CHAPTER FIVE

INTERFERENCE, STANDING AND PROGRESSIVE WAVES

Interference:

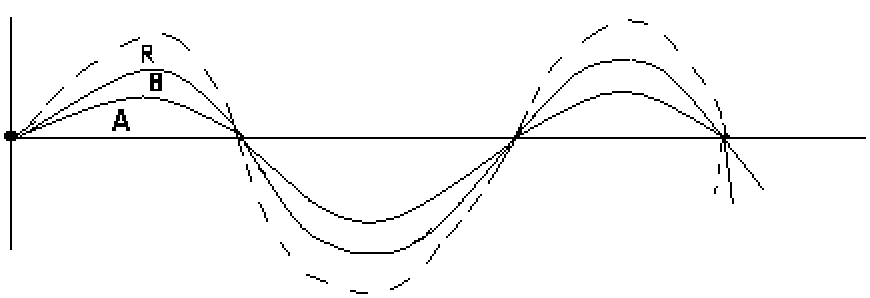
- This refers to the physical effect of superposing two or more wave trains, i.e. when two or more wave trains travel simultaneously through the same medium, they interact with one another and the physical effect of their interaction is said to be due to interference.
- Two or more waves of the same frequency are said to interfere, if they cross each other along their paths of propagation.
- The resultant displacement at a point in the medium, due to the interference of the waves is found from the superposition principle.

Types of interference: There are two types and these are:

(1) Constructive interference.

(2) Destructive interference.

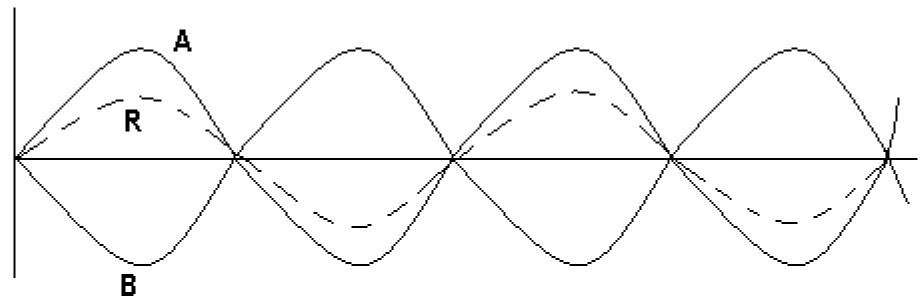
Constructive interference:



- Constructive interference occurs when two waves interfere, such that the crest of one wave meets a crest of the other, leading to the reinforcement of the two waves to give a resultant wave of larger amplitude.
- The phase difference in connection with this type of interference are 0, 2π, 4π,6π, etc.
- In the given diagram, the two waves A and B are the interfering waves, and the

wave R, is the resultant wave.
- The amplitude of R = the amplitude of A + the amplitude of B.

Destructive interference:



- This type of interference occurs when the two interfering waves are π out of phase, and the crest of one wave meets the trough of the other, leading to the production of a wave of smaller amplitude.
- The phase difference in connection with this type of interference are π, 3π, 5π, 7π,.. ……………...
- Destructive interference may be partial or complete, depending on whether the amplitudes of the interfering waves are equal or unequal.
- If these two waves are of unequal amplitudes, then partial destructive interference occurs.
- In the given figure, the assumption is that the amplitude of wave A is greater than that of wave B, and since the amplitudes of the interfering waves are not the same, then perfect cancellation does not occur.
- Complete destructive interference occurs, when the amplitudes of the interfering waves are the same.
- For this reason, perfect cancellation occurs i.e. the resultant amplitudes is zero.

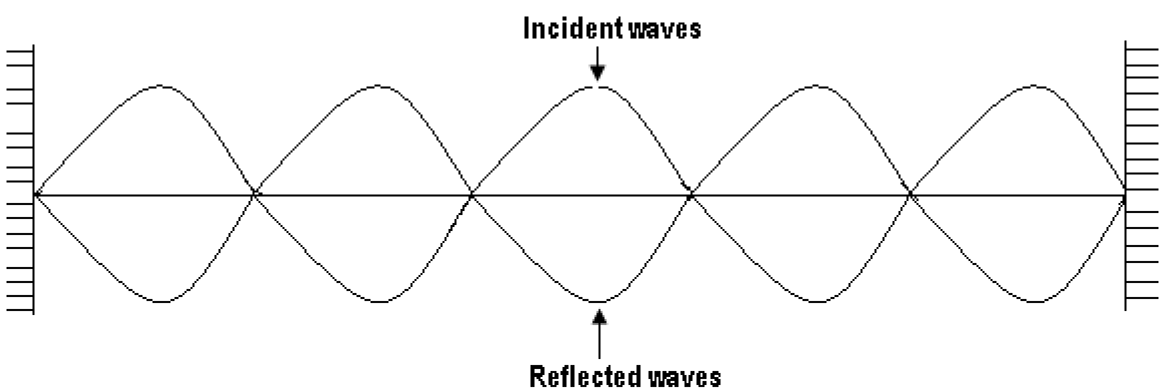
The superposition principle:

