Ratna Sagar

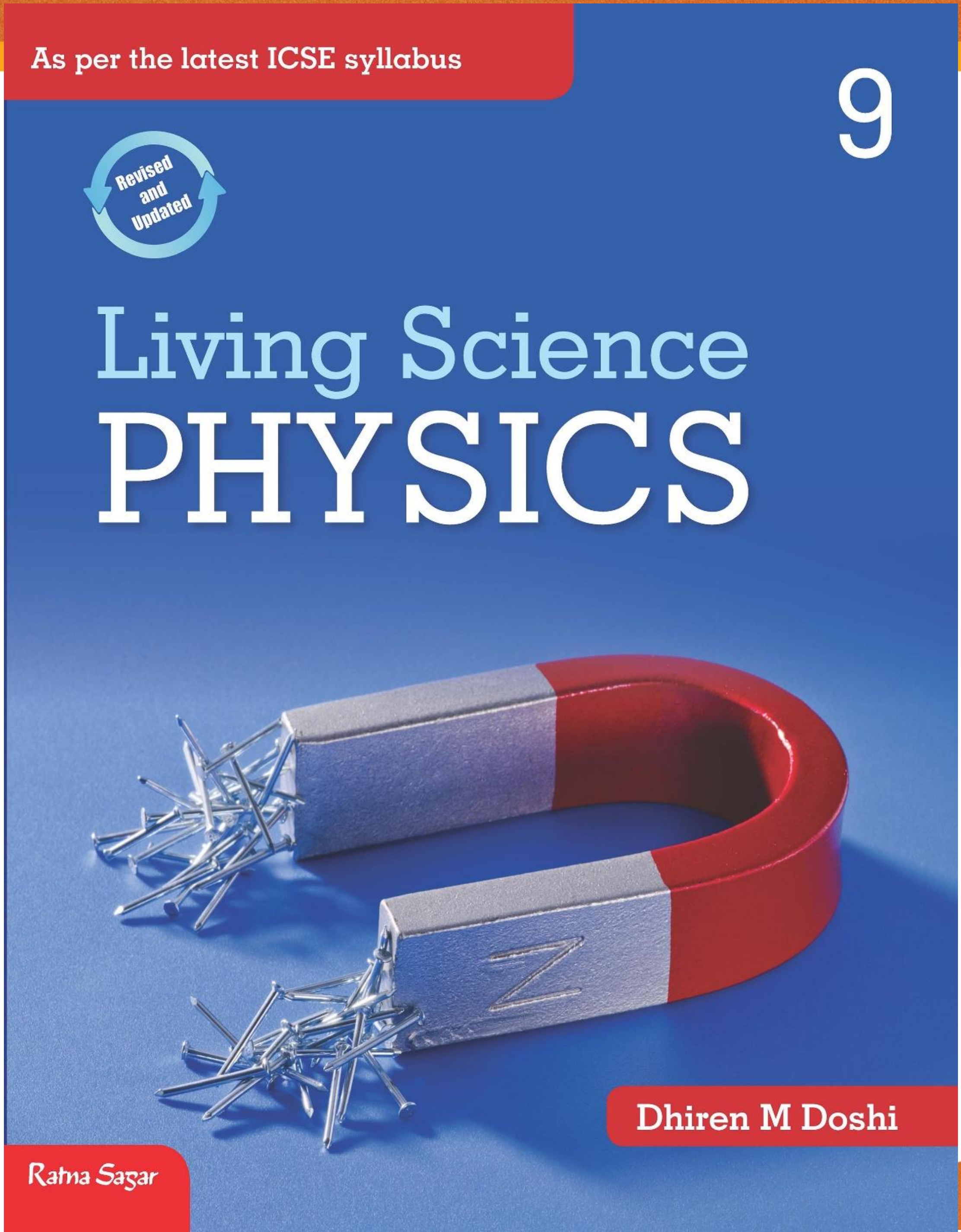
RATNA SAGAR | PRIMUS | BYWORD | E-LIVE

Education, Our Mission

ICSE
Living Science
Physics

Class 10

Chapter 11 Sound



As per the latest ICSE syllabus

9

Revised and Updated

Living Science
PHYSICS

Dhiren M Doshi

Ratna Sagar

LEARNING OBJECTIVES

Production of Sound

- Sound requires a medium for propagation

Propagation of Sound

- Characteristics of wave motion
- Classification of wave motion
- Longitudinal waves
- Transverse waves

