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18

SOUND AND COMMUNICATION

In our daily life we have conversation amongst ourselves. We hear the chirping of the birds or horn of the vehicles or mewing of the cat. They are of so many types, so many tones, and so many levels of loudness. In fact usually we can recognize a person by just his or her voice.

We communicate in many ways. Even an infant communicates and does it just with sound, expressions and without words. Adults communicate by talking or writing to each other. Most often it is our voice that enables us to communicate, whether directly or through phone. Even an illiterate person can speak. While talking directly is the most used form of communication, technology has enabled us to use many other ways like telephone, radio, television, text message like paging and sms, and internet. The direct communication and use of telephone, satellite etc. differ in the waves used for sending sound. All make use of waves, but we use sound waves (which are mechanical waves) in talking while electromagnetic radio waves in sending voice through the radio set or telephone.

OBJECTIVES

After completing this lesson, the learner will be able to:

- *describe the characteristics and nature of the wave;*
- *distinguish different types of waves- the mechanical (sound) and the electromagnetic waves;*
- *explain the uses of different kinds of waves; use in communication devices (SONAR and RADAR);*
- *describe the need and importance of communication;*
- *identify and appreciate different type of communication systems and*
- *highlight the use of computers and satellites in communication.*

18.1 CHARACTERISTICS AND NATURE OF THE WAVE

Sound is a result of vibration. The vibration is produced by a source, travels in the medium as a wave and is ultimately sensed through the ear - drum. Let's try to understand it better by an activity. We can do a simple experiment to show the association between vibration and sound.

ACTIVITY 18.1

Take an aluminum wire (about 30 cm in length) or simply a metallic hanger, such as of aluminum then bend it so as to shape it like a bow. Take a rubber band or an elastic string of sufficient length. You may also use a twig, a small piece of a tree-branch. Tie a thread or an elastic string such as a rubber band to the ends of the bow such that string remains under tension. Ask your friend to record that:

(i) If you pluck the string, you can hear some sound. You may have to adjust the curve of the bow to be able to hear the sound. You'd notice that the sound vanishes if you hold the string after plucking. If you look carefully, you can realize that the sound comes only as long as the string vibrates.

(ii) You can check the vibrations. Take a small paper strip (about a cm in length and 2 to 3 mm in breadth), bend it in middle to form a V and place it over the string. You may try the same with string instruments like guitar, sitar, and ektara or even use powder on percussion instruments like tabla, drum or dhol. If you leave a little powder or dust on the tabla, and cause the membrane to vibrate, you may be able to 'see' the vibrations. A gentle touch with finger tips will also tell you that vibrations are associated with sound in all these cases. If you strike a steel tumbler with a spoon, hear the sound and then hold the tumbler with firm hand, the vibrations will cease and so will the sound.

Discuss the observations with your friends. Can you now conclude that the **sound has an association with vibrations**? These vibrations are transmitted in a medium mechanically and that is how sound travels. It travels like a wave. **A medium is a must for mechanical waves like sound to travel**. We speak and expect to be heard. But it will surprise you to learn that without some aid, we can't converse on Moon as we do here. This is because there is no air on moon (actually there is some but very little) and sound needs a medium to travel. In contrast, we can receive electromagnetic waves from distant stars and artificial satellites in space as electromagnetic waves need no medium to travel. **A wave involves a periodic motion, movement that repeats itself**. It also transports energy. Let's understand waves better.

What happens if you throw a stone in a pool of water? You will see a disturbance of a circular shape moving from the point of fall of the stone outwards. We also observe that the disturbance is made up of a raised ring in water which seems to travel outward. Soon there is another similar circular feature originating at the same centre and moving outward. This goes on for quite some time. Even though there appears to be a movement of material, actually it is only the position of the disturbance that is changing. This is a wave and is made up of the raised part (crest) and low part (trough). So crest and trough are essential components of a wave. **A wave transfers energy from one point to the other without the medium particles moving from one point to the other.** Thus wave is clearly different from particle.

Understanding the nature of sound requires observations. We observe a flute player continuously shifting fingers over holes to produce different notes while playing a tune. Similarly a sitar player also keeps pressing the string at different points touching different frets (parda in Hindi). When you strike an empty glass with a spoon and when you strike one filled with water, different notes are produced.

The science of sound helps us in understanding the reasons behind such things. Besides, the understanding of sound has enabled scientists to devise gadgets which are very useful. These include hearing aids, sound instruments like speakers, sound recording and sound amplifying devices etc.. We shall also learn about various technological tools that have been developed to improve communication. By improvement we mean we can communicate to more people, at greater distances, and with more clarity.

18.2 REPRESENTING A WAVE

We need to describe a friend by name, height, colour, gender etc for identifying. Similarly, we have to specify some qualities that we shall call parameters, for wave description. A wave is represented in terms of its wavelength, amplitude, frequency and time period.

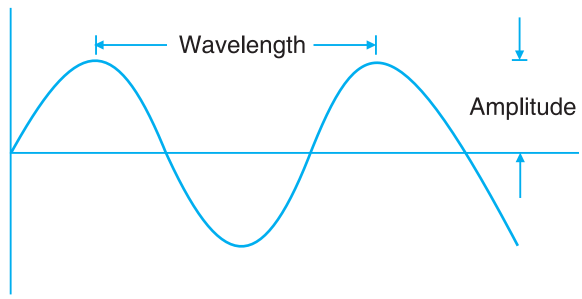


Fig.18.1 *A representation of wave*

18.2.1 Amplitude

The (maximum) height of the wave.

18.2.2 Wavelength

The distance between adjacent troughs or adjacent crests, measured in unit of length such as meters and expressed by symbol λ (lambda). For longitudinal wave, it will be distance between two successive rarefactions or compressions.

18.2.3 Time Period

This defines the time it takes for one complete wave to pass a given point, measured in seconds (s).

18.2.4 Frequency

The number of complete waves that pass a point in one second, measured in **Hertz** (Hz).

18.2.5 Speed or velocity

Wave speed is defined as the distance travelled by a wave disturbance in one second and is measured in meters/second (ms^{-1}). Speed is scalar quantity while velocity is a vector quantity.

Not all of these properties are independent; one can relate some. Period is inversely related to the frequency. This means if the frequency is high, the period will be low. This is understandable because frequency is number of times a wave completes a set of up and down movements (or a set of crests and troughs) in 1s. If these occur more frequently, it has to be done in very short time. Mathematically one may say period

$$T = 1/n$$

Where 'n' is frequency. We just said that wavelength is equal to the distance between two successive crusts or troughs. In one second this distance is covered a number of times given by frequency.

So, $$\text{Velocity} = \text{frequency} \times \text{wavelength}$$

or $$V = n \times \lambda$$

The waves that produce a sense of sound for living beings are called sound waves or audible waves. Only those waves that have frequencies lying in the range of 16 Hz to 20,000 Hz are audible to human beings. However, this range is an average and will slightly vary from individual to individual. Sound waves with frequencies below 16 Hz are called infrasonic waves and those above 20 kHz are ultrasonic waves. Animals like bats are able to produce and sense waves beyond the range of human audibility and use it for 'seeing' in the dark.

