PPP0101
PRINCIPLES OF PHYSICS

Foundation in Information Technology

ONLINE NOTES

Chapter
5(ii)
Waves

5.1 WAVES

1. A wave motion is a means of <u>*transferring between energy from one point to another*</u> without there being any transfer of matter between the points .

<u>Mechanical and Electromagnetic Waves</u>

1. Mechanical waves (e.g. water waves, sound waves, waves in stretched strings) require a material medium for their propagation.
2. Electromagnetic waves (e.g. light, radio. X-ray) can travel through a vacuum; their progress is impeded, to some extent, by the presence of matter.

<u>Types of Waves</u>

1. **Transverse Wave** (sometimes called a *shear wave*)
   The particle motion is ***perpendicular*** to the direction of the wave velocity.

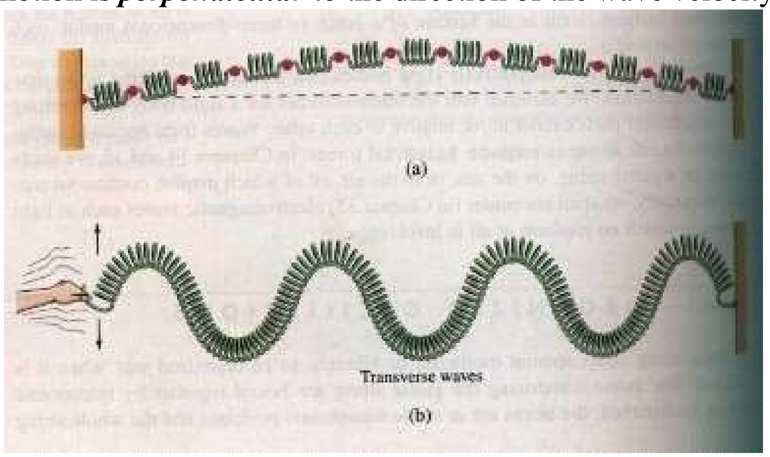

Diagram 1

2. **Longitudinal Wave** (sometimes called a compression wave)
   The particle motion is ***parallel*** to the direction of the wave velocity. Consist of a series of ***compressions*** and ***rarefactions***.

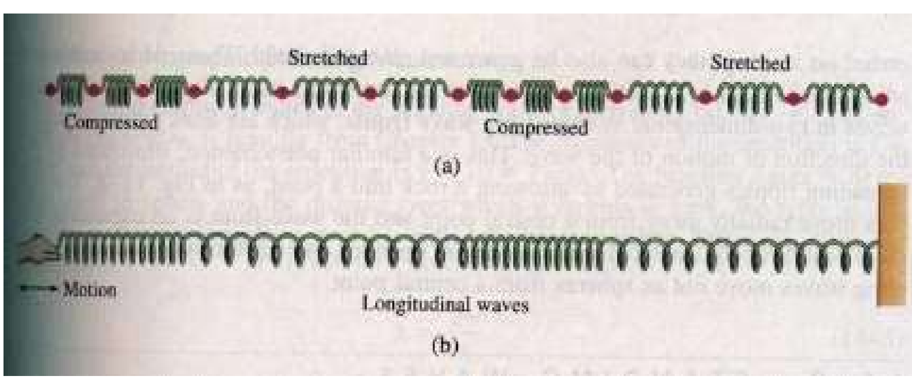

Diagram 2

Travelling Wave

1. Energy is propagated in a definite direction and with a definite speed. For instance, handshakes one end of a string and disturbs it.

Note: Both a transverse and longitudinal waves are said to be travelling (progressive) waves because the wave travels from one point to another.