Terms Related to Wave Motion

- Relation between time period and frequency
- Relation between wave velocity, frequency, and wavelength

Speed of Sound

- Factors affecting the speed of sound

Factors Which Do not Affect the Speed of Sound in Air

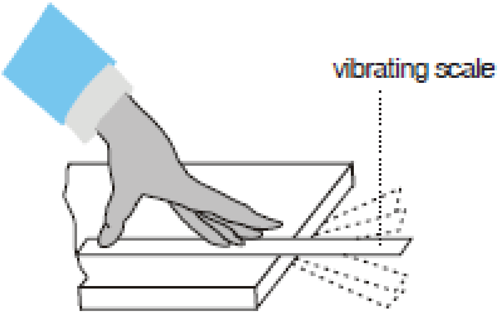
- Comparison of Speed of Sound with Speed of Light
- Range of Hearing

Properties of Ultrasonic Wave or Ultrasound

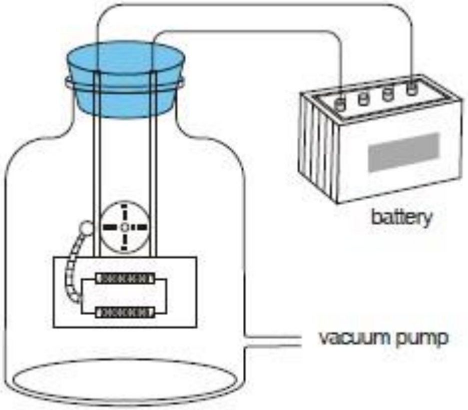
- Applications of Ultrasonic Waves or Ultrasound

Production of Sound

Sound is produced when an object vibrates, i.e. sound is produced by vibrating objects. The vibrating metre scale produces sound.



Sound Requires a Medium for Propagation



When the air is removed from the jar with the help of a vacuum Pump, the loudness of the sound slowly decreases until the sound becomes too faint. Finally, sound of the bell is not heard.

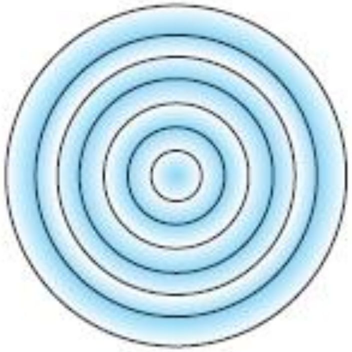
When air is allowed to enter the jar gradually, the sound of the bell inside the jar slowly increases. It shows that sound cannot propagate in the absence of a material medium like solid, liquid or gas.

Propagation of Sound

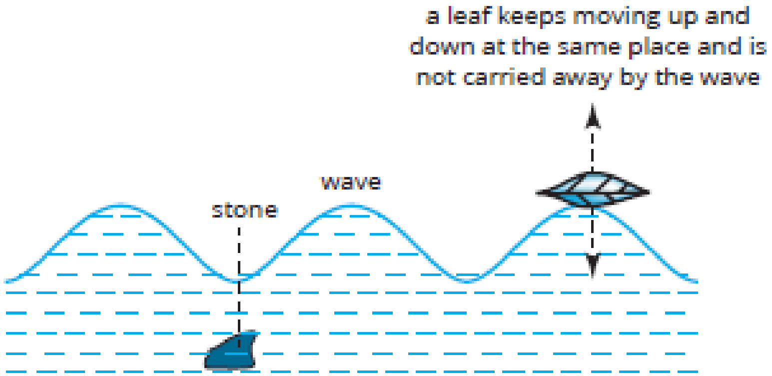
When an object vibrates, these vibrations set the particles of the medium (air) around the object into vibrations. These vibrating particles do not travel all the way from the vibrating object to the ears. These vibrating particles exert a force on the adjacent particles of the medium.

As a result of this force, the adjacent particles get displaced from their position of rest. These displaced vibrating particles then disturb their immediate adjacent particles and the process continues in the medium till the sound reaches our ears. So, it is the disturbance created by the source of sound in the medium that travels through the medium and not the particles of the medium.

Wave motion is a vibratory disturbance produced in one part of the medium that travels to another part involving the transfer of energy but not the transfer of any matter with it.



a. Ripples produced in the water when a stone is dropped into a pond.



b. Wave motion does not carry matter (material) away from or towards the source of disturbance.

