

## 4.5 STANDING WAVES

When two waves of same speed, wavelength & amplitude travelling in opposite directions meet, a standing wave is formed.

The resulting wave has a displacement of that is sum of the displacements of the two travelling waves.

Observations about standing waves:

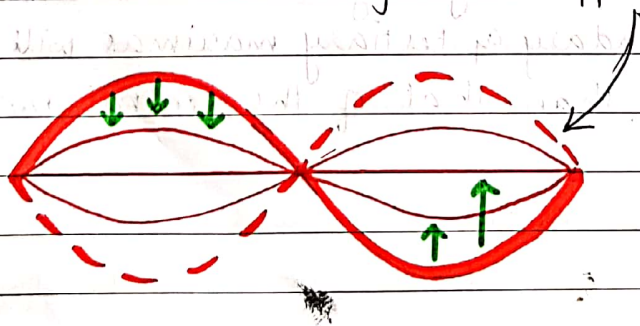
↳ Crests do not move left or right. They stay at the same place.

↳ At points of destructive interference, the displacement is always zero. These are points are nodes.

↳ Half-way between nodes, due to constructive interference are antinodes.

↳ Points between consecutive nodes are in phase. It implies that such points have velocity in the same direction.

↳ Points in-between the next pair of consecutive nodes have a velocity that is opposite.



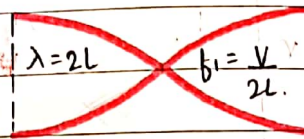
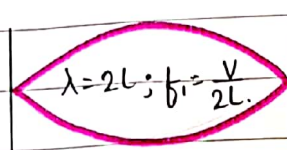
↳ The amplitude of oscillation is different at different points

↳ A standing wave **does not transfer energy**.

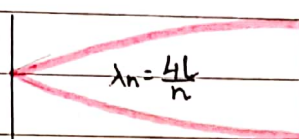
It consists of two travelling waves in opposite directions.

↳ The ends of a standing wave are either nodes or antinodes

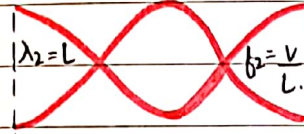
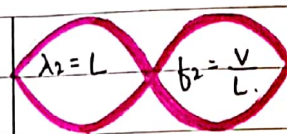
### STANDING WAVES ON STRINGS.



$n=1$



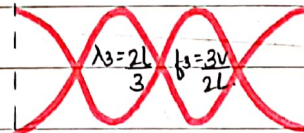
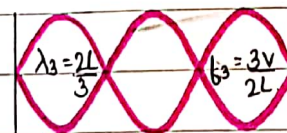
$n=1$



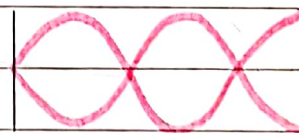
$n=2$



$n=3$



$n=3$



$n=5$

The first harmonic has the lowest (fundamental) frequency  $f_1$  the longest wavelength.

All harmonics ~~are~~ have frequencies that are integral multiples of the fundamental frequencies.