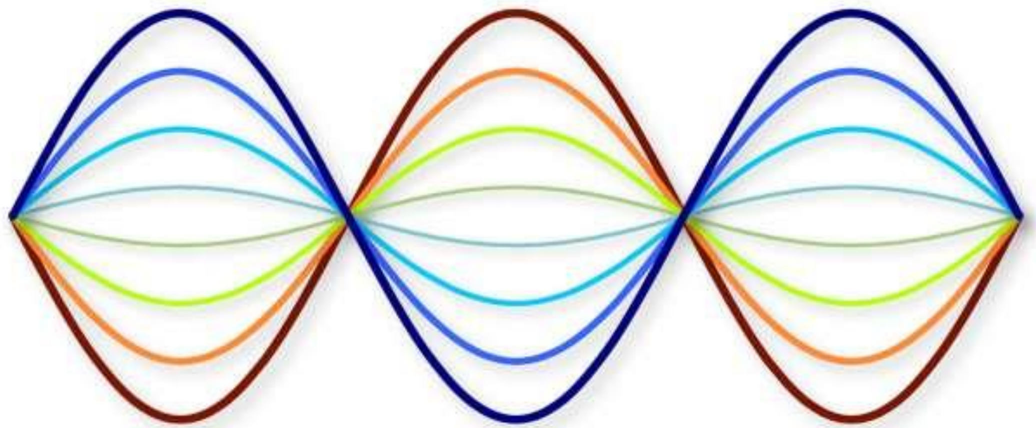
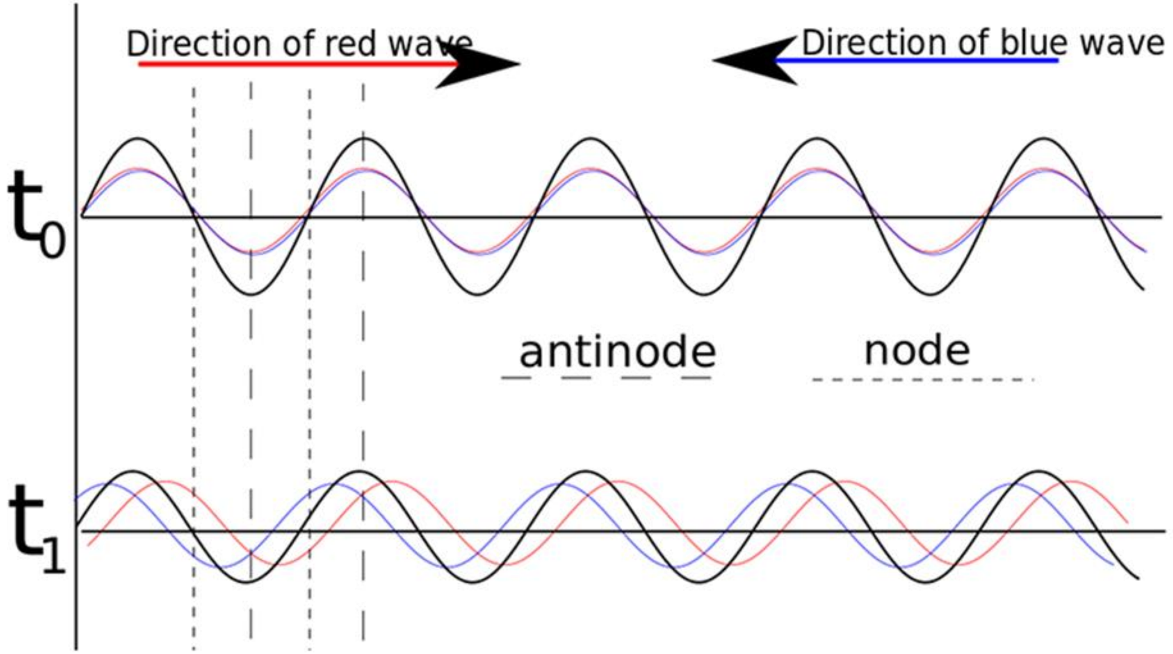
Stationary or standing wave

- A standing wave is a vibration of a system in which some particular points remain fixed (such as frequency), while other points vibrate with a maximum amplitude.
- Waves with equal amplitude, wavelength, and frequency travelling in *opposite* directions in the same medium.
- By the principle of superposition of waves, the resultant displacement of the particle of the medium is equal to the algebraic sum of the displacement due to component waves if the amplitudes are small



In stationary wave

- All the particles are in a state of vibration except where there are nodes which are at rest.
- All the particles between two consecutive nodes have the same phase but differ in amplitude.
- The particles on the opposite sides of each node move in opposite direction hence they are in opposite phase.



What Are Nodes And Antinodes?

