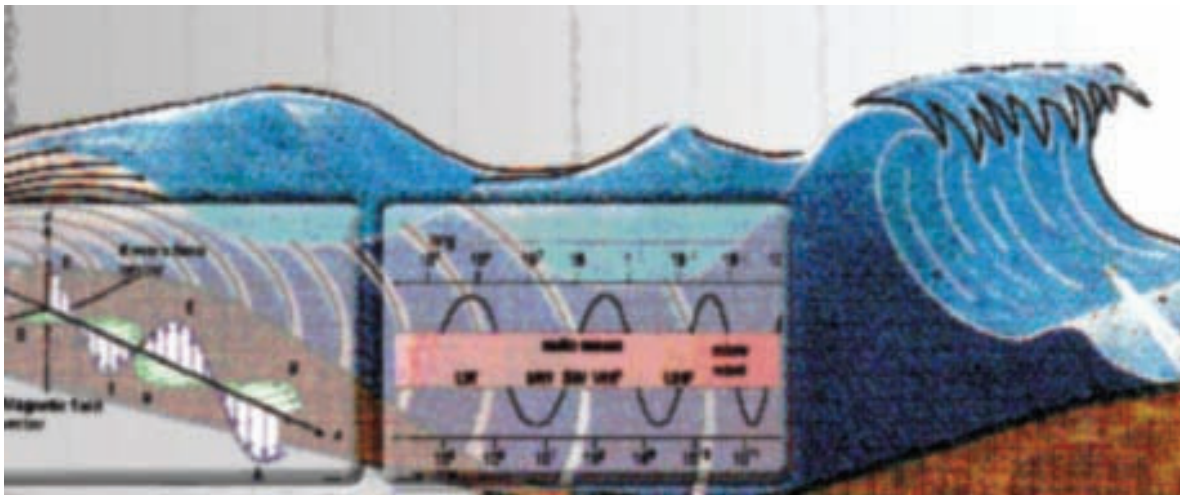
Physics

01. Waves and their applications



After studying this lesson, you will be competent to:-

- Quantify the properties of various types of waves.
- Investigate the effects created by the various waves and types of waves.
- Use the characteristics of sound waves for tuning musical instruments.

1.1 Properties of various types of waves

Waves play an important part in our everyday lives. There are many kinds of waves. We hear due to sound waves, see due to light waves, feel warmth due to heat waves. We are familiar with radio waves and television waves. The recent tsunami destruction was due to water waves. Seismic or earthquake waves could be just as destructive. Solar energy which is vital for plant life, too, comes in the form of waves. Sound waves, light waves, radio waves, micro waves, water waves and earth waves are some waves that have been identified so far.

Now let us investigate how waves form

You may have seen waves on the surface of the sea or in a water pool. When a pebble is thrown to still water or when a boat is moving, water particles vibrate. This could be observed as water waves.

The rhythmic movement of an object to either side across a fixed point is called vibration or periodic motion.

The vibration of a hacksaw blade, motion of water when a pebble is dropped vertically to still water are some of the vibrations we are familiar with in our day to day life.

Activity 1.1

Drop a pebble into a vessel which contains water. Waves or ripples are produced like expanding rings on the surface of water.

A periodic motion that travels across a medium or space, from one place to another is called a wave.

When we disturb the surface of still water, water particles are vibrated. That disturbance spreads as circular ripples (waves). Here, water is the medium of transmission of the wave.

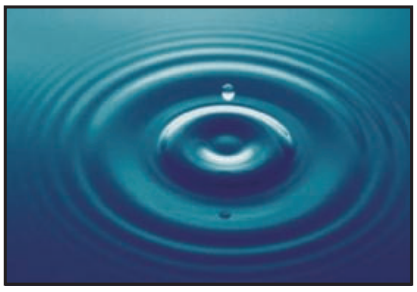


Fig 1.1 - Waves in water

Let us do the activity 1.2 to identify another types of waves that we come across in our day to day life.

Activity 1.2

Set the slinky on a flat surface, as shown in Fig. 1.2. Fix it at one end and move the free end forwards and backwards.