18.3 MOVEMENT OF SOUND IN AIR

Sound waves travel in fluids and solids as longitudinal waves. A longitudinal wave is a wave in which vibration or the displacement takes place in the direction of the propagation of the wave. Sound moves due to difference in pressure. If a sound is produced in air, it compresses the adjacent molecules. Due to the compression, the air pressure increases. This causes these compressed molecules to move in the direction of the pressure that is the direction of the wave. But displacement of the molecules causes fall in pressure in the place they left. If the wave is continuing then another rush of molecules comes in, fills the empty or rarified space. This process is repeated and the disturbance propagates. Thus a chain of compressions and rarefactions is generated due to sound. They travel and transport energy. If there is no medium, then produced sound will not be able to push any medium-molecules and sound will not move. That is the reason why we can't hear on moon; there is no air in Moon's atmosphere and sound can't travel.

INTEXT QUESTIONS 18.1

1. Which sound wave will have its crests farther apart from each other - a wave with frequency 100 or a wave with frequency 500?
2. If the velocity of sound is 330 metres per second (ms^{-1}), what will be wavelength if the frequency is 1000 Hertz?
3. What is the approximate audible range of frequency for humans?

18.4 DIFFERENT TYPES OF WAVES

The waves can be of different types. These may be mechanical or electromagnetic. Mechanical wave is a term used for those waves that require a medium for travelling. Its speed is dependent on the properties of the medium such as inertial and elastic properties. In other words the speed of the wave will depend on how easy or difficult is it to displace the particles of the medium (that is to say on their inertia) and on how those particles regain their original positions which is the elasticity.

An electromagnetic wave results from acceleration of charge. It doesn't require a medium to travel. It can travel through vacuum such as light do waves which travel from stars through empty space to reach us. The electromagnetic wave has electric and magnetic fields associated with it. The 2 fields, electric and magnetic, are perpendicular to each other and also to the direction of propagation. When we mention the wave length of an electromagnetic wave, we don't mean any physical separation between any crests or troughs or between rarefactions and compressions. This is because sound wave creates low and high pressure points in traveling through, say, air. But the electromagnetic wave needs no medium so there are no material troughs or crests or material rarefactions and compressions. It moves with the velocity of light viz. 2.997925×10^8 m s^{-1} that is 2.9997925 lac km s^{-1} in free space.

When thinking about movement of sound wave in a medium, we should always remember that the medium is a collection of particles. Movement of one particle can affect the other particles. You may have seen bicycles falling when parked in a row closely and one of them gets pushed accidentally. When the adjacent bicycles start falling in sequence, here also we see a wave, a movement of a disturbance. Here one bicycle imparts energy to the next bicycle, which transfers it to the next and so on. Here also there is a disturbance travelling without the medium component (the bicycles) moving to the end. The Sound wave is a mechanical wave but light waves, infra red rays, X-rays, microwaves, Radio waves etc. are electromagnetic (in short em). Gamma rays are alos em waves and result from radioactive decay of nuclei of atoms. Compared to sound waves, the em are much more energetic. They travel at the velocity of light that is about 3 lac kms per second in vacuum. In comparison, the sound waves travel very slowly. In air, it travels at 330 m s^{-1}. The velocity of sound in some media is given in the table which shows that sound moves faster in the solids than in gases or liquids.

Table 18.1: Velocity of sound in different materials

Medium	Velocity
Steel	5200 m/s
Water	1520 m/s
Air	330 m/s
Glass	4540 m/s
Silver	3650 m/s

Such difference in the velocities of light and sound means if there is an event in the sky, which produces light and sound both, we shall see the light almost instantly but it will be a while before we hear it. When there is a lightening in the sky, we see the light before we hear the sound. Mechanical wave can be either transverse or longitudinal while the electromagnetic wave is only transverse. The transverse wave is one in which the motion of wave and of the particles are perpendicular to each other. In a longitudinal wave, the motions are in the same direction. The sound wave can be of 2 types: Transverse and longitudinal.

We can try to visualize transverse wave by tying one end of a rope to a hook or peg in a vertical wall (or to a door-handle) and holding the other end such that the rope remains loose. We can demonstrate a transverse wave travelling along the rope if we quickly give up- and down- jerk (or even in horizontal plane) to the rope at our end. We see the wave travelling between our hand and the peg while the points on the rope move perpendicular to the rope and wave. This is a transverse wave, as the particles of the medium move perpendicular to the direction of wave movement. In the example of wave when we throw a stone in stationary water in a pond, it is more complex but here we confine to what happens on the surface. We see that on water surface the wave moves from the centre to the shore. If we see a duck or a small paper boat there, it oscillates up and down with water that is goes up temporarily after which they come back to their mean positions without shifting the position horizontally. That makes it a transverse wave.

In a **longitudinal wave**, the displacement of the particles and propagation of the wave are in the same direction. For instance, if we blow a horn, speak, or quickly move an object in air we are pushing the air molecules. These molecules, in turn, push the adjacent molecules which impart their energy to the next ones. After losing energy in the interaction, the molecule is back to its original (mean) position. This results in formation of compressions and rarefactions. So it's the compression (or rarefaction) which is travelling and not the molecules. Just like the distance between two successive crests or troughs is a measure of wavelength for transverse waves, the distance between two successive compressions or rarefactions is termed wavelength of the longitudinal wave.

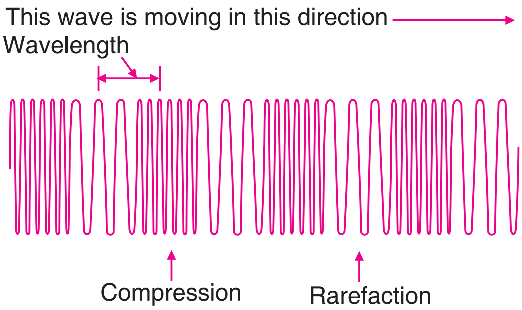


Fig. 18.2 *Formation of rarefactions and compressions in air and indication of wavelength*

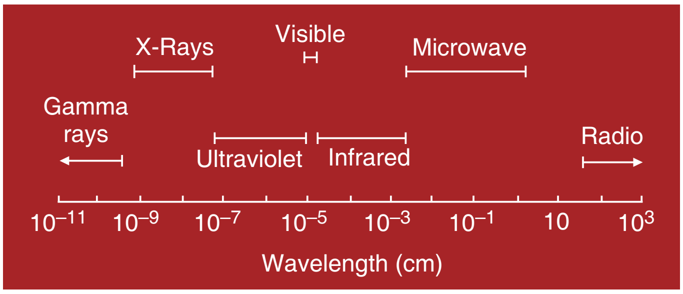
While transverse waves form only in fluids (air and liquid), the longitudinal waves can form in all the three media viz. solid, liquid and gas. One way to visualize a longitudinal wave is to take a spring, fix it between two ends and then pull or press it on one end along the length. Compressions and rarefactions can be seen moving and rebounding along the axis of the spring.

