## INTRODUCTION

More complicated systems possess more degrees of freedom. These compound oscillations (coupled) typically appears very complicated but can be simplified by *resolving the motion into normal modes*. As the number of degrees of freedom becomes arbitrarily large, the system approaches continuity. For example, a string or the surface of a body of water. In the classical limit, such systems have an infinite number of *normal modes* and their oscillations occur in the form of *waves* that can characteristically propagate.

## 10.1 WAVE MOTION - TYPES OF WAVES

One of the commonest modes of transfer of energy from one point to the another is in the form of *waves*. The waves propagates from the point of disturbance, as which they are generated. Thus, for example, we known that *water waves, sound waves, light waves* and *radio waves* all carry energy of one form or the other from one place to another, without any bulk motion of the interventing medium of the first two types of waves. For light and radio waves propagation, no medium is required at all. There is just propagation of energy takes place. Such a mode of transfer of energy is called **Wave motion**, and may be divided into two broad categories: (*i*) *mechanical* wave motion and (*ii*) *non-mechanical* or *electromagnetic wave motion*.

(*i*) **Mechanical wave motion** is possible only in material media (solids, liquids and gases) which possese inertia as well as elasticity; so that,water waves and sound waves are both example of this type of wave motion and are, therefore referred to as *mechanical waves*.

(*ii*) **Non mechanical or electromagnetic wave motion**, on the other hand, requires no material medium for its propagation; so that, light and radio waves, which can travel through empty space, belong to this category and are, therefore referred to *as non mechanical* or *electromagnetic waves*.

We are concerned here with only the mechanical type of wave motion and shall, for simplicity, refer to it merely as wave motion.

Since all material media posses elasticity as well as inertia, it is easy to see how a wave motion is produced and propagated through them. For, not particle of an elastic medium can be disturbed without affecting its immediate neighbour and, tending to recover its original position, it first stores up potential energy and then coverts it back into kinetic energy. The neighbouring particle which has thus been disturbed then performs a similar motion, so that each successive particle repeats, in turn, the movements of its predecessor a little later than it and hands the same on to its successor, resulting in the transference of energy from particle to particle all along the line. One complete oscillation of a particle of the medium obviously produces *one single wave* or a *pulse* and its repeated periodic motion, a succession of waves or a *wave train*.

We may thus define *a wave motion as a disturbance (or a condition) that travels onwards through a medium due to the repeated periodic motion of its particles about their mean or equilibrium position, each particles repeating the movements of its predecessor a little later than it and handing it on to its successor, so that there is a regular phase difference between one particle and the next.*

The simplest type of periodic motion performed by a particle is, of course, the simple harmonic motion and the corresponding wave motion is therefore called a *simple harmonic or a sinusoidal wave motion*, which alone is the most general type of wave motion and the one we shall deal with in the following discussion.

It may be emphasised again that, but for the properties of elasticity and inertia, no wave motion could be produced in, or propagated through , a medium. These two properties in fact determine the velocity of propagation of the wave motion through the medium, as we shall presently see. And, in order that a wave may travel through a medium over fairly large distances without attenuation (*i.e.*, without any decrease in its amplitude), a third property is also necessary, *viz.*, that the medium should offer the least frictional resistance so as not to unduly damp the periodic motion of the particles.

A wave motion which thus progresses onwards through a medium, with energy transferred across every section of it, is called a *travelling* or a *progressive wave motion* to distinguish it from what a called a *standing* or a *stationary wave motion*, which we shall study a little later and in which there is no onward movement of the wave motion through the medium and hence no transference of energy across any section of it.

## 10.2 TRANSVERSE AND LONGITUDINAL WAVE MOTION

There are two distinct class of wave motion: (*i*) *transverse* and (*ii*) *longitudinal*

(*i*) In a *transverse wave motion*, the particles of the medium oscillate up and down about their mean or equilibrium position, at *right angles to the direction of propagation of the waves itself.* This form of wave motion therefore travels in the form of *crests and troughs* (Fig. 10.1), as, for example, waves travelling along a stretched string. *A crest and an adjoining trough constitute one wave or pulse* and a succession of them, a *wave train.*

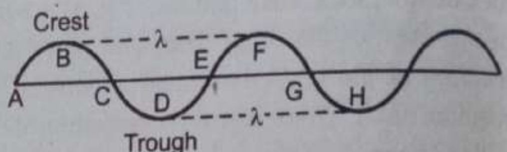


Fig. 10.1

This type of waves motion is possible in media which possess elasticity of shape or rigidity, *i.e.* in *solids*. But, as we know, they are also possible in water and liquids, in general, even though they do not possess the property of rigidity. This is because they possess another equally effective property of resisting any vertical displacement of their particles (or keeping their level). Gases, however, possess neither rigidity nor do they resist any vertical displacement of their particles (or keep their level). *A transverse wave motion is therefore, not possible in a gaseous medium.*

**N.B.** It may just be mentioned for the information of the student that an electromagnetic wave is necessarily a transverse wave because of the electric and magnetic fields being perpendicular to its direction of propagation.