Characteristics of Wave Motion

a. Wave motion is a **periodic disturbance** travelling through a medium which is produced by a vibrating body.

b. Wave motion travels at a **constant speed** in all directions in a medium and **transfers energy** in the medium.

The speed of a wave depends upon the nature of the medium through which it travels and not on the nature or the motion of the source.

c. In wave motion, the **particles** of the medium **do not move** from one place to another. They only vibrate about their fixed positions passing on energy they possess from particle to particle.

d. During wave motion, the medium does not move as a whole. Only the **disturbance travels** through the medium.

e. Wave motion is possible only in that medium which possesses the properties of elasticity and inertia.

Classification of Wave Motion

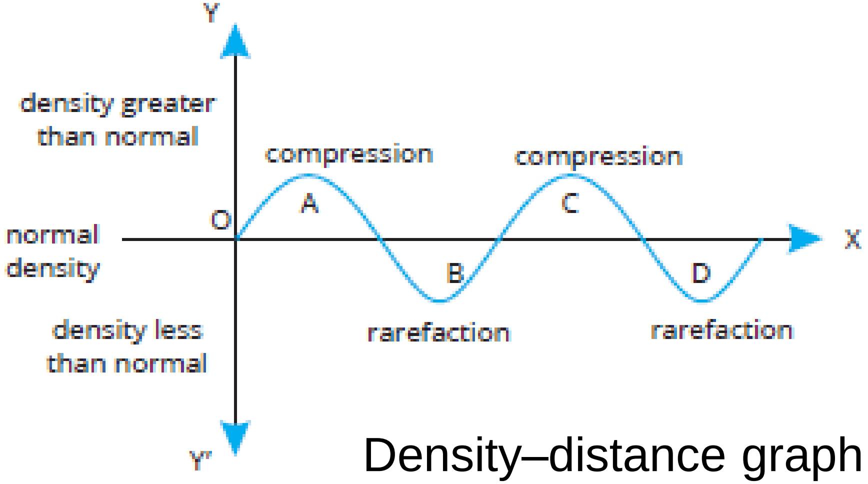
On the basis of the relative directions of the propagation of the wave with respect to direction of the periodic changes in the medium (such as displacement, pressure, etc.), the waves are classified into the following two groups: **1.** Longitudinal waves **2.** Transverse waves

Longitudinal Waves

A wave in which the particles of the medium oscillate (vibrate) to and fro (back and forth) in the same direction in which the wave is moving is called a longitudinal wave.

Graphical Representation of Longitudinal Waves

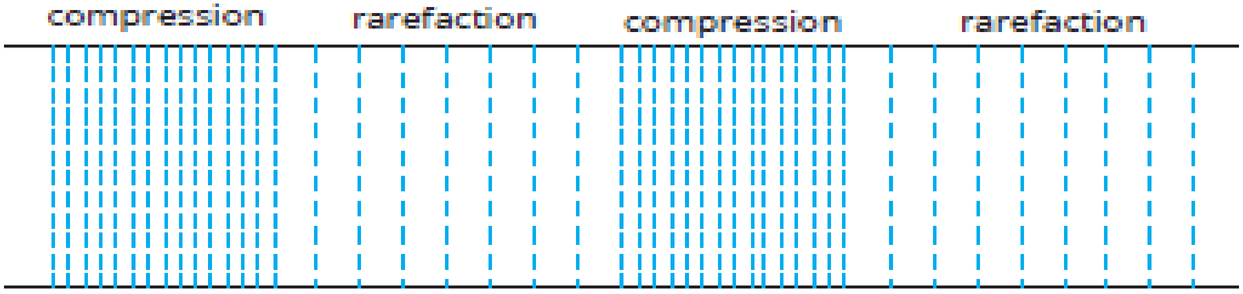
In a compression of a longitudinal wave, the density of the particles is high. In a rarefaction, the density of the particles is less than that in the normal.



Density–distance graph

Sound Wave is a Longitudinal Wave

When a sound wave passes through air, the particles of air vibrate back and forth parallel to the direction of propagation of the sound wave. **It forms compressions and rarefactions.** So, sound waves in air are longitudinal waves.



