Class 11-AS-A level Physics-WAVES

1. Mechanical Waves

1.1. Motion of Objects Oscillating in Isolation

Eg. Material Medium

Elastic forces bind the constituents to each other and, therefore, the motion of one affects that of the other

If a little pebble is dropped in a pond of still water, the water surface gets disturbed. The disturbance does not remain confined to one place but propagates outward along a circle.

If the dropping of pebbles in the pond, circles are observed to move rapidly outward from the point where the water surface is disturbed by the pebble.

It gives a feeling as if the water is moving outward from the point of disturbance.

If you put a small paper boat on the disturbed surface, it is seen that the boat moves up and down but does not move away from the centre of disturbance.

This shows that the water mass does not flow outward with the circles, but rather a moving disturbance is created

These patterns of energy , which move without the actual physical transfer or flow of matter as a whole, are called ***waves***.

Waves transport energy and the pattern of disturbance has information that propagates from one point to another

Speech means production of sound waves in air and hearing means their detection.

1.2. Communication involves different kinds of waves.

Sound Waves may be first converted into an electric current signal which in turn may generate an electromagnetic wave that may be transmitted by an optical cable or via a satellite.

Detection of the original signal will usually involve these steps in reverse order.

Sound waves require a medium for their propagation.

*1.2.1. **Light waves can travel through vacuum***.
The light emitted by stars, which are hundreds of light years away, reaches us through inter-stellar space, which is practically a vacuum.

1.2.2. Mechanical Waves

Waves on a string, water waves, sound waves, seismic waves, etc. are classified as **Mechanical Waves.**

1.2.3.1. *Properties of Mechanical Waves*

- They require a medium for propagation,
- They cannot propagate through vacuum
- They involve oscillations of constituent particles and
- The speed of propagation of energy depend on the elastic properties of the medium

2. OSCILLATING SOURCE AND PROPAGATION OF ENERGY

Waves in elastic media are intimately connected with harmonic oscillations. (Stretched strings, coiled springs, air, etc., are examples of elastic media).

A collection of springs connected to each other. The end A is pulled suddenly generating a disturbance, which then propagates to the other end

If the spring at one end is pulled suddenly and released, the disturbance travels to the other end. What has happened? The first spring is disturbed from its equilibrium length. Since the second spring is connected to the first, it is also stretched or compressed, and so on. The disturbance moves from one end to the other; but each spring only executes small oscillations about its equilibrium position.

Propagation of sound waves in air.

As the wave passes through air, it compresses or expands a small region of air. This causes a change in the density of that region, say δd,

This change induces a change in pressure, δp, in that region.

Pressure is force per unit area.

Hence there is a restoring force proportional to the disturbance, just like in a spring

In this case, the quantity similar to extension or compression of the spring *is the change in density*

If a region is compressed, the molecules in that region are packed together, and they tend to move out to the adjoining region, thereby increasing the density or creating compression in the adjoining region.

The compression or rarefaction moves from one region to another, making the propagation of a disturbance possible in air.

This shows that ***an oscillating system when placed in an elastic medium, becomes a source of energy, causing the neighboring particles, also to be set into oscillation.***

The medium particles will have amplitude according to the amount of energy of the source

The frequency of vibration of medium particles will necessarily be the same as the source.

In a crystalline solid, atoms or group of atoms are arranged in a periodic lattice.

In these, each atom or group of atoms is in equilibrium, due to forces from the surrounding atoms.

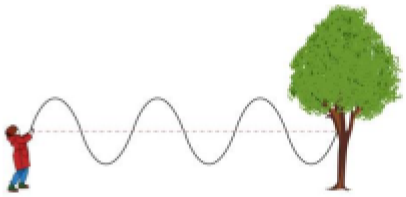
Displacing one atom, keeping the others fixed, leads to restoring forces, exactly as in a spring.

So we can think of atoms in a lattice as end points, with springs between pairs of them.

3. WAVES AND WAVE MOTION

The sudden travel of energy through a medium is called **pulse.**

if we tie one end of a rope to a tree and move the other end up and down, then a type of disturbance is produced in the rope which advances with a definite speed (shown in fig.). Such a disturbance is called a 'mechanical wave'.