- Suppose two sources of light, A and B, have exactly the same frequency and amplitude of vibration, and their vibrations are always in phase with each other (i.e. coherent sources), then their combined effect at a point is obtained by adding algebraically the displacements at that point due to the sources individually.
-This is known as the principle of superposition.
- In short, when two waves travel through a medium at the same time, their combined effect at any point can be found by the principle of superposition, which

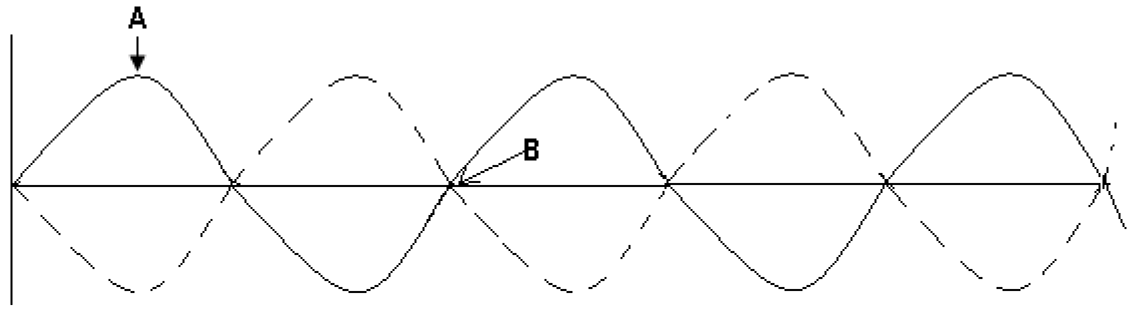
states that the resultant displacement at any point is the sum of the separate displacements, due to the two waves.

Stationary waves:

- These are waves which are formed when two equal progressive waves are superimposed on one another, when they travel in opposite direction within a medium at the same time.
- When two progressive or moving waves with the same amplitude and speed, travel along the same straight line in opposite direction, they are superimposed to form a resultant wave which is confined to the region in which it is produced.
- In other words, the wave profile no longer moves through the medium and the resultant wave is called a stationary wave.
- Stationary longitudinal waves are set up in the air column in an organ pipe, while stationary transverse waves are produced in a string fixed at one or both ends in a ripple tank.
- In each case, the interaction between the incident and the reflected waves produce a stationary wave.
- When a string instrument is bowed, plucked or stuck the reflection of the incident waves at the fixed end, similarly produces stationary waves.



Characteristics of stationary waves:



(1)There are points such as B where the displacement is permanently zero and these points are referred to as nodes.

(2) There are also points such as A where the displacement is maximum, and these points are called antinodes.

(3) All points between successive nodes are in phase, and this implies that when one of such points is at a maximum displacement from the equilibrium position, then all the other points are also at their maximum displacement from the equilibrium position.

(4) Each point along the wave, has a different amplitude of vibration from neighboring points.

(5) The distance between two successive antinodes or nodes is $\frac{\lambda}{2}$, and the distance between a node and the nearest antinodes is $\frac{\lambda}{4}$.