INTEXT QUESTIONS 18.2

1. Does a wave transfer energy or material?
2. How do mechanical and electromagnetic waves differ?
3. What is the difference between a transverse and longitudinal wave?
4. Do transverse waves form in solid?

Table 18.2: Ranges of wavelengths and frequencies of electromagnetic radiations.

Name	Wavelength (Angstroms)	Wavelength (centimeters)	Range of frequency (Hz)	Energy (eV)
Radio	$>10^9$	>10	$<3\times10^9$	$<10^{-5}$
Microwave	10^9-10^6	10-0.01	3×10^9-3×10^{12}	10^{-5}-0.01
Infrared	10^6-7000	0.01-7×10^{-5}	3×10^{12}-4.3×10^{14}	0.01-2
Visible	7000-4000	7×10^{-5}-4×10^{-5}	4.3×10^{14}-7.5×10^{14}	2-3
Ultraviolet	4000-10	4×10^{-5}-10^{-7}	7.5×10^{14}-3×10^{17}	3-10^3
X-rays	10-0.1	10^{-7}-10^{-9}	3×10^{17}-3×10^{19}	10^3-10^5
Gamma rays	<0.1	$<10^{-9}$	$>3\times10^{19}$	$>10^5$



The electromagnetic spectrum

Fig. 18.3 *Various radiations with wavelength and frequency*

18.5 NATURE, MEASURE AND QUALITY OF SOUND

Sound level is measured in units of decibel (dB). Here deci means one- tenth and bel is the level of sound. The term Bel is after the name of inventor of telephone Alexander Graham Bel. Actually it's a unit which compares the levels of power of two sources. Two power levels P_1 and P_2 are known to differ by n decibel if

$$n = 10 \log_{10} P_2/P_1$$

Here $\log_{10}$ means log with 10 (and not e) as base. Here P_2 is the sound which is measured while P_1 is a reference. Normally, the reference is a sound which is just audible. For average human ears, the whisper is about 30 decibel. The normal conversation is about 65 decibels while a jet plane taking off makes a noise of about 150 decibel. Beyond 85 decibels, sound is damaging and can lead to temporary loss of hearing. Prolonged exposure to noise can cause permanent hearing loss. We must be careful not to cause noise even when it means celebration for us. So it is not advisable to play band in a marriage procession (barat) near hospitals where patients can suffer because of noise. Noise raises the blood pressure and causes anxiety. Even if we don't realize, constant noise causes tension. Crackers during festivals are also harmful as they not only pollute air but also create noise.

Do you know

Considering the effect of sound on human health, it becomes necessary to develop an instrument to measure loudness of sound. The Decibel meter makes use of a special crystal called Piezo electric crystal. This has a quality that when subjected to pressure, it generates electrical voltage. In a Decibel Meter, a combination of a mic and piezoelectric crystal is used. Sound causes the diaphragm to vibrate and press the crystal and an electrical voltage generated is measured giving an idea of the sound level. This voltage can be converted into digits using calibration and displayed. Thus one can estimate noise from fire crackers, vehicles and machines and monitor so that people are not exposed to noise above certain level. The fact is that even music played at a very high level can cause deafness if done for a long time.

Different sources sound different. We should not confuse between loudness and pitch. Sound from a metallic tumbler on hitting with a metallic spoon is higher in pitch than sound from a pitcher when hit with a wooden stick. The voice of females is generally higher in frequency than male voice. However, we should also know that voice is not just one frequency. It is a mix of many frequencies, some of which are multiples (called **harmonics**) of the same frequency called fundamental note for the person.

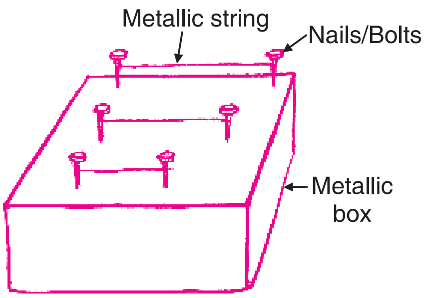


Fig.18.4. *A musical string instrument (which you can make using a metallic box and metallic strings)*

Now, that we know the relationship between wavelength and frequency, we can appreciate why a flute produces a higher pitch (smaller wavelength, larger frequency) when all holes are open. When all holes are closed, it produces the largest wavelength. Actually, the clue lies in relationship $v \propto 1/\lambda$ and by blowing harder we can produce louder notes.

ACTIVITY 18.2

You can do a simple experiment to understand the relation between the pitch of a sound and the wave length. This will help us to understand difference in sounds from a dhol and tabla as well as from a small and a long string. The smaller one will produce a higher frequency.

Take a hollow preferably metallic box such as of toffees or sweets. If unavailable, you may use a ply-board or cardboard box. Take 3 pieces of metallic strings (wire) available from a musical instrument shop or get from a hardware shop. Nails or nuts and bolts (also available from the hardware shop)

The nails/bolts have to be fixed on the box. Hammer the nails to fix them on the box/board using adhesive if needed. Alternatively, drill holes in the board (or top of the box) and using nuts, fix bolts as 3 sets of 2 each. As shown in the diagram, the distance between nails in the sets should be different. For instance, if the 2 nails/ bolts are spaced by 10 cms, make it 20 and 30 cms in the other sets. Now metallic strings, should be stretched one each between 2 nails/ bolts in each of the three sets.

If you pluck the string, you can hear some sound. For each length of string, the sound will be different. The shorter string will produce higher frequency.

Invite a group of friends for a show of this home made instrument. All of you can observe that when you pluck the strings, the pitch of each of the three strings is different. The longer string will allow a longer wavelength to be set up and hence have the shorter frequency (remember that higher wave length means the lower frequency for the same velocity). This is also the principle on which sitar and other such string instruments work. The frequency also depends on the tension in the string which is vibrating. This may be verified with a simple experiment. You may vary the tension in the strings by rotating the bolts or slightly bending the base board if it's flexible. It may be also achieved by passing the string over a metallic base (while one end remains fixed to nail/bolt) and suspending different weights from the other end of the string one by one. You may also fill water in similar glass or steel tumblers but to different levels. When you strike them with spoon, the sounds in them will be different in pitch. The pitch or the frequency will be higher where the air pipe is shorter (water level is higher). The wave length of the sound produced will be proportional to the air column lengths. Which of the 2 in a set of 2 tablas generate higher frequency? Is it the one with smaller diaphragm or bigger? A bigger diaphragm allows bigger wavelength to be set up.

