Wave

The disturbance that travelling through a medium or vacuum from one place to other by transferring the energy is called a wave. When the wave is travelling through a medium it will experience some local oscillations, but the particles in the medium do not travel with the wave.

Types of Wave

Waves can be classified into three types:

1. Mechanical

2. Electromagnetic

3. Matter

Mechanical Waves

Mechanical Waves act as the propagation of a disturbance through a material medium due to the repeated periodic motion of the particles of the medium about their mean positions, the disturbance being handed over from one particle to the next.

The Propagation is possible due to property of medium like elasticity and inertia. Mechanical waves cannot travel through vacuum. Examples: vibration of string, the surface wave produced on the surface of solid and liquid, sound waves, tsunami waves, earthquake waves, ultra sounds, vibrations in gas, and oscillations in spring, internal water waves etc.

Mechanical waves are of two types:

1. **Transverse Wave** (The medium has particles that vibrate in a direction perpendicular to the direction of the propagation of wave)
2. **Longitudinal Wave** (Consider a wave moving. if the vibration of the particles of the medium are in the direction of wave propagation)

Electromagnetic Waves

Electromagnetic waves are the disturbance, which does not require any material medium for its propagation and can travel even through vacuum. They are caused due to varying electric and magnetic fields.

Properties:

- ❑ **In vacuum E.M waves travel with light velocity.**
- ❑ **E.M waves can be polarized.**
- ❑ **E.M waves are transverse in nature.**
- ❑ **Medium is not required for propagating the E.M waves.**
- ❑ **E.M waves have momentum.**

Example: **Radio waves, light waves, thermal radiation, X ray etc.**

Matter Waves

Matter Waves are the waves produced in electrons and particles. These are also called De Broglie waves. They show or depict the wave nature or wave like nature of all matter, everything that makes up our body, the atoms etc.

Considering the quantum physics we have a proof that the wavelength of matter waves is very small. There are various equations called the De Broglie equations which basically suggest the dual nature of matter. The frequency of these waves is directly depends on their kinetic energy. Momentum is not directly proportional to the wavelength of the particle and not inversely proportional.

Standing Wave

When a wave remains in a constant position it is called Standing wave. This is possible due to 2 reasons: When the medium moves in a direction opposite to the direction of propagation of wave, it is possible.

When the phenomenon of interference takes place between the two waves traveling in an opposite direction, it is possible.

When two waves having equal frequency and amplitude overlap each other, we get a standing wave. This is possible due to the obstruction of the wave by some boundary and hence the reflection of it back in the same medium.

Plane progressive wave

A plane progressive wave is one which travels onward through the medium in a given direction without attenuation, i.e., with its amplitude constant.

$$y = a \sin \frac{2\pi}{\lambda}(vt - x)$$

Wave travels towards the right direction

$$y = a \sin \frac{2\pi}{\lambda}(vt + x)$$

Wave travels towards the left direction

Phase (Wave) velocity

The compression and rarefaction of longitudinal wave or crest and trough of transverse wave advances through a medium with a constant velocity. In other words, advance of phase through a medium takes place with same velocity. This velocity of advance is known as phase or wave velocity.

The equation of a plane progressive wave

$$y = a\sin\frac{2\pi}{\lambda}(vt - x)$$

Here, v is the phase velocity. It means wave propagate of this velocity.

Particle velocity

The equation of a plane progressive wave

$$y = a\sin\frac{2\pi}{\lambda}(vt - x)$$

Here, y is the displacement of the particle in the medium.

The displacement of y with respect to time is called the particle velocity in the medium.

$$v_{\text{particle}} = \frac{dy}{dt}$$

Show that
Phase velocity = Wave velocity

The equation of a plane progressive wave

$$y = a\sin\frac{2\pi}{\lambda}(vt - x)$$

Here, v is referred to as the wave velocity.

$$\Rightarrow y = a\sin\left(\frac{2\pi vt}{\lambda} - \frac{2\pi x}{\lambda}\right)$$

$$\Rightarrow y = a\sin(2\pi nt - kx)$$

$$\Rightarrow y = a\sin(\omega t - kx)$$

Here, *n* is the frequency of the wave and *k* is the propagation constant of the wave.

Now (*wt - kx*) is the constant phase of the wave which travel along the positive direction of the x-axis and its velocity, i.e., the phase velocity of the wave should be given by $\dfrac{dx}{dt}$.

Since, phase is constant, we can write

$$(\omega t - kx) = \text{Const.}$$

$$\therefore \frac{d}{dt}(\omega t - kx) = 0 \quad \Rightarrow \omega - k\frac{dx}{dt} = 0 \quad \Rightarrow \frac{dx}{dt} = \frac{\omega}{k}$$

But, $$\frac{\omega}{k} = \frac{2\pi n}{2\pi / \lambda} = n\lambda = v = \text{Wave Velocity}$$

Thus, for a single wave, in any given medium,
Wave velocity = Phase velocity

$$\frac{dx}{dt} = \frac{\omega}{k} = v$$