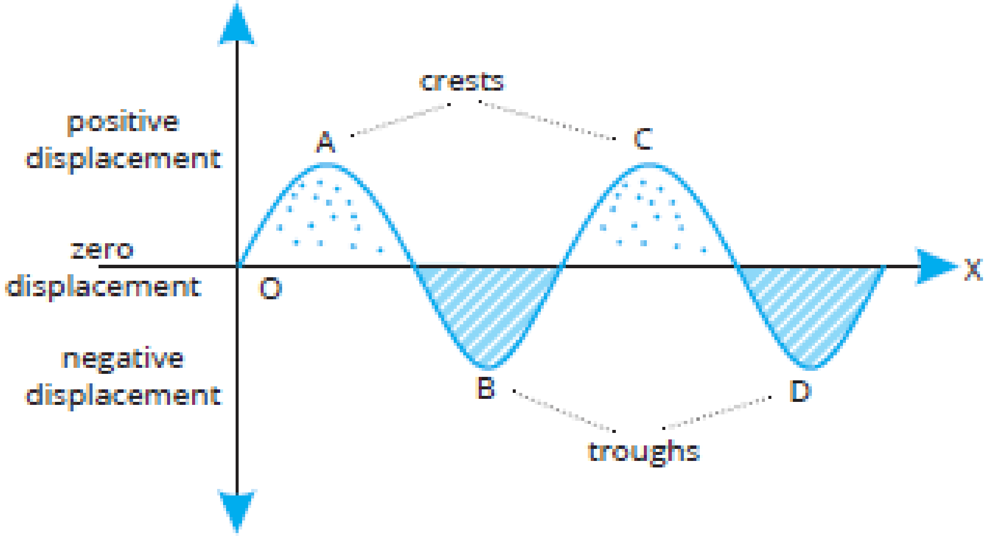
Sound waves producing compressions and rarefactions

Longitudinal Waves

A wave in which the particles of the medium oscillate (vibrate) up and down, i.e. perpendicular to the direction in which the wave is moving is called a transverse wave.

Graphical Representation of Transverse Waves

When a transverse wave passes through a medium, then some particles of the medium are displaced above the line of zero disturbance whereas others are displaced below the line of zero disturbance.

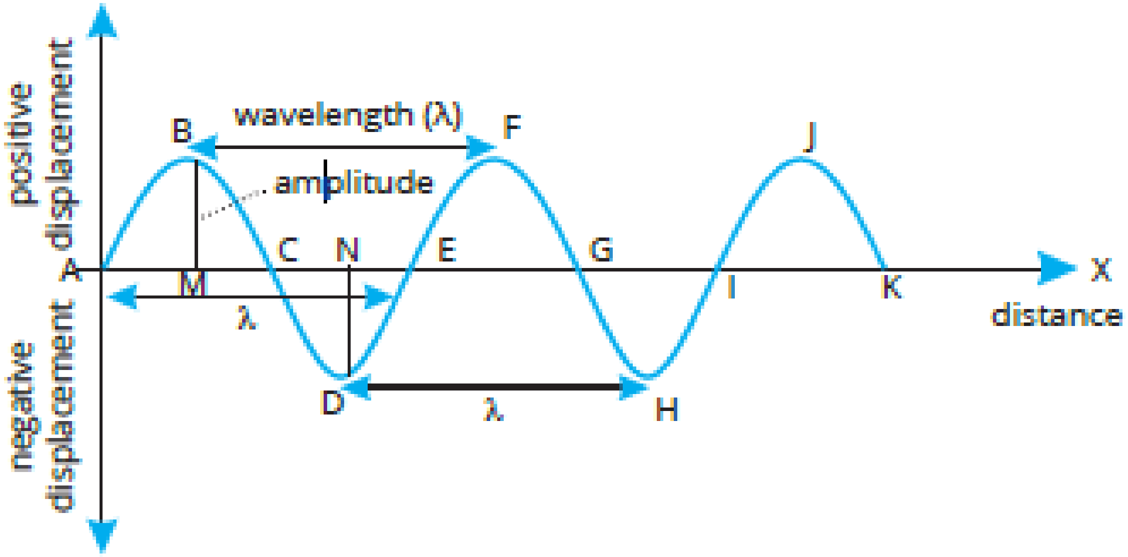


So, a transverse wave is represented graphically by plotting the displacement of different particles of the medium from the line of zero disturbance against the distance from the source. A transverse wave is represented by a displacement– distance graph.

Terms Related to Wave Motion

1. **Phase:** The points on a wave which are in the same state of vibration are said to be in the same phase.

2. Wavelength: The wavelength of a wave is the length of one wave. The wavelength of a periodic wave is defined as the distance travelled by the wave during the time in which any particle of the medium completes one vibration about its mean position.



