UNIT 11

SOUND

After studying this unit, the students will be able to:

a) Explain how sound is produced by vibrating sources and that sound waves require a material medium for their propagation.

b) Describe the longitudinal nature of sound waves (as a series of compressions and rarefactions).

c) Define the terms pitch, loudness and quality of sound.

d) Describe the effect of change in amplitude on loudness and the effect of change in frequency on pitch of sound.

e) Define intensity and state its SI unit.

f) Describe what is meant by intensity level and give its unit

g) Explain that noise, is a nuisance.

h) Describe how reflection of sound may produce echo.

i) Describe audible frequency range.

j) Describe the importance of acoustic protection.

k) Solve problems based on mathematical relations learnt in this unit.

Q.1 What are sound waves? What is the necessary condition for the production of sound?

Answer

Like other waves sound is also produced by vibrating bodies. Due to vibration of bodies the air around them also vibrates and the air vibration produces sensation of sound in our ear. For example, in a guitar, sound is produced due to the vibrations of its strings.

Our voice results from the

vibrations of our vocal cords. Human heart beats and vibrations of other organs like lungs also produce sound waves. Doctors use stethoscope to hear this sound.

Necessary condition for the production of sound

Activity (1)

In school laboratories, we use a device called tuning fork to produce particular sound. If we strike the tuning fork against rubber hammer the tuning fork will begin to vibrate. We can hear the sound produced by tuning, fork by bringing it near our car.

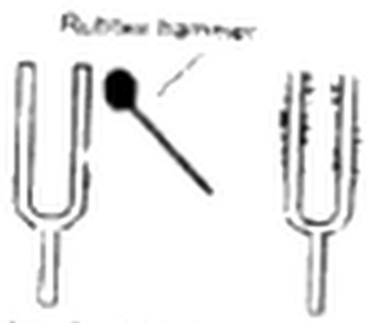
We can also feel the vibration by slightly touching one of the prongs of the vibrating tuning fork with a plastic ball suspended from a thread.

Touch the 'ball gently with the prong of a vibrating tuning fork. The tuning fork will push the ball because of its vibration. Now if we dip the vibrating tuning fork into a glass of water, we will see a splash. This is due vibrations produced in the prongs of the tuning fork.

From this activity we can conclude that sound is produced by vibrating bodies.

For your information

Stethoscopes operate on the transmission of sound from the chest-piece, via air-filled hollow tubes, to the listener's ears. The chest-piece usually consists of a plastic disc called diaphragm. If the diaphragm is placed on the patient's body sounds vibrate the diaphragm, creating acoustic pressure waves which after multiple reflection travel up the tubing to the doctor's ears.



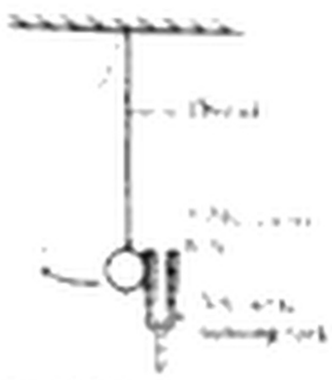


Fig. 11.3 Production of sound waves from a vibrating tuning fork

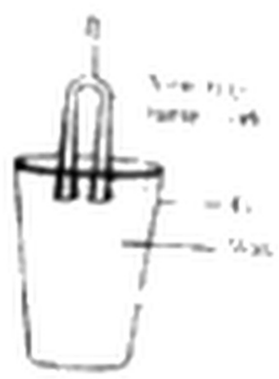


Fig. 11.4

Activity (2)

Unlike light waves which are electromagnetic in nature and can also pass through vacuum, sound waves required some material medium for their propagation. This can be proved by bell Jar apparatus as shown in the fig. 11.5.

The bell jar is on the platform of a vacuum pump. An electric bell is suspended in the, bell jar with the help of two wires connected to a power supply. By setting ON the power supply, electric supply will begin to ring. We can hear the sound of the bell.

Now start pumping out air from the jar by means of a vacuum pump. The sound of the bell starts becoming more and more feeble, and eventually dies out, » although bell is still ringing. When we put the air back into the jar, we can hear the sound of the bell again.

From this activity we conclude that sound waves can only travel / propagate in the presence of air (medium).

For your Information
A sound wave with a frequency of 3500 Hz and an intensity of 80 decibels sounds about twice as loud to us as a sound of 125 Hz and 80 decibels. It is because our ears are more sensitive to the 3500-Hz sound than to the 125 Hz. Therefore intensity by itself does not mean loudness. Loudness is how our ears detect and our brains perceive, the intensity of sound waves.