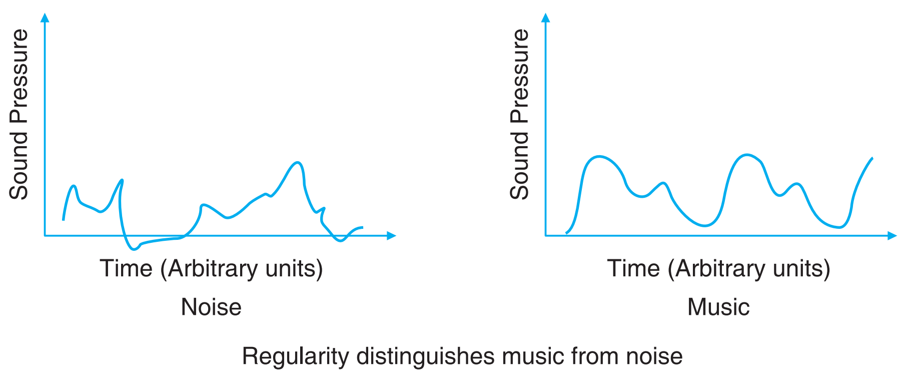


Fig.18.5 *Graphical representation of changes in sound pressure with time in musical and noisy sound*

Music is a set of sound that is pleasing to hear and is not random. It refers to the quality of sound as well as the tune. Noise is random and irritates while music has periodicity whether in beats, or rhythm. For instance, in a song, you'd notice that the same tune is repeated after certain period. After a stanza, the singer comes back to the same tune (combination of notes). If we plot sound pressure with time, we'd notice that it is sweet if it changes in a regular fashion. Noise, in contrast, changes in an irregular fashion and irritates. Sound is evaluated by musicians in 3 terms: quality, pitch and loudness. Two sounds may have the same loudness, may be at the same pitch but can still have different quality/timbre. That is how we can distinguish the sounds from Sitar and guitar even when the loudness and the pitch are the same.

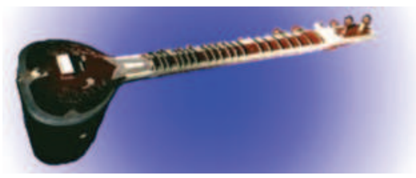
ACTIVITY 18.3

Take a flute and close all the 6 holes of the flute with your fingers (don't use smallest fingers). Blow in to the flute and hear the sound. Now keeping the same positions of the fingers (that is keeping all the holes closed), blow harder. You'd hear a louder sound. If we blow intermittently the sound you hear may be unpleasant but when you blow continuously you can hear a pleasant sound.

In India we see many musical instruments. Flute (Baansuri), Sitar, Sarod, Tabla, drum ghatam (pitcher), and even some Western instruments like guitar, piano and harmonium are quite popular. Some are string instruments where sound is produced by plucking a string and setting it to vibrate such as Tanpura, sitar and ektara. Some like tabla and dholak are percussion instrument where a membrane is made to vibrate by striking with hand or a stick. Then we also have flute and trumpet where we blow air into a pipe to produce sound.

Tanpura

Sarod



Sitar

A set of Tablas

Drum

Flute

Trumpet

Dholak

Fig. 18.6 *Some musical instruments*

Do you know

Flute is believed to be the oldest musical instrument. A flute made with bone from a vulture's wing was found in Ulm (South West Germany) in 2008. It had only 5 holes while modern flutes have 6 or more. It was dated to be about 35,000 year-old.

INTEXT QUESTIONS 18.3

1. What is the unit to measure sound intensity?
2. Why do they have many holes at the side of a flute lengthwise ?

18.6 USES OF DIFFERENT KINDS OF WAVES IN COMMUNICATION DEVICES (SONAR AND RADAR)

SONAR is a technique that makes use of this property of sound. SONAR stands for SOund NAvigation and Ranging. This works on the principle of echo of transmitted sound waves from objects. For instance, if you hit a wall in front with a tennis ball, the ball will bounce back to you. But if the wall is removed, the ball will not come back to you. Thus even with eyes closed, you have a way of knowing whether there is an object or a rebounding surface in front. SONAR works in the same fashion.

Use of sound waves to detect objects is based on the above simple example. The advantage of using sonar wave over electromagnetic waves is that electromagnetic waves lose energy fast in the ocean water because water can conduct electricity. In contrast sonar waves can travel farther in water.

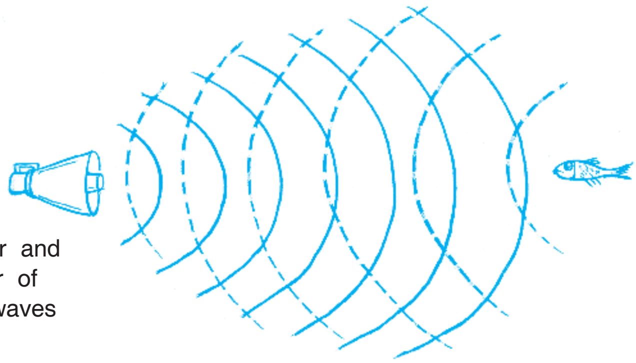


Fig. 18.7 *Working of SONAR: The continuous lines are used for transmitted SONAR waves and the dashed lines are used for reflected SONAR waves.*

There can be two types of SONAR set-ups. One is Passive and the other Active. In Passive SONAR, one detects sound waves that are present around. Leonardo da Vinci did it as early as 1490 AD. He dipped a pipe in water and placed his ear next to the end which was out of water. He used this to detect the waves generated by ships. Today, the techniques are far more sophisticated. SONAR became a topic of very serious studies during the World War II as detection of movements of ships and submarines assumed significance.

Do you know

Have you ever been to a valley and shouted or clapped to hear echo (or echoes) of your voice or of clapping sound? The echo comes from the hills. It's a reflection of your voice, or of the sound produced by you. Even in a very huge hall or between two fairly distant walls or building, one can hear echo. When the reflection is from a far away object, we can distinguish it as an echo. But if the reflection is from a close by object, it is perceived by mind to be a part of the original sound. The reason most of the people find their voice so pleasing to hear in the bathroom is that there the echo comes quite early, such that it is joined to the original sound. We can discern a sound in time if it is separated by more than 0.1 second. A bathroom is usually too small and the reflected sound comes back well within 0.1 second.

Now Active SONAR is very important. It has two major components:

1. A transmitter consisting of a signal generator, power amplifier and a transducer
2. A detector which may be a single detector or an array of several detectors

One has to ensure that the signal is sent as a narrow beam. If not, then the reflections will be coming from many directions and will be confusing. Theoretically, the distance travelled by the wave is twice the distance between the transmitter/detector and the target to be detected. So if velocity of the sound in water is v, then distance of the object

$$d = \frac{1}{2} \times v \times t$$

where 't' is the time-lapse between transmission and detection of sonic signal.

The wave may be reflected from surface or bottom of the sea, ships, whales or other animals, submarines and other objects. The whole thing looks very simple but in practice, there are several other factors to be considered. For instance, the velocity of sound in a medium depends on the density and bulk modulus of the medium.

18.6.1 Radar

RADAR is an acronym for RAdio Detection And Ranging and is useful in many ways to us:

1. Observation of atmospheric objects and phenomena like clouds, cyclones, rain drops etc. and prediction of weather
2. Air Traffic Control
3. Ship navigation
4. In military use (early warning and fighter control radar)

RADAR is radio wave equivalent of SONAR. In RADAR, a radio wave does the same job as sound wave in SONAR.