Displacement-distance graph to describe the characteristics of a wave

In transverse wave motion, the distance between two consecutive crests or between two consecutive troughs is called the wavelength. In longitudinal wave motion, the distance between two consecutive rarefactions or between two consecutive compressions is called the wavelength. Wavelength is denoted by λ (lambda). The SI unit of wavelength is metre (m).

3. Amplitude: The maximum displacement of the particles of a medium from their mean positions during the propagation of a wave is called the amplitude of the wave. The amplitude of a wave is denoted by *A*. The SI unit of amplitude is metre (m).

4. Time period: The time required to produce one complete wave (or wave cycle) is called the time period of the wave. In other words, the time taken to complete one vibration is called time period. The time period of a wave is denoted by the letter *T*. The SI unit of time period is second (s).

5. Frequency: The rate at which waves are produced by a source is expressed by its frequency. **The frequency of a wave is defined as the number of waves produced per second.** Frequency is denoted by the letter *n*, *f* or the Greek letter v called **nu**. The SI unit of frequency is hertz (Hz). The SI unit of frequency is hertz (Hz).

Relation Between Time Period (*T*) and Frequency (*f*)

We know that the time required to produce one complete wave is equal to the time period (T) of the wave. So, if time period is measured in seconds, then

Number of waves produced in T s = 1

Number of waves produced in 1 s = $1/T$

But the number of waves produced in one second is equal to the frequency (f) of the wave. Therefore, $f = 1/T$ Hz

Frequency = 1 / Time period (in seconds) Hz

6. Wave Velocity: The distance travelled by a wave in one second is called the velocity of the wave. The wave velocity is denoted by v. **The SI unit of wave velocity is metre per second (m/s or m s^{-1}).** The velocity of a wave depends upon the nature of the medium through which it travels.

Wave velocity = Distance travelled by a wave / Time taken

Relation Between Time Period (*T*) and Frequency (*f*)

Wave velocity (v) = Distance travelled by a wave / Time taken

$v = \lambda / T$ or $v = (1/T) \times \lambda$

$\therefore v = f \times \lambda$ [Since $f = 1/T$]

or Wave velocity = Frequency x Wavelength

Speed of Sound

According to Newton, speed of sound depends upon the following two factors:

1. The elasticity of the medium (solid, liquid or gas)

2. The density of the medium.

Newton gave the formula:

$$v = \sqrt{E/\rho}$$

where v = the speed of sound in the medium

E = the coefficient of elasticity of the medium

ρ = the density of the (undisturbed) medium.

Newton assumed that the changes in pressure and volume of a gas when sound waves are propagated through it are **isothermal**. The amount of heat produced during compression, is lost to the surroundings and similarly the amount of heat lost during rarefaction is gained from the surroundings, so as to keep the temperature constant.

Laplace, a French mathematician explained that **the changes in pressure and volume of a gas** when sound waves are propagated through it are **not isothermal** but **adiabatic**. This is because

1. The speed of sound in a gas is quite large and that there is no time left for any exchange of heat amongst the particles themselves or with the surroundings.

2. A gas is a bad conductor of heat. It does not allow free exchange of heat between the compressed layers, rarefied layers and the surroundings. Thus, **no exchange of heat is possible** when a sound wave passes through a gas. Heat produced during compression raises the temperature of the gas and heat lost during rarefaction lowers the temperature of the gas. Hence, the changes are **adiabatic** not isothermal.

According to Laplace, the speed of sound in a gas is given by $v = \sqrt{\gamma P/\rho}$
where v = the speed of sound in the gaseous medium
γ= a constant equal to ratio of the specific heat at constant pressure to the specific heat at constant volume (i.e.$\gamma = C_p/C_v$). It is 1.41 for air.
P = the initial pressure of the gas
ρ = the density of the gas.
The speed of sound in air at N.T.P. by using the above relation, i.e. $v = \sqrt{\gamma P/\rho}$ is 331.2 m/s.