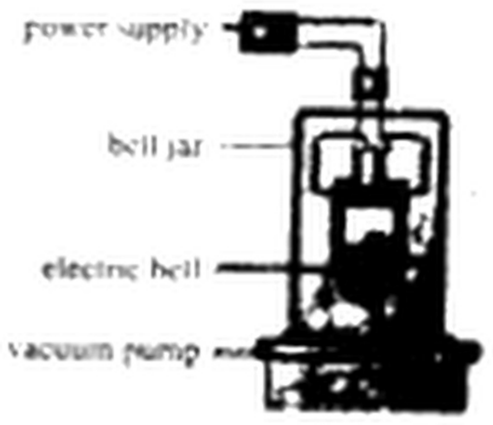


Fig. 11.5 Bell jar apparatus

Q.2 Write about the longitudinal nature of sound waves?

Answer

Propagation of sound waves produced by vibrating tuning fork can be understood by a vibrating tuning fork as shown in fig. 11.6. Before the vibration of tuning fork density of air molecules on the right side is uniform (a).

When the right prong of tuning fork moves from mean position '0' to 'B' (b), it exerts some pressure on the adjacent layer of air molecules and produces a compression. This compressed air layer in turn compresses the layer-next to it and so on. A moment later the prong begins to move from B towards A as shown in fig. 11.6 (c).

Fig 11 6 Vibrations of tuning fork after striking with a rubber hammer

Now the pressure in the adjacent layer decreases and a rarefaction is produced. This rarefaction is transferred to the air layer next to it and so on. As the tuning fork moves back and forth rapidly a series of compressions and rare factions are created in the air in this way, sound wave propagates through the air.

As In the figure the direction of propagation of sound waves is 'along the direction of oscillating air molecules. This shows the longitudinal compressional nature of sound waves."

Wave Length

Distance between two consecutive compressions or rarefaction is the wave length of sound wave.

Q.3 Write a note on the characteristics of sound?

Answer

Sounds of different objects can be distinguished on the basis of different characteristics as described below:

Loudness

Loudness is the characteristic of sound by which loud and faint sounds can be distinguished.

Example

When we talk to our friends, our voice is low, but when we address a public gathering our voice is loud. Loudness of a sound depends upon the following main factors.

Speed of sound in various media

Medium	Speed (m s⁻¹)
Gases	
Air(0°C)	331
Air (25°C)	346
Air(200°C)	386
Hydrogen (0°C)	1290
Oxygen (0°C)	317
Helium (0°C)	972
Liquids at 25°C	
Distilled water	1498
Sea water	1531
Solids 25°C	
Wood	2000
Aluminium	5420
Brass	3700
Nickel	6040
Iron	5950
Steel	5960
Flint Glass	3980

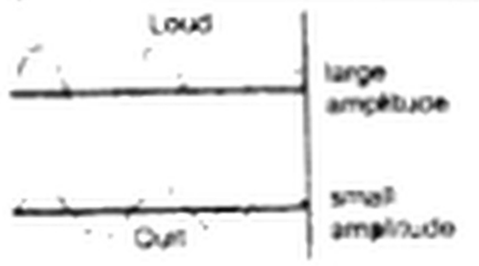


Fig 11.7 Variation of loudness with amplitude

Amplitude of the vibrating body

Loudness of the sound varies directly with the amplitude of the vibrating body.

Example

Sitar will produce loud sound on plucking its wires violently and same with drum when beaten forcefully.

Area of the vibrating body

Large area of the vibrating body produces more loud sound and vice versa.

Example

If we strike a tuning fork on a rubber pad, a feeble sound will be heard. But if the vibrating tuning fork is placed vertically on the surface of the bench, we will hear a louder sound.

Distance from the vibrating body

It is observed that the amplitude of the sound is decreased by increasing the distance between the source of sound and the listener and vice versa.

Example

If No listeners A and B are standing at different distances from the horn played by the train then the listener A who is at less distance will hear more loud sound as compared to the other who is comparatively at more distance.

Pitch

Pitch is the characteristic of sound by which we can distinguish between a shrill and a grave sound.

A higher pitch means a higher frequency and vice versa.

Example

The voice of ladies and children is shrill and of high pitch (frequency).

Quality

The characteristic of sound by which we can distinguish-between two sounds of same loudness and pitch is called quality.