(*ii*) In a *longitudinal wave motion*, the particles of the medium oscillate to and fro about their mean or equilibrium position, *along the direction of propagation of the wave motion itself.* This type of wave motion, therefore, travels in the form of *compressions* (or *condensations*) and *rarefactions*, *i.e.* in the particles of the medium getting closer together and further apart alternately, (Fig. 10.2), and is possible in media possessing elasticity of volume, *i.e.*, in solids, liquids as well as gases. As examples may be mentioned sound waves in air [Fig. 10.2 (*a*)] and waves in a spring or helix when one end of it is suddenly compressed or pulled out and then released [Fig. 10.2 (*b*)].

Here, *one compression and the adjoining rarefaction constitute one wave or pulse* and, as in case (*i*) a succession of them, a *wave train.*

In some cases, the waves are neither purely transverse nor purely longitudinal as, for example, *ripples* or *surface waves* on water (produced by dropping a stone in water), in which the particles of the medium (here, water) oscillate across as well as along the direction of propagation of the wave motion, describing elliptical) paths.

We need not, however, bother ourselves with any such types of waves here.

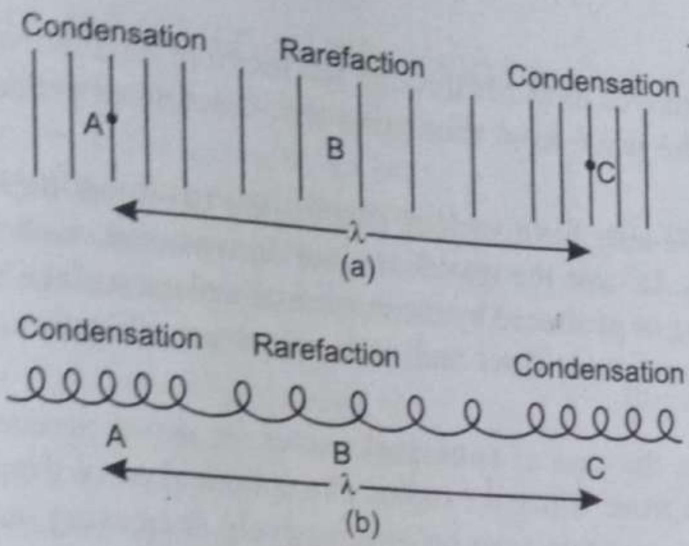


**Fig. 10.2**

Again, waves may be *one-dimensional*, *two dimensional* or *three dimensional* according as they propagate energy in just one, two or three dimensions. Thus, transverse wave along a string or longitudinal wave along a spring are one-dimensional, surface waves or ripples on water are two-dimensional and sound wave proceeding radially from a point-source are three dimensional.

Before proceeding further, we had better summarise here the important characteristics of a wave motion, in general, whether transverse or longitudinal, *viz*., that

(*i*) It is simply a disturbance, a condition or a state of motion that travels through the medium and nothing material, *i.e*., *there is no transference of any part of the medium (or matter) from one point to another*. For, as we have seen, the particles of the medium simply oscillate up and down or to and fro about their mean position and do not move onwards with the wave motion itself.

(*ii*) Each particle of the medium receives the disturbance a little later than its predecessor, repeats its movements and hands it on to the next succeeding particle, *i.e*., *there is a regular phase lag between one particle and the next*.

(*iii*) *The velocity of the particles of the medium or the particles velocity, as it is referred to, is entirely different from the velocity of the wave motion or the wave velocity*.

**Characteristics of wave motion.** A progressive simple harmonic wave is that whose amplitude remains constant with time. Its characteristics are:

(*i*) A wave is a form of disturbance which propagates in a medium.

(*ii*) When the wave propagates the particles of the medium simply oscillate about their mean position.

(*iii*) There is a definite phase different between every two consecutive particles.

(*iv*) The velocity of the wave is different from the velocity of the particles. The velocity of the wave is a constant for a given medium but the velocity of the particle goes on changing, being maximum in the mean position and minimum in the extreme position.

(*v*) Wave motion is possible only in media which have the property of inertia and elasticity.

(*vi*) The energy of the vibrating particle at the extreme position is wholly potential and in the mean position wholly kinetic.

(*vii*) When a wave travels in a medium, there is a flow of energy without any transfer of matter.