The basic elements of RADAR system are:

1. A pulse source and a transmitter with an aerial which'd emit radio waves
2. An object which'd reflect the radio wave
3. A receiver with an antenna and a display system like Cathode Ray Tube (somewhat like a television or a computer monitor)

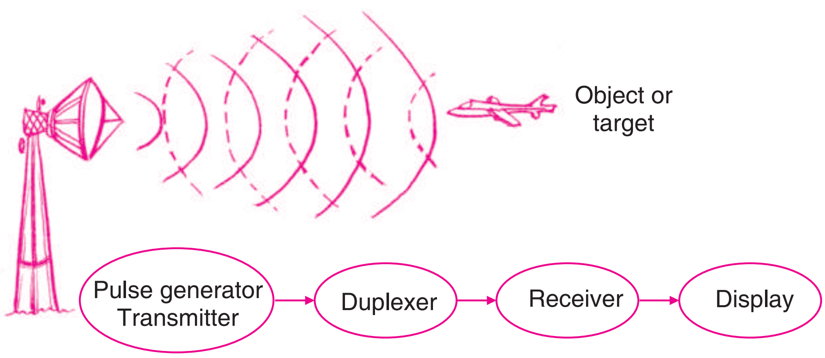


Fig. 18.8 *A simple sketch of components of RADAR*

Transmitter: The transmitter in a RADAR system generates and sends a radio wave. The radio waves go in all directions. If there is any object, the wave is reflected by it. There has to be a receiver to detect the reflected wave. The radio waves are electromagnetic radiation and travels at the velocity of light. It's obvious that the time gap between the outgoing radio wave and arrival of the reflected wave is very small. So what is done is that as soon as a radio wave is emitted, the transmitter is switched off and the receiver is switched on. Thus the reflected wave is not masked by the emitted wave and even a weak reflected wave is not missed by the receiver. If, after certain gap, there is no reflection received, we can presume that there is no object within certain distance and we can switch off the receiver and switch on the transmitter. This process goes on as was the case with SONAR. This is called a pulsed transmitter. However, for detecting moving objects, one can use continuous wave transmitter. If an object is moving away, the frequency of the reflected wave will be lower than the transmitted wave. If the object is moving closer, the frequency will be higher for the reflected wave. This is called Doppler Effect for sound. One can always adjust the receiver such that it doesn't receive the radio waves of the frequency emitted, but receives the radio waves of lower or higher frequencies. Called Doppler RADAR, such RADAR can only detect a moving object because it can't receive the frequency at which a radio wave was transmitted and only a moving object will change the frequency of the reflected wave.

RADAR is useful in air traffic control as it can 'see' in the dark. RADAR can monitor movement of clouds, detect rain drops. It can also detect presence of distant ships and big animals like whale in the sea. It can also be used to estimate the speed of the object approaching or moving away from us. It is used by weather scientists to track storms, tornadoes and hurricanes. Space and earth scientists make its use in tracking satellites and also in mapping earth surface. In fact it is useful even in making auto-open doors in shops or airports. This is because a wave will be reflected and sensed only if there is an obstacle in the way of emitted radio wave.

18.7 NEED AND IMPORTANCE OF COMMUNICATION

Many of our actions are in relation with actions, expectations or thoughts of others. The same is true of others. Communication need not always be verbal though sometimes facial expressions or body language give clues to what is going on in mind. But that is not very common and, generally, thoughts are in mind and we can't read them. Have you ever seen a face that conveyed sadness as if seeking help, you took pity and did something for that person? Possibly yes. But unless you talked, you wouldn't know the requirement exactly. It's by communicating among ourselves that we know each other's thoughts and take actions. Therefore, communication is very important in life and an illiterate person doesn't read or write, communication through sound assumes prime place. Sometimes, sound is heard directly, sometimes through instruments like loud speakers and sometimes it's communicated over large distances using complex equipments.

18.7.1 Different type of communication systems and devices

Some common devices for sound communication, other than independent oral or printed communication, are given below:

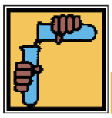
(i) Microphone and speakers

(ii) Telephone

(iii) Satellite, Computer and internet in communication

(iv) HAM

(i) Microphone and speakers



ACTIVITY 18.4

To understand that air pushes when in motion, take a candlestick, matchbox, a fan and a loudspeaker. Light the candlestick and hold it in front of a running fan. The flame flickers, and sometimes extinguishes. Air in motion has pushing quality. If you do the same exercise with a burning candle and a loud speaker, a similar thing happens. The reason for the flame getting extinguished is the pressure of the air. In the first case the source is the fan, in the other it is the loud speaker. A loud speaker reproduces sound through the motion of its diaphragm which pushes the air, leading to compressions and rarefactions.

The microphones (mic or mike in short) and the speakers are very common equipments. You see them not only in public meetings and conferences, you come across them even when you use your phone. The work of a microphone and a speaker are opposite of each other. A microphone converts sound into electrical entity (voltage) while a speaker converts the voltage into sound by moving the diaphragm of the speaker and producing vibrations in the air. Basically a microphone has a diaphragm which moves when sound pressure pushes it. This movement can be converted into proportional voltage using several possible transducers. Here a transducer is a device which receives electrical, mechanical or acoustic waves from one medium and converts them into related waves for a similar or different medium.

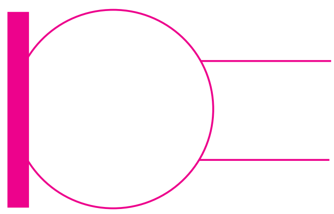


Fig. 18.9 *Symbol of a microphone*

The microphones can be of several types such as electrostatic (condenser/capacitor using plain or RF voltage), piezo-electric (crystal and ceramic), contact resistance (carbon), and magnetic (moving coil and ribbon).