Superposition and Interference of Waves

1. The principle of superposition states that whenever two or more travelling waves are moving in the same region the total displacement at any point is equal to the vector sum of their individual displacements at that point.
2. If the amplitude of the combined wave is smaller than that of any of the individual waves, it is called *destructive interference.*
3. If the amplitude of the combined wave is greater than that of any of the individual waves, we have what is called *constructive interference*.
4. ***The total destructive interference*** takes place if two waves of the same frequency and amplitude are *completely 180 º out of phase*. (i.e they have a phase difference of π radian ; the crest of one wave is aligned with the trough of the other and vice versa, as in diagram 3(a)).
5. ***Total constructive interference*** occurs when two waves of the same frequency and amplitude are *exactly in phase* (i.e they have a phase difference of zero; the crest of one wave is aligned with the crest of the other, as in diagram 3(b))

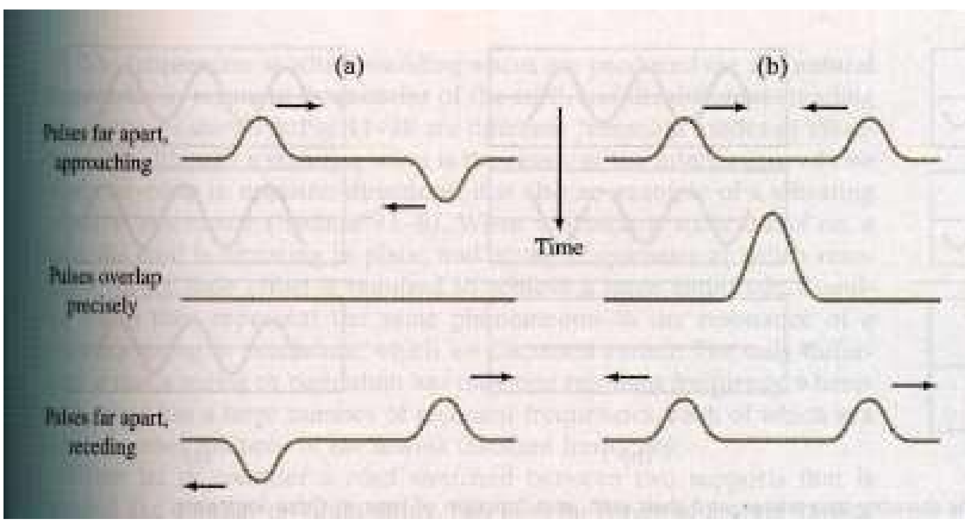

Diagram 3

Sinusoidal Waves

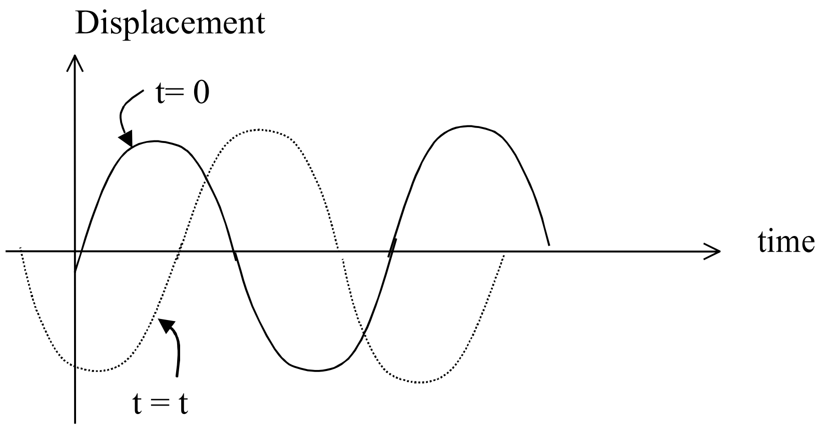

Diagram 4

1. Diagram 4 shows one dimensional sinusoidal wave travelling to the right with speed, v.
2. The bold curve represent a snapshot of the travelling sinusoidal wave at t = 0s. The dotted curve represent a snapshot of the wave at some later time t.
3. The vertical displacement of the curve is

$$Y = A \text{ Sin } \left(\frac{2\pi}{\lambda} x \right) \text{.............................}(1)$$

If the wave *moves to the right* with a speed , v, the wave function at some time later, t , is

$$Y = A \text{ Sin } \left[\frac{2\pi}{\lambda} (x\text{-}vt) \right] \text{.......................}(2)$$

And if the waves *moves to the left,*

$$Y = A \text{ Sin } \left[\frac{2\pi}{\lambda} (x + vt) \right] \text{...................}(3)$$

$$v = f\lambda = \lambda / T \text{.....................................}(4)$$

Substitute equation (4) into (2)

$$Y = A \text{ Sin } \left[\frac{2\pi}{\lambda} \left(x - \frac{\lambda}{T} t\right) \right]$$

$$Y = A \text{ Sin } \left[2\pi \left(\frac{x}{\lambda} - \frac{t}{T} \right) \right] \text{……………}(5)$$