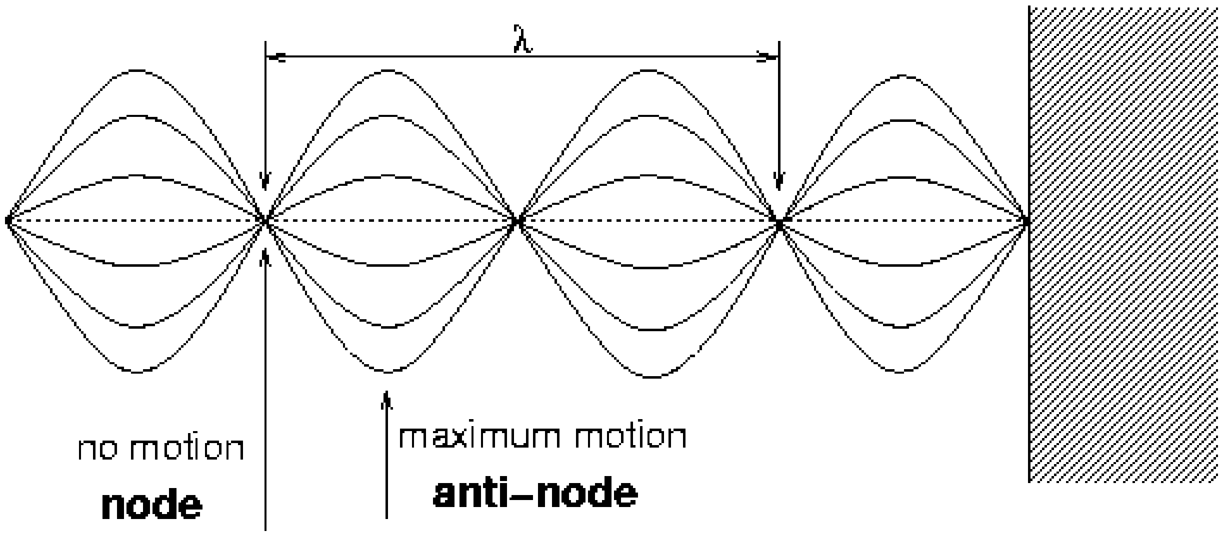
- Points of no displacement in a standing wave pattern are referred to as nodes.
- Points of maximum displacement are known as antinodes. Exact location of nodes of a standing wave can be found using the equation: x= m(λ /2) where m is 0, ±1, ±2…
- Exact location of antinodes can be found using the equation x = (m+0.5)(λ /2) where m is 0, ±1, ±2…
- According to the standing wave equation, there is a position dependent amplitude:

$$A(x) = 2Asin(kx) = 2Asin(2\pi/\lambda\ x)$$

- So, we can simplify the standing wave equation to:

$$D(x,t) = A(x)\cos(wt)$$

- When $D(x,t) = 0$, there is zero amplitude and therefore exists a NODE.
- Similarly, when $D(x,t) = 2A$, this denotes maximum amplitude and therefore exists an ANTINODE.



NODES

Occur at $\boldsymbol{A(X) = 2Asin\left(\frac{2\pi}{\lambda}x\right) = 0}$

- Solving for x, we get $\frac{2\pi}{\lambda}x = \pi m$, where m=0, ±1, ±2...
- Simplify to get: $x = m\frac{\lambda}{2}$, m=0, ±1, ±2...
- So, nodes are found at **x= 0, ± λ/2, ± λ, ±3λ/2...**

ANTINODES

Occur at $\boldsymbol{A(X) = 2Asin\left(\frac{2\pi}{\lambda}\mathrm{x}\right) = 2A}$

- Solving for x, we get $\frac{2\pi}{\lambda}x = (m + \frac{1}{2})\pi$, m=0, ±1, ±2...
- Simplify to get: $x = \left(m + \frac{1}{2}\right)\frac{\lambda}{2}$ m=0, ±1, ±2...
- So, antinodes are found at **X= ±λ/4, ± 3λ/4 , ±5λ/4...**

Comparison of stationary and progressive waves

Property	Stationary wave	Progressive wave
Energy and momentum	No net transfer from one point to another	Both move with speed $c = f*\lambda$
Amplitude	Varies from zero at NODES to a maximum at ANTINODES	Is the same for all particles within a wave
Frequency	All particles at the same frequency except those at NODES	All particles oscillate at same frequency
Wavelength	This is equal to twice the distance between adjacent NODES	This is equal to the distance between particles at the same phase
Phase difference between two particles	Between NODES all particles are at the same phase. Any other two particles have phase difference equal to 'mπ' where m is number of NODES between the particles	Any two particles have phase difference equal to '$2\pi d/\lambda$', where d is the distance between two particles