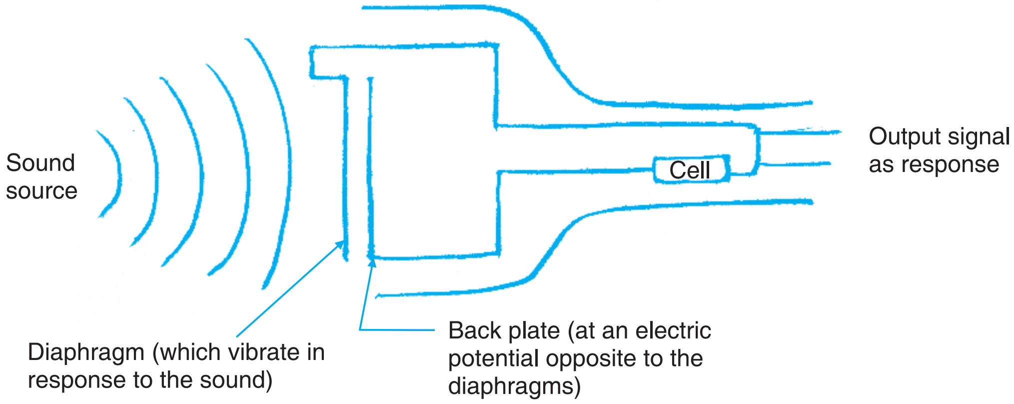


Fig. 18.10 (a) *Structure of a condenser (capacitor) microphone*

The diagram shows a **condenser microphone**. It has a thin diaphragm of thickness 1 to 10 micrometers. One micrometer (or micron) is one millionth of a meter or one thousandth of a millimeter. Close to this plate (metallic or metalised plastic) stands another metallic plate with holes. These 2 plates act as electrodes and are kept at opposite polarities by supplying voltages from –60 to +60 Volts (DC). To behave as a condenser, they should be insulated from each other. When sound wave pushes the diaphragm, it vibrates and the capacitance of the condenser (or capacitor) changes. This is because the capacitance is proportional to the potential difference and inversely proportional to the separation between the plates. Any change in the separation changes the capacitance. The capacitance is also dependent upon the medium but as the medium here remains the same, so we ignore this parameter. The values of the resistance and the capacitance are chosen such that the change in voltage is immediately reflected in the voltage across the resistance in series. Any change in the capacitance (meaning any change in sound) leads to voltage change. The voltage is fed to an amplifier. When the amplified voltage is applied to the coil of a speaker, it reproduces the sound which changes with the input- sound. The functioning of the speaker is just reverse. There, electrical voltage is fed to the speaker coil and the change causes the diaphragm to vibrate and produce sound.

Fig. 18.10 (b) *Condenser microphone*

In a **ribbon microphone**, a corrugated ribbon made of a metal is suspended in a magnetic field. Sound causes the ribbon to vibrate. This means change in magnetic flux through the ribbon. This induces an electric current which drives a speaker. When this current is flown through a coil attaches to diaphragm of a speaker, the diaphragm vibrates and produces sound. Special materials developed using nano technologies are being used to make ribbons that will be light but strong. Being light improves the response to sound. The ribbon microphone senses pressure- gradient and not just pressure. Therefore, it detects sound from both sides.

INTEXT QUESTIONS 18.4

1. Give three examples of devices that make use of microphones or speakers or both.
2. In a condenser microphone, what will happen if the diaphragm is made very heavy?

(ii) Telephone

Invention of the telephone is credited to Alexander Graham Bell. The telephones are of several types: hand sets, mobile phone, satellite phone and through internet. The basic function of a phone is to allow communication of voice both ways. Of late, phones with facility of transmitting images have also become available. The telephone may be with or without wire. In a wired phone, the basic structure is as follows. It has a microphone and a speaker. The microphone receives our voice and converts it into electrical signal. Similar process occurs inside the mouthpiece of the telephone. A basic telephone has 3 main parts:

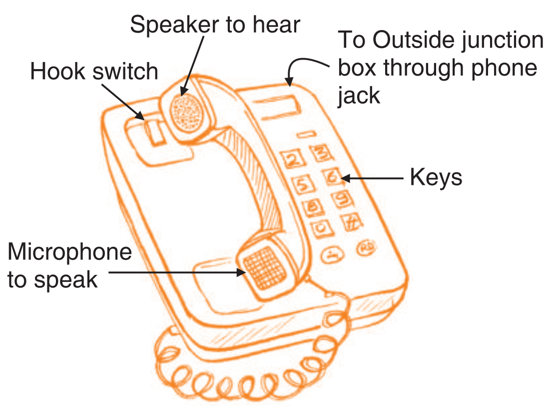


Fig. 18.11 (a) *The basic structure of a wired phone set (In actual phone there is a provision so that your voice does not reach and disturb you)*

(i) Cradle with a hook switch.

(ii) A mouth piece which houses a microphone

(iii) A hearing piece which houses a speaker (usually an 8 ohm speaker)

The phone is rested on the hooks. As soon as the phone is lifted, the hooks pop up and a connection gets made inside the body of the cradle which completes a dial tone ringer circuit. This produces a tone which is actually a mix of 2 tones (2 frequencies). On hearing the dial tone, we know that the phone is connected and we can dial a number. If the number is busy when we dial, we hear another mix of tones. Over the times, the telephone has undergone many changes including introduction of the cordless (for short range) and mobile phones. But as far as basic structure of a telephone set is concerned, it has remained the same.

Now the dialing is by pressing the keys. We speak into the mouth piece and hear the other person through the speaker. In a basic phone, the speaker and the microphones form the ends of the phone set. In this way, the set can be held close to face such that the speaker is close to our ear and the mic to our mouth.

The speech is controlled by a mouth piece which contains a mic. It includes a diaphragm. In the old phones, the diaphragm was made of a 2 metallic sheets between which carbon granules were filled. As one speaks, the diaphragm gets pressed following the same pattern as the sound of a speaker. In turn, the carbon granules also get compressed and decompressed, coming closer and moving away, thus increasing and decreasing the conductivity. A current is sent through the diaphragm. The source of this DC current (a few mA) is a battery at telephone exchange and the current comes to our phone. This leads to varying electrical current. This current will depend upon the sound pressure hence this can pattern the signal being sent through the amplifier and the cable. Now-a-days, there are electronic microphones. This signal (as electrical current) is sent to a junction box outside house using a pair or copper or aluminum wires. There are signals from other houses also reaching this junction box. All of these electrical wires carry voice- signals (sound converted into electrical signal) that are sent through a common coaxial cable, housing many pairs of copper wires, to the telephone company's exchange. From there, they can be routed either through metallic or fiber optical cables. These days, the signals are also routed from the exchange through microwaves using satellites especially for international calls. To avoid our own voice reaching our ears, a duplex coil is placed in the circuit of the microphone. In addition, there is a ringer. When someone calls, it rings a bell and we know that we have to attend a phone call.

The hearing is controlled by a speaker. It consists of a diaphragm with a permanent magnet attached to it on one end and an electromagnet close to the other end. The electromagnet is a piece of soft iron with a coil wound around it. The signal comes and flows through the coil. This causes the iron core to be magnetized. This naturally causes the diaphragm to vibrate in the same pattern as incoming current (voice). This generates sound that we hear.

Mobile phones have brought great convenience in daily life. The basic working principle remains the same in mobile phones also. But for them, the sound doesn't travel through cables or wires. It travels as electromagnetic wave through space via antennas, base towers, switching stations (or even satellite) and then again the antenna. When a number is dialed, the (electromagnetic) field is spread all around through antenna of the mobile. The signal is received by the nearby microwave tower and then by the switching station. This station re-transmits it in all directions (it doesn't know where the intended mobile may be) and a part is available to the other antennas in other places. When an antenna near the intended receiver gets the signal, it also retransmits it and this is received by the antenna of the intended mobile, which rings.