Example

Interesting information
Some people use silent whistle to call dogs whose frequency lies between 20,000 Hz. It is silent for humans but not for dogs. Because the audible frequency range for dogs is much higher.

For your information
Thin walled glass goblets can vibrate when hit by sound waves. This is due to a phenomenon of sound known as resonance. Some singers can produce a loud note of particular frequency such that it vibrate the glass so much that it shatters.

While standing outside a room, we can distinguish between the notes of a piano and a flute played inside the room.

For your information

Intensity (of Sound)

Sound energy passing per second through a unit area held perpendicular to the direction of propagation of sound waves is called intensity of sound.

The unit of intensity of sound.is "Watt per square meter" (Wm^{-2}).

Q.4 What do you mean by the term intensity level of the sound? Name and define the unit of intensity level of sound?

Answer

Sound intensity level

The human ear responds to the intensities ranging from 10^{-2} Wm^{-2} to more than I Wm^{-2} (which is loud enough to be painful).

Because the range is so wide; intensities are sealed by factors often. The barely audible and the faintest intensity of sound i.e. $10^{-12} Wm^{-2}$ is taken as reference intensity, called zero bel (a unit named after Alexander Graham Bell)

The loudness of sound depends not only on the intensity of sound but also on the physical condition of the ear.

The human ear is more sensitive to some frequencies rather than the others.

The loudness (L) of a sound is directly proportional to the logarithm of intensity i.e.

$$L \propto \log I$$

$$L = K \log I \text{ ---------- (1)}$$

Where 'k' is a constant of proportionality.

Let 'L_0' be the loudness of the faintest audible sound of intensity L, and L be the loudness of an unknown sound of intensity 'I', then eq. (I)can be written as:

$$L_o = K \log I_o \ldots\ldots\ldots(2)$$

Subtracting eq. (1) from eq. (2), we get.

$$L - L_o = K(\log I - \log I_o)$$

$$= K \log I / I_o$$

This difference (L - L_0) between the loudness 'L' of an unknown sound and the loudness "L_o," is called the intensity level of the unknown sound. Therefore, the intensity level of an unknown sound is given by.

$$\text{Sound Level} = K \log I / I_o \ldots\ldots\ldots(3)$$

The value of 'k' not only depends on the units of 'I' and 'I_0' but also on the unit of intensity level.

If intensity I of any unknown sound is 10 times greater than the intensity in of the faintest audible sound i.e. $I = 10\ I_0$ and the intensity level of such a sound is taken as unit called "bel". The value of 'k' becomes 1. So, eq. (3) becomes:

Sound level = I/I_0 (bel) (5)

bel is a very large unit of intensity level of a sound. Generally, a smaller unit called decibel is used. Decibel is abbreviated as (dB). It must be remembered that I bel is equal to (H), if the intensity level is measured in decibels. eq. (4) becomes.

$$\text{Sound level} = I / I_o(bel) \ldots\ldots\ldots(5)$$

Using eq. (5) we can construct a scale for measuring the intensity level of sound. Such scale is known as "decibel scale".

$$\text{Sound level} = 10\, I / I_o(bel) \ldots\ldots\ldots(4)$$

Q.5 What is the reflection (echo) of sound? Give one example?

Answer

Echo (Reflection of sound): Definition

When sound is incident on the surface' of a medium, it bounces back into the 'first medium. This phenomenon is called echo or reflection of sound.

Do you know?
Elephants use low frequency sound waves to communicate with one another. Their large ears enable them to detect these low frequency sound waves which have relatively long wavelengths. Elephants can effectively communicate in this way, even when they are separated by many kilometres.

Explanation

The sensation of sound persists in our brain for about 0.1 S. To hear a clear echo, the time interval between our sound and the reflected sound must be at least 0.1

S. If the speed of sound is supposed to be 340 ms^{-1}, the total distance covered by the echo should be at least

340 ms^{-1} x 0.1s = 34 m. Thus, for hearing distinct echoes, the minimum distance of the obstacle from the source of sound must be half of the distance that is 17m.

Activity

Take two identical plastic pipes of suitable length as shown in the figure 11.10.