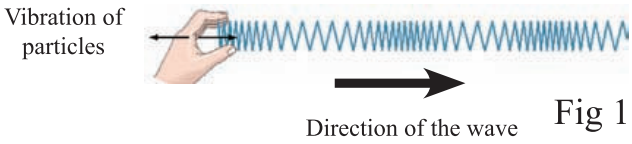


Fig 1.2 - Waves in a slinky along its axis

By moving one end of the slinky forwards and backwards, we can create a disturbance. This disturbance is propagated along the slinky and the turns of the slinky move closer or further apart. Here the medium of propagation is the slinky.

When a wave is transmitted through a medium, the particles of the medium move periodically. The particles move forwards and backwards or up and down. In water waves, particles move up and down. In the transmission of waves in the slinky, the coils of the slinky move forwards and backwards. But as the particles come back to the intial position, the wave is transmitted without an effective displacement of particles.

When a wave passes along, a particle that vibrates at one place, transfers the energy to the next particle. In this way energy is propagated from one place to another place through waves.

Depending on the movement of particles in relation to the direction of the wave, there are two types of waves.

(1) **Longitudinal waves**
(2) **Transverse waves**

Longitudinal waves

If the particles of the medium vibrate parallel to the direction of the wave, such waves are called longitudinal waves. When a slinky is vibrated along its axis, longitudinal waves are formed in the slinky. By vibrating a hacksaw blade or a tuning fork, longitudinal waves can be produced in air.

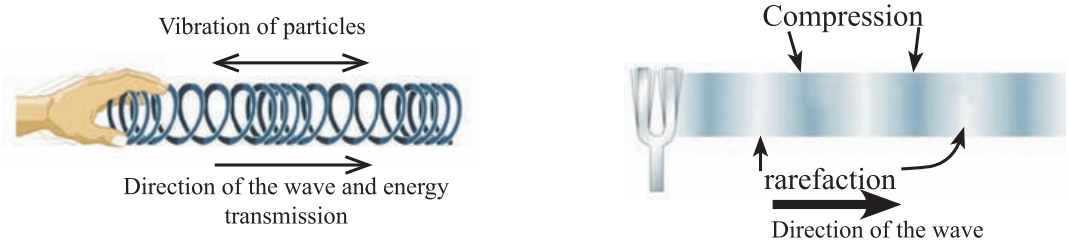


Fig 1.3 - Longitudinal waves produced by a slinky and a tuning fork

In the above, the places where particles of air are close together are called **compressions**. When the arms of the fork get closer, the air compressed before get spaced out. Such places are called rarefactions. The former compressions now become **rarefactions**. Due to the elasticity of air, particles of air move forwards in a wave of alternative compressions and **rarefactions**.

Transverse waves

Waves in which the particles vibrate perpendicular to the direction of the wave are **transverse waves.** We can observe the formation of these waves by dropping a pebble to still water, moving a rope up and down or vibrating a slinky perpendicular to its axis.

We can observe this type of wave by moving a slinky up and down (Fig 1.4).

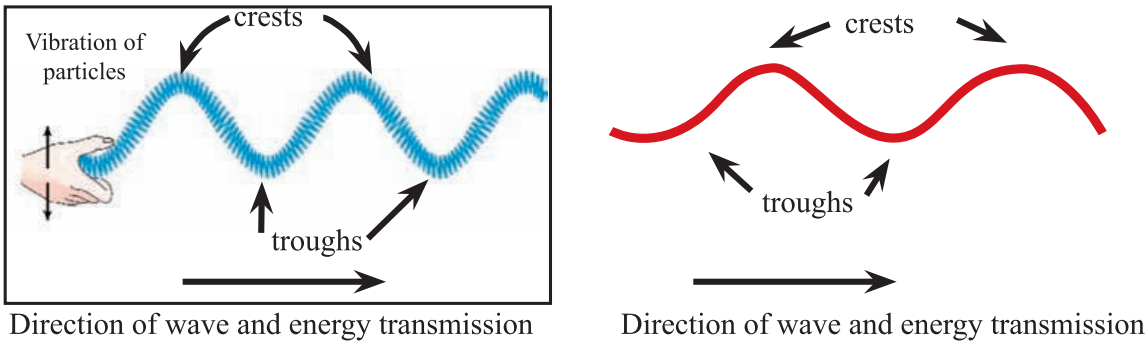


Fig 1.4 - Transverse waves produced by a slinky

Activity 1. 3

Make a disturbance on the surface of water and keep a light object such as a plastic ball, a piece of styrofoam or a paper boat on the surface.