Fig. 18.11 (b) *Mobile*

While fully conclusive evidence may not be available, there are apprehensions about the possible health hazards, such as brain tumour, associated with use of mobile phone. The microwaves, used by mobile phones set-ups, are absorbable by water. It is apprehended by some that prolonged conversation on mobile phone can result is considerable microwave dose to brains which contains fluids. The children's brains contain more fluids and the skull is thinner. Hence they are more susceptible. Experimental evidence exists and common experience suggests that long duration conversations lead to temperature increase in body part close to the mobile phone. A study conducted with the support of World Health Organisation by the International Agency for Research on Cancer, catagorises the radiofrequency electromagnetic fields as group B agents that could possibly be 'carcinogenic to humans'. It may be advisable not to hold them too close to head. One should limit the use of mobiles to the shortest possible durations especially at a stretch and close to the same ear. One may also be advised to use earphones if long duration talk becomes necessary.

(iii) Use of satellites, computers, and internet in communication

(a) Satellites

Satellites are bodies that revolve around planets. All the planets in Solar System, except Mercury, have natural satellites. Moon is a natural satellite of Earth. But we have artificial satellites launched by several countries. You may have some times noticed, after sun- set, tiny points of light moving in the low sky. They are moving too fast to be stars. These are artificial satellites glowing due to scattered Sun light which is below our horizon by that time. The first artificial satellite was by name Sputinik-1 and launched by USSR on October 4, 1957. It carried a radio transmitter. The first American satellite to relay communications was Project Score in 1958. India launched its first artificial satellite 'Aryabhata' from a USSR launching facility on 19th April, 1975. This was followed by Bhaskara-I (7th June, 1979). After developing indigenous launch vehicle SLV-3, India launched 35 kg Rohini-I satellite (18th July, 1980) using a 4- stage SLV-3 vehicle followed by 2 more in the Rohini series. The next was Apple (Arianne Passenger Pay Load Experiment). These were followed by many satellites like Bhaskara-II and INSAT (Indian National Satellite) series which have been used for communication, TV and radio broadcasts. In 1988, the first satellite of IRS series was launched aimed at serious remote sensing work and applications. Since then, India has successfully launched many satellites for remote sensing and communication.

Having satellites in space places us in a privileged position. If we are on ground there is a limit up to which Earth's features can be seen by us. But viewing Earth from a distance has an advantage. It allows us to look at up to half of the planet if the distance is sufficiently large. We can send electromagnetic signals to the other side of the globe through the satellites in space. Therefore, the artificial satellites have come to play a very important role in any country's infra structure. They serve very important role in communication, space research, survey of natural resources like minerals on Earth, weather prediction including movement of clouds, also change in course of rivers, and disaster monitoring (floods, cyclones, tsunami etc.). Communication becomes important for imparting education. The idea that satellites could be used for communication came from Arthur C Clarke in mid forty's. That is the reason the geostationary (or geosynchronous) orbit is also called Clarke orbit. Clarke rose to become one of the greatest science fiction writers.

Electromagnetic waves sent from any part of Earth can't reach just any part of Earth. If sent downwards, they will be limited to a small distance due to curvature of Earth. If transmitted up, they will keep going straight and hit ionosphere, a layer of charges in the space, at 50 kms and more above the ground. Then they will be reflected to Earth and reach some part which is far away from the source. Thus a huge area in- between will be a dark zone where the signal wouldn't reach. Instead of the ionosphere, one may use satellites to retransmit the signals. But we need more than one satellite which can receive the signal sent from ground and re - transmit it in different directions. Therefore, it was thought that several satellites in space could together cover whole of Earth and facilitate communication.

A satellite's position and orbit are critical. The satellite has to be launched using a rocket, lifted into the correct orbit and given suitable energy and momentum in the right direction so that it keeps moving. A satellite could be geostationary which remains stationary with respect to Earth. A satellite in a geostationary orbit keeps moving at the same angular speed as Earth and in the same direction as rotation of Earth. So a geostationary satellite has a revolution time which equals the rotation time of Earth viz. 24 hours. It appears to be in a fixed position to an observer on Earth. It can keep looking at the same spot on earth for a very long time, monitor the changes and transmit the data to ground station. Thus to direct antennas towards the satellite to receive the signal, one doesn't have to keep tracking a moving satellite. That would have demanded expensive instruments on ground for direct TV transmission. This means huge savings because it does away with the need for too many ground antennas. Placing a satellite at 36,000 kms has added advantage that it just falls under the gravitational pull of Earth and is energy - economical though it's more expensive to launch compared to low orbit satellites. Low orbit satellites are placed about 400 kms above ground. But being low, they can see only a small portion of the ground below. There are Polar Satellites that move over the poles. The remote sensing satellites have been placed in comparatively low (less than 1000 km high) orbits in contrast with communication satellites in geostationary satellites which move at 36,000 kms above Earth. The remote sensing satellites should be launched such that they make observation at any place between 10 AM and 2 PM so that the ground is illuminated from the top and images come out clearer.

A geostationary satellite is useful for countries at low latitude such as India. The satellite is placed at an altitude of 36,000 kms, going around in the plane of equator and making one revolution around Earth in 24 hours. However, as Earth also makes one rotation in 24 hours, the satellite looks at the same place on ground all the time. From this altitude, it can view about one- third of Earth. The signal is sent from ground to the satellite as microwave at certain frequency and the satellite re- transmits it to the other parts of Earth at a different (but still as microwave) frequency. Microwave is at wavelengths of the order of a millionth of a meter. The highly directional antennas on Earth receive these microwave signals. Thus satellites make it possible to send TV, radio signals to far away places on Earth, even on the other side of globe.

Orbital radius	Km
Low Earth Orbit (LEO)	160-1,400
Medium Earth Orbit (MEO)	10-15,000
Geostationary Earth Orbit (GEO)	36,000

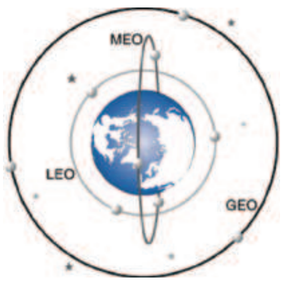


Fig. 18.12 *A satellite moves in Low (LEO), Geostationary orbit (GEO) or in an orbit. LEO goes over the poles in each revolution (Polar orbit) which is used for mapping Earth. This is useful in weather studies because it allows looking at clouds etc. at the same time every day. The geostationary and LEO satellites monitor the same place on Earth.*

(b) Computer and Internet

Today computers are inevitable in daily life. Computers play a major role in publishing industry; designing of houses, controlling the functioning of cars and garments; computerized machining, regulating air traffic, and in simple as well as the most sophisticated scientific instruments. Even at home, majority of the gadgets, whether television, automatic washing machine, television or microwave oven, one finds application of computers. Besides this, they have revolutionized communication.

Computers are used for communication to and from aircrafts, ships, and even huge boats; in money transactions and in maintaining and processing financial records such as in Automated Teller Machine (ATM) and banks. In the form of application to internet, computers have emerged as a very strong communication link. Using e-mail, one can send a message, chat live (that is send and receive text) and even talk instantly which has revolutionized communication. Earlier it would be weeks before one could send a message and receive reply from abroad. Today, it's a matter of seconds. This certainly helps the dissemination and growth of knowledge.