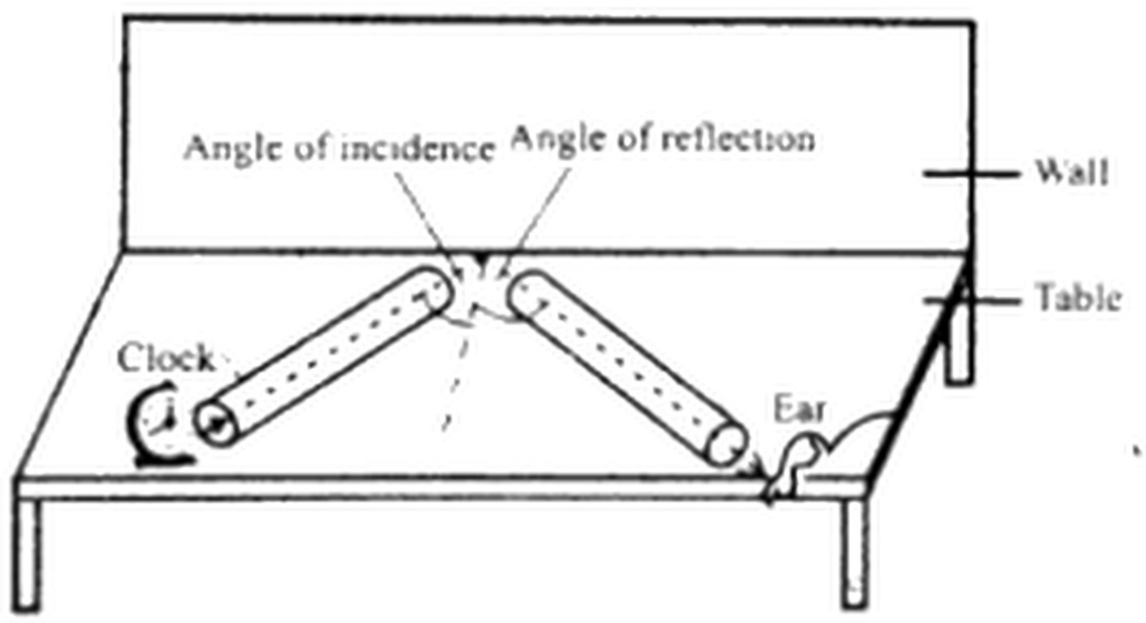


Fig. 11.10: Reflection of sound

1) Arrange the pipes on a table near wait.

2) Place a clock near the open end of one of the pipes and try to hear the sound of the clock through the other pipe.

3) Adjust the position of the pipes so that you can hear the sound of the clock clearly.

4) Now measure the angle of incidence and reflection and relationship between the angles.

5) Lift the pipe on the right vertically to a small height and we will observe that the sound will start becoming fainter and finally no sound will be heard at some certain distance.

Q.6 What is the effect of the medium on the speed of sound?

Answer

Illustration of longitudinal wave formed by vibrating tuning fork in the air. Compressions are places where air pressure is slightly higher than the surrounding air pressure due to high density of air particles. While rarefactions are the regions correspond to low air pressure due to low density of air particles

By using an oscilloscope, we can "see" sound waves.

Sound waves can be transmitted by any medium containing particles that can vibrate. It cannot pass through vacuum. However, the nature of the medium will affect the speed of the sound waves. In general, the speed of sound in liquids is five times that in gases the speed of sound in solids is about fifteen times that in gases.

The speed of sound in air is affected by changes in some physical conditions such as

Temperature, pressure and humidity etc.

The speed of sound in air is 343 $^{ms-1}$ atone atmosphere of pressure and room temperature (21°C). The speed varies with temperature and humidity. The speed of sound in solids and liquids in faster than in air.

Following relation can be used to find the speed of sound.

$$v = f\lambda$$

Where 'v is the speed, "f" is the frequency and 'λ' is the wavelength of sound wave.

Q7 How can you find the speed of sound by echo method? What factors can affect the accuracy of this method.

Tidbits
Bats can hear frequencies up to 120,000 Hz. Other animals cannot hear such high-pitched sounds. Mice can hear frequencies up to 100,000Hz, dogs up to 35,000Hz, and cats up to 25,000Hz. Humans hear sounds only upto about 20,000Hz, but children can usually hear higher-frequency sounds than adults.

Answer

To measure the speed of sound, the following experiment can be performed:

Apparatus

Measuring tape. Stop watch, flat wall that can produce a good echo.

1) Use the tape to measure a distance of 50 m from the wall.

2) Now clap your hands in front of the wall at a distance of 50 meters and check if you can clearly hear an echo from the wall. Make sure the echo is not coming from any other wall in the area.

The time taken by the sound to travel 100 meters is the time difference, between the clap and the echo.

3) Now restart the clapping and Start the stop watch at the first clap. Count the number of claps, and stop the clapping and the stopwatch when you hear the echo of the (say) 10^{th} clap.