We can see that the paper boat is moving up and down vertically while the water waves are moving outwards. The boat does not move with the wave.

Let us consider waves produced by the dropping of a pebble into still water. There is a disturbance in the water by the pebble and this causes a wave. The water particles are dipped down at that point and a **trough** is formed. The water particles which come up make a **crest**. When transverse waves propagate the water particles which were at a trough, become a crest. At the same time, a crest becomes a trough. Hence, by forming alternate troughs and crests a wave propagates forward.

Fig 1. 5 shows how a transverse wave is denoted.

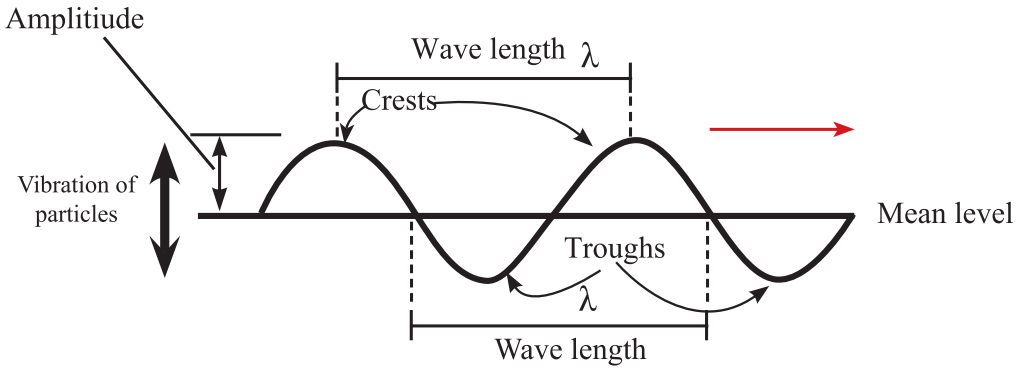


Fig 1.5 Representation of a Transverse wave

The wave length

Wave length of a wave is the distance between any particle and the nearest one which is at the same phase of its motion. This indicates a complete cycle. A wave consists of a number of such cycles. The symbol of wave length is λ. The SI unit of wave length is metre (m).

Amplitude

Amplitude of a wave is the maximum displacement of any particle from its mean position. The SI unit that measures the amplitude is metre (m).

Frequency

Frequency (f) of a wave is the number of vibrations or the number of cycles made by a particle of the medium in one second. The unit is **Hertz**. Symbol is Hz. In one vibration one cycle is made.

Speed of a wave

Speed (V) of a wave is the distance travelled per second by the wave. The distance that the wave travels in one cycle is equal to the wave length. If "f" number of cycles are formed in one second, the displacement in one second is ;

$$V = f\lambda$$

This is the equation for the speed of a wave. The unit that measures the speed is ms^{-1}.

Worked example:

The wave length of a wave produced by a turning fork of frequency 512 Hz is 0.65 m. Find the speed of sound in air.

Solution:

Frequency of the tuning fork = 512 Hz

Wave length = 0.65 m

$V = f\lambda$

$= 512 \times 0.65 \text{ m s}^{-1}$

$= 332.8 \text{ m s}^{-1}$

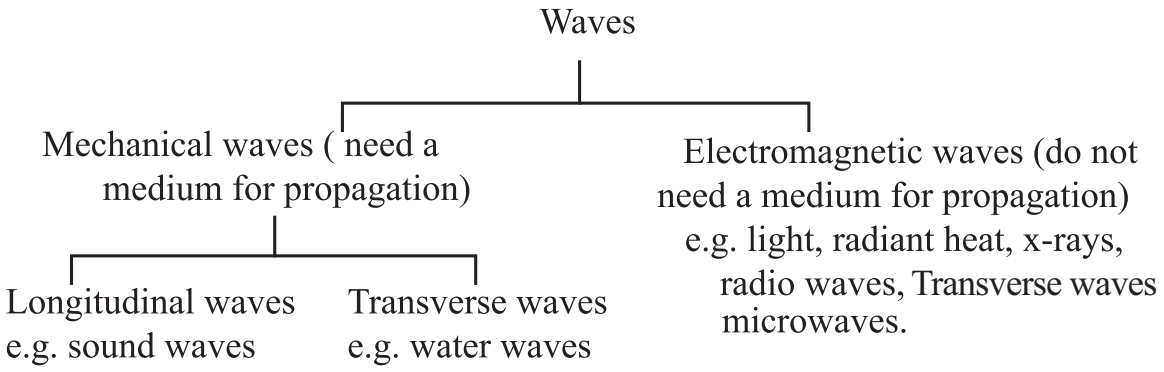
1.2 Types of waves

We know that most of the energy types such as light and sound are transferred as waves. Though sound waves need a medium for transferring, heat and light energy which is emitted by stars and sun do not need a medium. They can travel even through a vacuum. Information from space crafts reach the earth as waves. Such types of waves are called electromagnetic waves.

According to the media of propagation the waves in our environment can be divided into two main types.

(1) Mechanical waves

(2) Electromagnetic waves



(1) Mechanical waves

Waves that need a medium to be transmitted belong to the group of mechanical waves. Accordingly, sound waves, water waves and earthquake waves belong to this group.

Sound waves are grouped under mechanical longitudinal waves. Voice of humans, sounds of animals, noises of vehicle horns, ringing of bells are some of the sounds that we hear in the environment. We get the sensation of hearing because of sound energy. The sources which make sound are called **sources of sound.** Many animals make sounds by vibrating the vocal chords in their throat. The main method of communication between each other is sound. Sounds propagate as longitudinal waves. Man has made many technical instruments that generate sound waves.

• Earthquake waves

Sliding of tectonic plates that occurs naturally in the interior of the earth causes earthquakes. Earthquakes are caused by the sudden release of built up stress along faults or cracks in earth.

When the plates of the sea bed (tectonic plates) come into contact with each other, a sudden release of energy comes up as earthquakes. The shock waves from this sudden movement comes to the surface as an earthquake.

The place where an earthquake is formed is called the epicentre. From an epicentre, two types of waves are formed. They are surface waves and body waves. Surface waves move along the earth's surface and cause most of the damage. They are transverse waves.

Body waves are also of two types. They are named primary waves and secondary waves. Primary waves are longitudinal waves. Secondary waves are transverse waves and have the ability of travelling through the interior of earth. The occurance of body waves can be identified using **seismometers.** They are used to study the interior of the earth.

• Water waves

We learnt that transverse waves are formed when a pebble is dropped into a pond of water. These are transverse waves where the particles move perpendicularly to the direction of the waves.

• Shallow water waves

These are formed in shallow waters. When a wave approaches shallow water near a shore it is unable to complete its circular motion and is formed into more elliptical path. The surface waves get higher and steeper there. When the depth becomes too shallow, the wave breaks. The crest of the wave falls forward to form surf.

Tsunami waves are also a type of shallow water waves. At the beginning these waves have a long wave length. When they propagate, they lose a little energy.

When they reach at the shallow water near the coast, the wave length decreases. Then they get a high amplitude and reach the coastal area as destructive waves.

Most of the tsunamis are generated by sudden displacement of the sea floor (sea bed) by earthquakes because of volcanic eruptions, landslides, under water explosions and meteorite impacts.