Factors affecting the speed of sound in a gas

The speed of sound in any gaseous medium is affected by a number of factors which are as follows:

1. Effect of density 2. Effect of temperature 3. Effect of pressure
4. Effect of humidity 5. Effect of wind

Factors which do not affect the speed of sound in air

There is no effect on the speed of sound in air due to the following factors:

1. Change in frequency
2. Change in wavelength
3. Change in amplitude
4. Change in factors like phase, loudness, pitch and quality of sound
5. Change in pressure

Range of Hearing

The human ear can hear sounds having frequencies between 20 hertz to 20,000 hertz. This is called the audible range of frequencies for human ears. Sounds having frequencies lower than 20 hertz are known as **infrasonic sounds**. Earthquakes, volcanic eruptions, simple pendulum and some animals like whales and elephants produce infrasonic sounds. Sounds having frequencies higher than 20,000 hertz are known as **ultrasonic sounds**. Bats can hear ultrasonic sounds having frequencies upto 1,20,000 hertz.

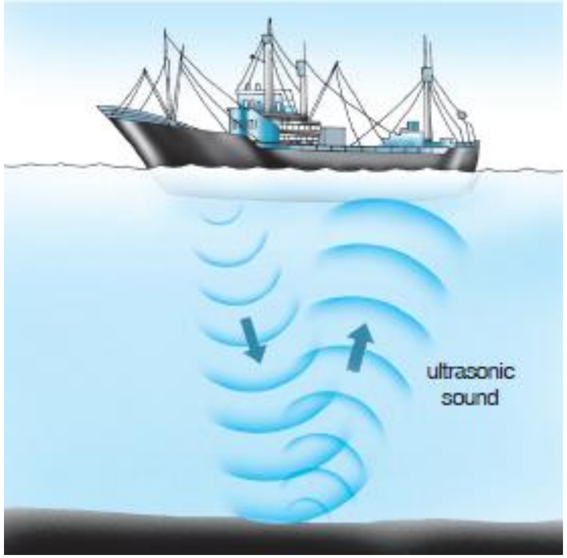
Properties of Ultrasound

Because of their very high frequencies, i.e. more than 20,000 Hertz, ultrasounds have the following special properties which audible sound does not have.

1. High energy: A wave carries energy with it. Due to its high frequency, an ultrasound has very high energy associated with it.
2. High directivity: When a low-frequency sound meets an obstacle, it easily bends round the corners and spreads in all directions. But, ultrasounds are able to travel along well-defined straight paths, even in the presence of obstacle. This mean they do not bend appreciably at the edges of the obstacle.

Applications of Ultrasound

Some of the important uses of ultrasound are given below:
1. Sonar: The word ‘SONAR’ stands for **So**und **N**avigation **A**nd **R**anging. This is a method for detecting and finding the depth of a sea or to locate underwater objects like submarines and sea rocks. The device used in this method is also called **sonar**.



The total distance covered by the ultrasound from the sonar to the underwater object and back is 2d.
We know, speed = distance x time = $2d / t$
or $d = vt /2$

2. Medical applications: Ultrasound is being used in medical diagnosis in hospitals. **Echocardiography** is a technique in which ultrasound are sent to the heart, gets reflected from various parts of the heart, form an image of the heart. **Ultrasonography** is a technique in which ultrasound reflected from various human organs enables the doctor to see the images of the patient’s organs such as the liver, gall bladder and uterus. It helps doctors to detect abnormalities such as stones in the gall bladder, tumours, etc. It is also used to monitor the growth of a foetus inside the mother’s womb.

3. Surgical application: Ultrasound is also used to break small ‘stones’ that form in the kidneys into fine grains. These grains get flushed out with urine.

4. Detection of defects in metals: If there are cracks or holes inside the metal used in buildings, bridges, etc. such defects are not visible from the outside. Ultrasonic waves or ultrasound can be used to detect such defects.

SUMMARY...

1. Wave motion: It is a vibratory disturbance produced in one part of the medium, travels to another part involving the transfer of energy but not the transfer of any matter with it.

2. Amplitude: The maximum displacement of the particles of a medium from their mean positions during the propagation of a wave is called the amplitude of the wave.

3. Time period: The time required to produce one complete vibration is called the time period. Its SI unit is second.

4. Frequency: The frequency of a wave is defined as the number of waves produced per second. Its SI unit is hertz.

5. Wave velocity: The distance travelled by a wave in one second is called the velocity of the wave. Velocity = Frequency × Wavelength.

6. Infrasound: Sound having frequencies lower than 20 hertz are known as infrasonic sounds.

7. Ultrasound: Sounds having frequencies higher than 20,000 hertz are known as ultrasonic sounds.

8. Sonar: It is a method for finding the depth of a sea or to locate underwater objects like submarines, searocks and shipwrecks.

RATNA SAGAR | PRIMUS | BYWORD | E-LIVE

THANK YOU