4) Now find the average time for 10 claps. After calculating the time interval 't' between claps and using the formula s=vt. We can calculate the speed of the sound.

Factors which can affect the accuracy of this method

Following factors can affect the accuracy of this method:

I) The wall from where we get echo (reflection of sound) is not smooth.

2) The echo may come from some other wall.

3) Human reaction time in using the stop watch may affect the accuracy.

4) The speed of sound in air is affected by changes in some physical conditions such as temperature, pressure and humidity so accuracy in the measurement of speed of sound can be reduced;

Q.8 What is noise pollution? Explain that noise is a nuisance?

Answer

We enjoy the programmes of radio and television by hearing sounds of different qualities in musical programmes. We hear sound produced by musical instruments such as flute, harmonium, violin, drum etc..

Sound of these instruments cast pleasant effect on our ears.

Musical sounds

Such sounds which are pleasant to our ears are called musical sounds. These sounds cast pleasant effect on our ears.

Noise

Sound which have jarring and unpleasant effect on our ears is called noise. Like, sound of machinery the slamming of a door, the sounds of trafficking hill. They also observed a young city.

Noise corresponds to irregular and sudden vibrations produced by some sounds.

1) Noise pollution has 'become a major issue of concern in big cities

2) Noise is an undesirable sound that is harmful for health of humans and other species.

3) Transportation equipment and heavy machinery are the main sources of noise pollution.

For example; noise of machinery in industrial areas loud vehicle horns, hooters and alarms.

4) Noise has negative effects on human health as it can cause conditions such as hearing loss, sleep disturbances, aggression, hypertension, high stress levels.

5) Noise can also cause accidents by interfering with communication and warning signals.

Interesting Information
Researchers in 1993 observed giraffes to stop and wait for others giraffes that were out of sight over hill. They also observed a young male giraffe who tried to break through high brick wall to get to his mother. Yet the researchers heard nothing. very long wavelength sound that turn (diffract) over the hilltop, and also around the brick wall.

The safe level of noise depends upon two factors:

1) The level (volume) of the noise; and the period of exposure to the noise.

The level of noise recommended in most countries is usually 85-90 dB over an eight-hour work day.

2) Noise pollution can be reduced to acceptable level by replacing the noisy machinery with environment friendly machinery and equipment, putting sound reducing barriers, or using hearing protection devices.

Q.9 Describe the importance of acoustic protection?

Answer

Acoustic protection

"The technique or method used to absorb undesirable sounds by soft and porous surfaces is called acoustic protection.

Importance of acoustic

Reflection of sound is more prominent if the surface is rigid and smooth, and less if the surface is soft and irregular.

Soft porous materials, such as draperies and rugs absorb large amount of energy and thus quiet echoes and softening noises.

Thus, by using such material in noisy places we can reduce the level of noise pollution. However, if she surfaces of classrooms or public halls are too absorbent," the sound level may be low of the audience.

Sometimes when sound reflects from the walls, ceiling, and floor of a room, the reflecting surfaces are too reflective and the second becomes garbled. This is due to multiple reflections called "reverberations."

In the design of lecture halls, auditorium or theatre halls, a balance must be achieved between reverberation and absorption.

It is often advantageous to place reflective surfaces behind stage to direct sound to the audience.

Generally, the ceilings of lecture halls, conference halls and theatre halls are curved so that sound after reflection may reach all the corners of the hall.