N/B: The stationary wave equation is given by

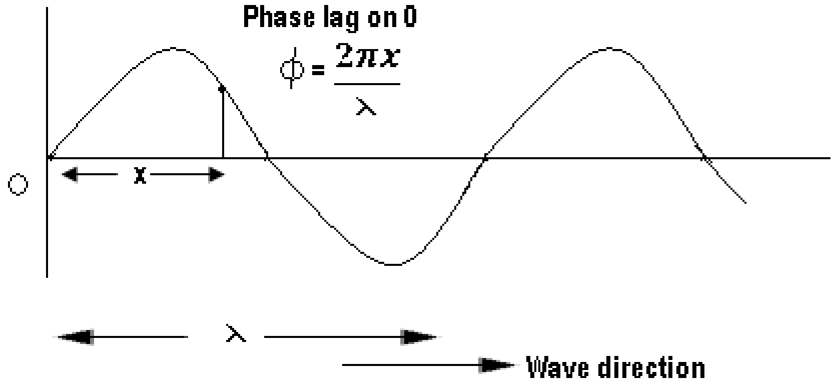
(1) y = Y sin wt, where Y = amplitude of vibration at the point concerned.

(II)y = A cos kx. Sin wt.

Progressive waves:

- A progressive wave is the type in which the wave profile moves along with the speed of the wave.
- The vibration of the wave particles in a progressive wave are of the same amplitude and frequency.

Progressive wave equation:



Definitions used:

y = Particle`s displacement.

a = amplitude of the wave.

λ= wavelength of the wave.

V = velocity of the wave.

t = time that has elapsed since the wave was set in.

f = the frequency of the wave.

T = the period of the wave.

x = wave displacement from the origin.

$\emptyset$ = phase difference.

w = angular velocity, (w = 2πf).

N/B:

- $\emptyset$, the phase difference at the point p as shown in the diagram, is given by $\emptyset = \frac{2\pi x}{\lambda}$.

-The displacement of any particle at a distance x from the origin is given by y = a sin(wt – θ)………………..Eqn (1).

But since $\emptyset = \frac{2\pi x}{\lambda}$ => y = a sin (wt– $\frac{2\pi x}{\lambda}$)……….Eqn (2).

Also since $w = 2\pi f = 2\pi \frac{V}{\lambda}$, since $f = \frac{V}{\lambda}$

=> $y = a \sin \left(\frac{2\pi vt}{\lambda} - \frac{2\pi x}{\lambda}\right)$……………………Eqn (3),

=> $y = a \sin \frac{2\pi}{\lambda} (vt - x)$………………Eqn (4).

Lastly, $y = a \sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)$.

-The negative sign within the bracket => the wave moves from left to right.

-If its movement is from right to left, then the sign within the bracket will be positive.

-Therefore the equation $y = a \sin 2\pi\left(\frac{t}{T} - \frac{x}{\lambda}\right)$ is that for a wave which is moving from left to right.

-Assuming the same wave is travelling from right to left or in the opposite direction, then the equation will be given by $y = a \sin \left(\frac{t}{T} + \frac{x}{\lambda}\right)$.

(Q1) A wave is represented by $y = a \sin \left(2000\pi t - \frac{\pi x}{17}\right)$, where t is in seconds and y is in cm. Determine its:

(a) Wavelength.

(b) Velocity.

(c) Frequency.

(d) Period.

Soln:

The equation of the wave is given as $y = a \sin \left(2000\pi t - \frac{\pi x}{17}\right)$. Comparing this with the equation $y = a \sin \left(\frac{2\pi vt}{\lambda} - \frac{2\pi x}{\lambda}\right)$ implies the following

(i) $\frac{2\pi}{\lambda} = \frac{\pi}{17}$ => $\lambda \pi = 17 \times 2\pi$

=> $\lambda = \frac{17 \times 2\pi}{\pi} = 34$cm.

(ii) $\frac{2\pi v}{\lambda} = 2000\pi$,

$$=> V = \frac{2000\pi⅄}{2\pi} = 1000⅄,$$

=> V = 1000 x 34 = 34000cms^{-1}.

(a) F = $\frac{V}{⅄} = \frac{34000}{34} = 1000Hz$.

(b) The period T = $\frac{1}{f} = \frac{1}{1000}$

= 0.001s.

N/B:

(1) By comparing the two equations, it can be seen that

(a) $\frac{\pi x}{17} = \frac{2\pi x}{⅄}$,

=> $\frac{x}{17} = \frac{2\pi}{⅄}$, => x⅄ = 17 x 2 π

=>⅄ = $\frac{17 \text{ x } 2\pi}{\pi}$ = 34.

(b) 2000πt = $\frac{2\pi vt}{⅄}$,

=> 2000π= $\frac{2\pi v}{⅄}$,

=> 2000⅄ = 2πv

=> v = $\frac{2000⅄}{2\pi}$ = 1000⅄.