Source: Wikimedia

In the above example, when the stone falls in the water, the water particles at that place start *moving up and down*.

These particles pass over their motion to the neighboring particles and come back to their original positions.

The neighboring particles, in turn, hand over their motion to their next particles and this process continues.

In this process, the water particles do not leave their positions permanently; they simply oscillate up and down about their mean positions while the disturbance produced by the stone is continuously transmitted through water.

Visualization of the above process

- ***A cork placed on the water surface is moved up and down at its place, by the disturbance***
- ***If a rope marked with a ribbon tied tightly at any point with a disturbance produced at its end, it will be observed that the mark moves up and down at the same place, while the disturbance proceeds ahead.***

It is thus inferred, that the mechanical waves transmit energy and momentum through the limited motion of the particles of the material medium, while the particles remain in their positions.

The above behaviour is a result of the elasticity and inertia of the media.

.Water-waves, sound-waves, waves in a spring, etc., are examples of mechanical waves.

4. ELECTROMAGNETIC WAVES

Electromagnetic waves propagate through space carrying radiant energy.

For example; radio waves, microwaves, infrared, (visible)light, ultraviolet, X and gamma radiation.

Electromagnetic radiation consists of electromagnetic waves. These are synchronized oscillations of electric and magnetic fields that propagate at the speed of light through vacuum.

The oscillations of EM fields are perpendicular to each other in a plane which is perpendicular to the direction of propagation of the wave.

The EM wave is transverse in nature.

It is produced by moving charged particle and it carries energy and momentum which it imparts to matter when it interacts with it.

Difference Between Mechanical And Electromagnetic Waves

MECHANICAL WAVES	ELECTROMAGNETIC WAVES
Necessarily requires a medium for their propagation These are elastic waves These are due to variation of EM fields	It doesn't need any medium to travel or can propagate through vacuum also
Particles of the medium perform SHM about their mean position	Oscillating electric and magnetic fields perpendicular to each other and perpendicular to the direction of propagation
These are elastic waves	These are due to variation of EM fields
Its typical speed is that of sound 330 m/s in air	Its speed is 3×10^8 m/s in air or vacuum
They can be Transverse, longitudinal, and surface waves.	These are transverse in nature

Video clip: https://youtu.be/SNUNohhpwQs

5. TRANSVERSE AND LONGITUDINAL WAVES

When a progressive mechanical wave propagates in a medium; the particles of the medium are set in oscillation.

Depending upon the direction of oscillation of these particles, the waves have been classified as of two types: transverse waves and longitudinal waves

Transverse Waves:

If on propagation of a mechanical wave through a medium, the medium particles oscillate *along a direction perpendicular to the direction of propagation of the wave,* the wave is called a **'transverse' wave**. For example, when one end of a horizontal rope is tied to a hook and the other end is moved up and down or sideways, then waves are propagated in the rope along its length. If there is a mark on the rope, then this mark is seen to oscillate perpendicular to the direction of propagation of the wave. Hence, the waves in the rope are transverse. Light (electromagnetic) waves are also transverse.

In a transverse wave, the position of maximum displacement in the upward direction is called 'crest' and the position of maximum displacement in the downward direction is called 'trough',

These states of crest and trough continue to advance in the direction of motion of the wave.

The distance between two successive crests, or between two successive troughs, is called the **'wavelength' of the transverse wave**

Mechanical transverse waves can be produced only in solids which have rigidity.

Hence, *transverse waves cannot be produced in gases.*

In l**iquids**, *transverse waves cannot be formed in the interior; they can be formed only on surfaces of liquids*

Longitudinal Waves:

If on propagation of a mechanical wave through a medium, the medium particles oscillate parallel to the direction of propagation of the wave, the wave is called a **'longitudinal' wave**.

For example, when one end of a long spring (slinky) is tied to a hook in a wall and the other end is moved forward and backward, then every turn of the spring oscillates parallel to the length of the spring and longitudinal waves propagate through the spring.

Wave -Simulations:

URL: https://ophysics.com/waves1.html