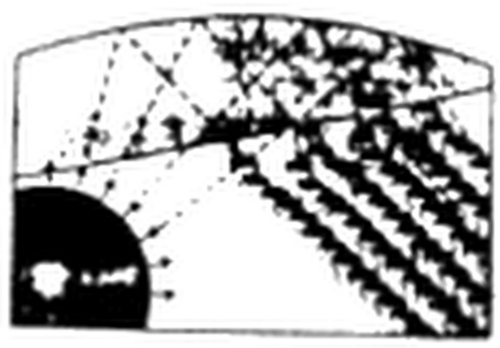


Fig. 11.11 Curved ceiling of a conference hall

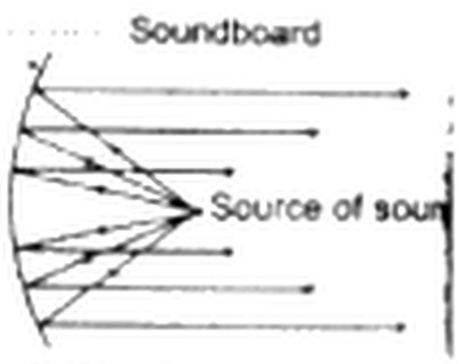


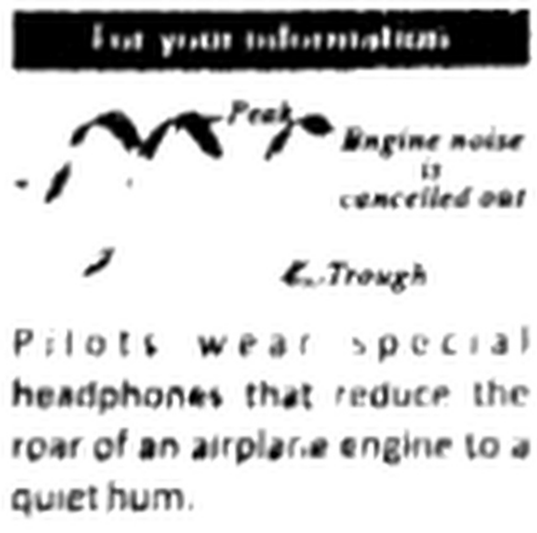
Fig. 11.12 Soundboard used in a big hall

Sometimes curved sound boards are placed behind the stage so that sound after reflection is distributed evenly across the hall.

Q.10 What is the audible frequency range? What are the uses of ultrasound in medicine? Answer

Audible frequency range:

The range of the frequencies which a human ear can hear is called the audible frequency range. It his between 20Hz and 20.000 Hz.



Pilots wear special headphones that reduce the roar of an airplane engine to a quiet hum.

The frequency below 20Hz is not audible for human ear and is called "infrasonic" and the frequency above 20,000 Hz is also not audible for human ear and is headphones that reduce the called "Ultrasonic or Ultrasound."

Ultrasound: (uses):

1) Ultrasonic waves carry more energy and higher frequency than audible sound waves. Therefore, according to the wave equation, $v = f\lambda$ the wave length of ultrasonic waves is very small and is very useful for detecting very small objects.

2) Ultrasonic are utilized in medical and technical fields. '

3) In medical field ultrasonic waves are used to diagnose and treat different ailments. For diagnosis of different diseases, ultrasonic waves are made to enter the human body through transmitters. These waves are detected differently by different organs of the body on the screen as shown in figure 11.13. Such an image helps in detecting the defects in these organs.

4) Powerful ultrasound is now being used to remove blood clots formed in the arteries.

5) Ultrasound can also be used to get the pictures of thyroid gland for diagnosis purposes.

6) Ultrasound is used to locate under water depths or is used for locating objects lying deep on the ocean floor, etc.. The technique is called "SONAR". (Sound navigation and ranging).

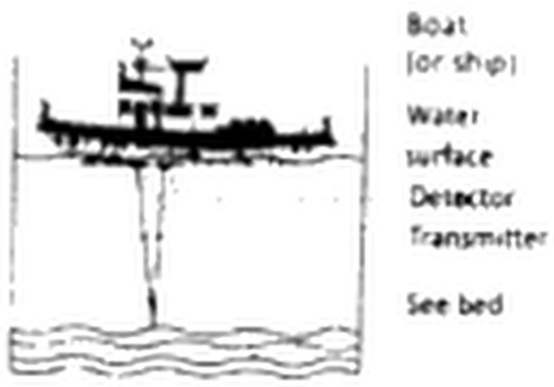


Fig. 11.14 Ultrasonic are used to measure the depth of water by echo method

Fig. 11.13.1 Doctors are taking ultrasound test of a patient with an ultrasound machine

The sound waves are sent from a transmitter and a receiver collects the reflected sound as shown in the figure 11.14.

The time lapse is calculated, knowing the speed of sound in water, the distance of the object from the ocean surface can be estimated.

7) SONAR ranging is also used to see the shape and the size of the object. Cracks appear in the interior of moving parts of high-speed heavy machines such as turbines, engines of ships and airplanes due to excessive use. These cracks are not visible from outside but they can be very dangerous. Such cracks can be detected by ultrasonic.

A powerful beam of ultrasound is made to pass through these defective parts. While passing, these waves are reflected by the surface of these cracks and flaws. The comparison of the ultrasonic waves reflected from crack and from the surfaces of these parts can give a clue of the existence of the cracks.

8) Germs and bacteria in liquids can also be destroyed by using high intensity ultrasonic waves.