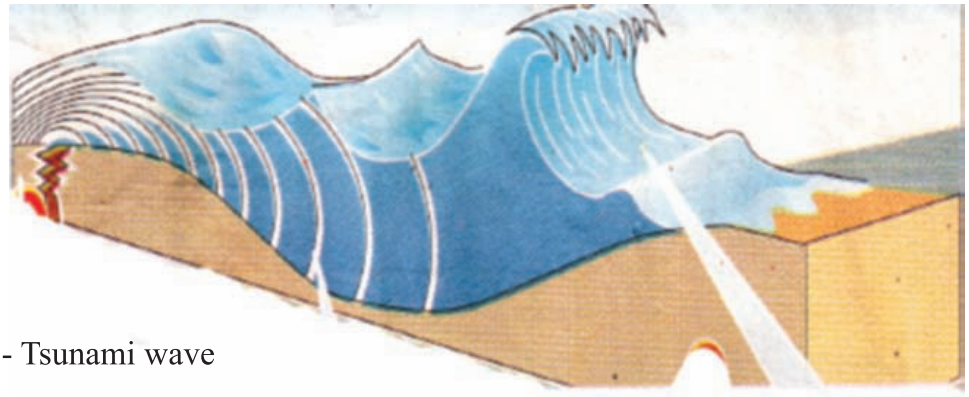


Fig 1.6 - Tsunami wave

(2) Electromagnetic waves

Electro magnetic wave consists of electric and magnetic fields that oscillate mutually perpendicular to each other and also perpendicular to the direction of propagation of the wave.

X, Y, Z - axes that are perpendicular to each other
B - magnetic field
E - electric field
O-X - direction of the wave

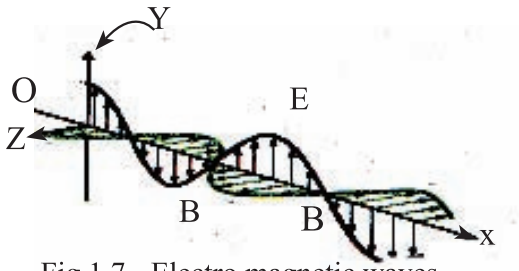


Fig 1.7 - Electro magnetic waves

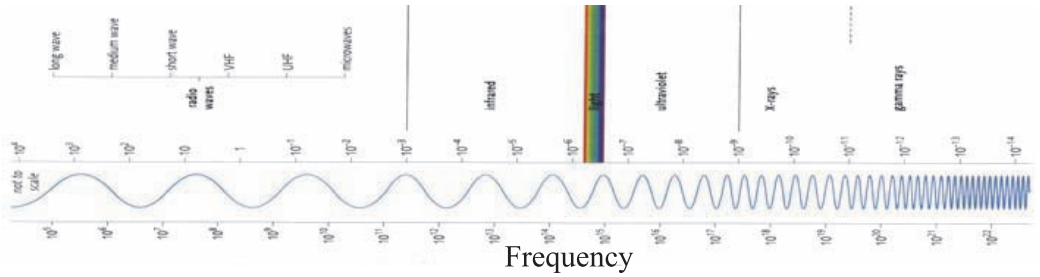


Fig 1.8 - Electro magnetic spectrum

Electromagnetic waves have a range of different wave lengths and frequencies. Therefore they have different properties.

With the development of technology, man has designed many equipment that make use of various types of electromagnetic waves.

Radio and television, microwave ovens, infra-red cameras, spacecraft and medical equipment are some of them.

Some common characteristic features of all types of electromagnetic waves are as follows:

- A medium is not necessary for the transmission
- They transmit electro magnetic energy
- They are a type of transverse waves.
- In a vacuum, waves travel in straight lines at a velocity of 3×10^8 m s^{-1}
- Have electrical and magnetic properties.
- Obey the laws of reflection and refraction.
- They are uncharged.

Radio and television waves

These waves have the longest wave length among the electro magnetic waves. They are used for communication activities such as radio, and television broadcasting. Waves that belong to kHz range are AM (amplitude modulation) radio waves. Waves that are in MHz range belong to FM (frequency modulation) radio waves. Television waves also belong to the MHz range.

Micro waves

Waves which have a frequency higher than that of radio and television waves are called microwaves. These are used in communication and in radars. From recent times they are used in microwave ovens. As the microwaves produce heat in the food itself, food can be cooked quickly and efficiently without any loss in the nutrient value.

Infra-red rays

The frequency of these waves are higher than that of microwaves. These waves are a type of heat rays. All warm or hot objects lose heat energy by emitting infra-red radiation. Objects gain heat energy by absorbing infra-red rays. When something is exposed to sunlight to dry or to heat up, infra-red rays are used. Infra-red ray cameras are used to take infra-red photographs. In the medical field too infra -red rays are used.

Visible light

The visible light with which we see is also a type of electromagnetic waves. Natural sources like stars including sun give out light as electromagnetic waves. Visible light comprises seven colours. These colours have different wave lengths.