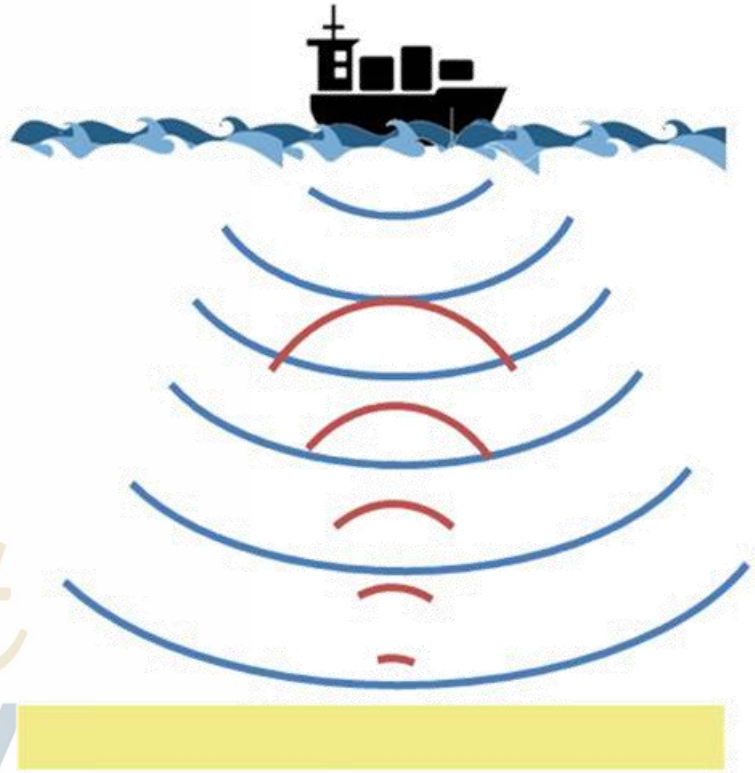
The sonar emits ultrasound waves in the ocean, and receives the echo 60ms later.



Calculate the depth of the ocean knowing that the speed of the waves in water is 1500 m/s

Applications of Ultrasound wave

The distance covered by the sound wave during 60ms is:



$$d = \frac{v\Delta t}{2}$$

$$d = \frac{1500 \times 60 \times 10^{-3}}{2}$$

$$d = 45m$$

Hence the depth of the ocean is : $d = 45\ m$

Applications of Ultrasound wave

b) Sonography (Ultrasound Imaging):

Sonography is a medical technique used to generate pictures of the body's internal structures.

The fetus can be seen by moving an ultrasonic transmitter- receiver across the mother’s tummy.

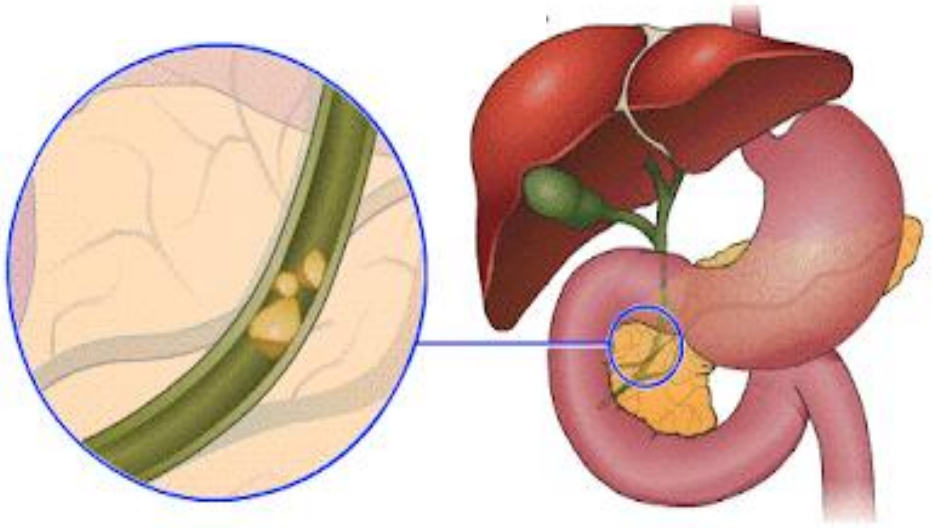
A part of the ultrasound is reflected back as echoes.

The ultrasonic scanner transforms the echoes into electric signals which are displayed on a TV screen.

Applications of Ultrasound wave

2) Lithotripsy:

Lithotripsy is a procedure that uses shock waves to break up stones in the kidney.



After the procedure, the tiny pieces of stones pass out of your body in your urine.

Applications of Ultrasound wave

3) Ultrasonic Cleaning:

Ultrasonic cleaning works through high-frequency sound waves transmitted through liquid to clean the surface of immersed parts.

The vibration of ultrasound are used to clean watches, Jewellery, cloths, dental and surgical instrument and teeth.

The End