(iv) Ham

The term HAM is not from the English language. It was coined taking the first letters from the surnames of those 3 persons who started this way of wireless two way communication. They were S Hyman, Bob Alby and Poogie Murray. It was in 1908 that they started an Amateur Radio Club which has grown to the present worldwide group of amateurs. Even today when mobile phones are so common, the HAM comes handy in case of disasters when all other means of communication break down. HAM uses radio waves. Radio waves are electromagnetic waves in the range (about 10 cm to 10 km, see Fig. 18.3) and hence they travel at a velocity (in vacuum) of about 3 lac kms per second. Sound is converted into electromagnetic signal and transmitted using an antenna. The sound is intercepted by the receiver which converts it back to sound.

INTEXT QUESTIONS 18.5

1. List some uses of satellites.
2. If a satellite equipped with cameras remains fixed at one height above ground even as earth rotates and moves in its orbit, what is its possible use?
3. Arrange the low orbit, geostationary and polar satellites in decreasing order of altitude above Earth (the highest one comes first).
4. Which of the satellites are preferred for communication application?

WHAT YOU HAVE LEARNT

- Sound results from vibration and needs a medium to travel, be it gas (like air), solid or liquid. It is faster in solids than in liquids and is the slowest in the gases.
- Electromagnetic radiations also are waves but they can travel through vacuum.
- Wave, sound or electromagnetic, involves periodic movement, movement that repeats itself.

- A wave is described in terms of wavelength, frequency and amplitude. Velocity is equal to the product of wavelength and frequency.
- Noise is random while music is periodic. Music is pleasing to hear but it is also subjective. Sustained exposure to noise and even music at high decibel harms.
- The functioning of musical instruments like Tabla, Sitar and flute (Baansuri) can be understood as vibrations in membranes, strings and organ pipe.
- Sound Navigation and Ranging (SONAR) and Radio Detection and Ranging (RADAR) are two techniques which have many applications. They make use of sound and electromagnetic (radio wave) waves respectively. SONAR is more useful than RADAR in water as electromagnetic waves lose energy fast in water.
- The inventions of microphone, speakers, telephone, satellite, computer and internet and HAM have revolutionized communication. They all work through the conversion of sound wave/text into electromagnetic waves at transmission end and reconversion to sound wave/text at the receiver's end.
- A microphone (mic) converts sound into electrical signal, while the speaker converts it back into sound. Mic can be of different types like condenser, piezoelectric, contact and magnetic mic.
- Sound pollution can have dangerous implications and hence care should be exercised that the level is kept low. Prolonged use of mobile phone can damage us and there is possibility of serious illness.

TERMINAL EXERCISE

1. Fill in the blanks:

   (i) Sound travels at a .... velocity than light.

   (ii) When there is lightning, we first .... and then hear it.

   (iii) SONAR makes use of .... waves while RADAR makes use of .... waves.

   (iv) Microphone converts sound into .... while speaker converts electric signal into ....

2. Multiple choice type questions

   (i) Which satellite will see a wider area on Earth?

   (a) A low earth orbit satellite (b) A high earth orbit satellite

   (c) A medium earth orbit satellite

(ii) India's first self launched satellite was

(a) IRS (b) Aryabhat (c) Rohini (d) INSAT

(iii) For the same velocity, will a higher frequency of a sound wave mean

(a) Higher wavelength (b) Lower wavelength

(c) The same wavelength

(iv) Sound travels fastest in

(a) Solid (b) Liquid (c) Gas

(v) The most suitable medium for RADAR would be

(a) Gas (b) Liquid (c) Solid

3. Why can't we hear each other on Moon?
4. Describe 2 experiments to show that sound has vibrations associated with it.
5. What is the relationship between velocity, wavelength and frequency?
6. State 3 differences between sound waves and micro waves.
7. What are the differences between longitudinal and transverse sound waves?
8. Will sound move faster in solid or air?
9. What is the basic difference between noise and music?
10. What makes your voice appear more musical when you sing in a bathroom?
11. How is active SONAR different from passive SONAR?
12. What are the relative merits of SONAR and RADAR? Why is it better to use SONAR in water?
13. How does SONAR help in estimating the distance of an object?

ANSWERS TO INTEXT QUESTIONS

18.1

1. The wave with frequency 100 will have its crests farther apart as its wave length will be higher. For sound waves, the velocity 'v' is equal to the product of wavelength and frequency ($v = n \times \lambda$ or $v/n = \lambda$) and thus wavelength and frequency are inversely proportional. So for the same velocity, the lower frequency wave will have a larger wave length. Therefore, for the wave with a frequency of 100 Hz, will have a higher wavelength and the crests will be farther apart compared to the wave with frequency 500 Hz.

2. Wavelength = 0.33 meter
3. About 20 Hz to 20KHz

18.2

1. A wave transfers energy. Even when the material is displaced, it's temporary and it comes back to its normal position such as in case of a ripple in water.
2. Medium is essential for propagation of mechanical waves. Electromagnetic waves can travel through vacuum as well as any medium. But they lose energy in liquids and solids very fast. Sound waves can travel through liquids and solids with much lower losses. The velocity of sound waves is highest in solids (a few thousand metres per second). The velocity of electromagnetic waves in contrast is extremely high: about 3 lakh km per second.
3. In a transverse wave, the direction of propagation of the wave (the direction of energy-transfer) is perpendicular to the direction of oscillations whereas in longitudinal waves, particles of the medium vibrate parallel to the direction of wave propagation.
4. Yes. The sound waves travel in solids.

18.3

1. The unit to measure sound level is decibel. It's one tenth of a bel. Actually the decibel is a comparative scale. For us, the reference is fixed at the just audible sound so we normally speak of sound level in decibels.
2. Flute is an organ pipe in which air columns vibrate. More the length of the air column, more the wavelength of sound produced and hence loss the frequency. Holes are provided by the side of the flute so that by closing the holes length of vibrating air column may be changed.

18.4

1. Telephone, Radio and Television
2. In a condenser microphone, if the diaphragm is made very heavy, the inertia of the diaphragm will be higher. This means it will be difficult for the diaphragm to move rapidly. Its movement can't be fast enough and so it will not be possible to reproduce very high frequencies.

18.5

1. Satellites are useful in communication, surveying, photographing of geographical features of earth and astronomy.

2. If the satellite is stationary but earth below it keeps moving, the view will keep changing. Thus without the satellite moving, the satellite cameras will see whole surface of earth facing it.

3. The geostationary, polar and low satellites. The geostationary satellites are the highest at about 36,000 km. The Polar satellites are lower than them and the Low Earth Satellites (160-1400 km) are the lowest.

4. Geostationary satellites are preferred for communication application. This is because from earth they appear fixed at the same place. Thus if the antennas are directed towards them once, we don't have to worry about tracking them.