λ T

$\frac{2\pi}{\lambda} = k$, angular wave number............(6)

$\frac{2\pi}{T} = \omega$, angular frequency................ (7)

From (5), The wave function for a sinusoidal wave is :

Y = A Sin (kx-ω t)… ....(8)

Frequency, f = 1/T ,....................................(9)

Speed of a sinusoidal wave, $v = \omega / k$.......(10)

Using (6), (7), (9) and (10),

Propagation of wave is :

$\Rightarrow v = f\lambda$□(11)

From equation (8),

The **vertical displacement** , y is **zero** at x = 0 and t = 0.

If the **vertical displacement** is **not zero** at x = 0 and t = 0,

Y = A Sin (kx-ω t-ϕ)… .... (12)

where ϕ is the **phase constant**

Properties of Sinusoidal Waves

1. **Amplitude, A**
   The magnitude of the maximum displacement of any particle from its equilibrium position.

2. **Wavelength, λ**
   The distance between two adjacent crests or troughs. (or the distance between any two successive particle that are in phase; that is, at identical points on the wave form.)
3. **Period, T**
   The time taken for the wave to travel a distance of one wavelength (or the time taken for any particle to undergo a complete oscillation)
4. **Frequency, f :**
   The number of wavelengths per second which pass a given point.

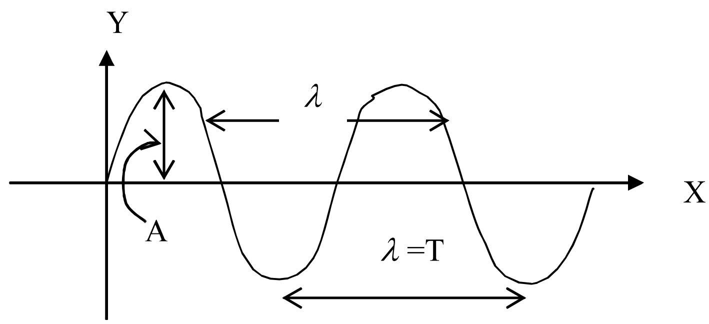

Diagram 5

Standing Waves

1. **A standing (stationary) wave** result when two waves which are traveling in **opposite** directions, and which have the **same speed and frequency and approximately equal amplitudes**, are superposed.
2. The resultant displacement, y is given by

   $y = A \sin (kx-\omega t) + A \sin (kx+\omega t)$ ………(a)

3. Applying trigonometric relation:
   $\sin(A-B) + \sin(A+B) = 2\sin A \cos B$

4. Therefore,
   $y = 2A \sin kx \cos \omega t$............. (b)

5. Wave function for a standing wave , where, $2A \sin kx$ is the amplitude of oscillations of the string element that is located at position x.

Nodes and Antinodes

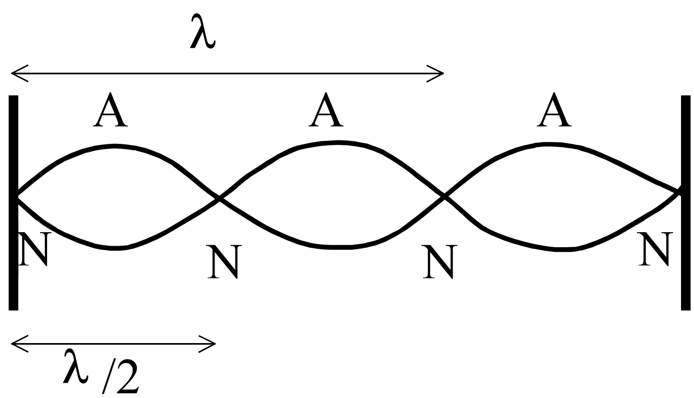

Diagram 6

1. **Nodes** is the position of **zero amplitude** , called **nodes**
2. **Antinodes** is the position of maximum amplitude , called **antinodes**.

End of Chapter 5