18.2 Standing Waves

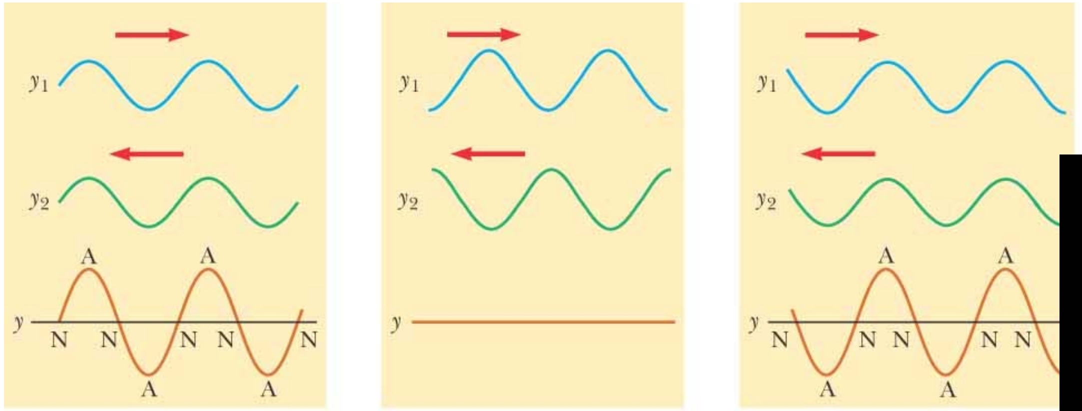
– Superposition of two waves propagating in opposite directions.

- **Wave function of a standing wave :**

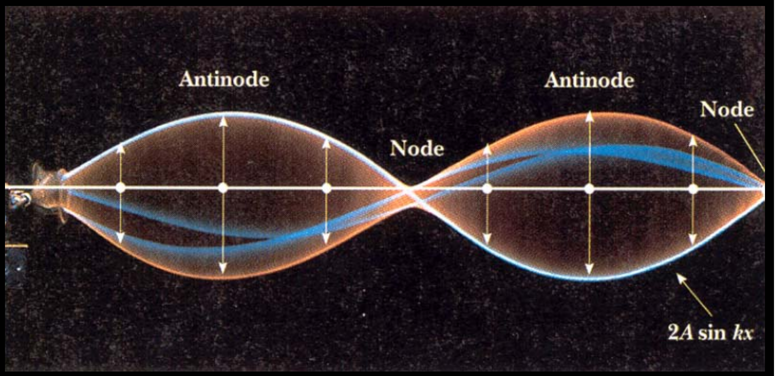
$$\boxed{y = [2A \sin(kx)] \cos(\omega t)}$$

$\Rightarrow$ A particle at any position x vibrates in SHM (because of the factor $\cos(\omega t)$), and all particles in the wave vibrate with same frequency $f = \omega/2\pi$ with amplitude $2A \sin(kx)$.

- **Standing wave pattern :** Nodes & Antinodes

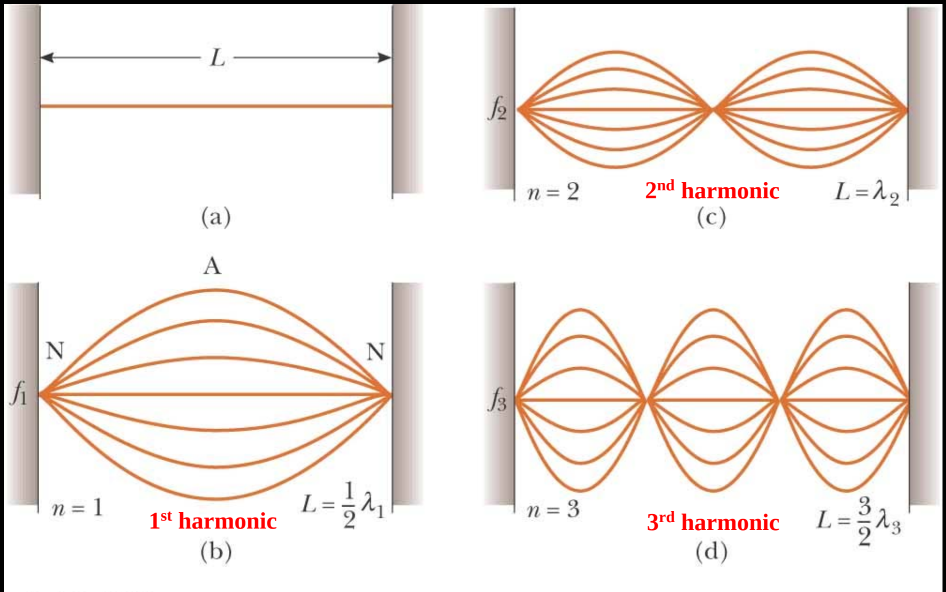


(a) $t = 0$ (b) $t = T/4$ (c) $t = T/2$



18.3 Standing waves in a string fixed at both ends

Oscillation modes for standing waves in the string :



(a) A string of length L fixed at both ends. The normal modes of vibration form a harmonic series: (b) the fundamental, or first harmonic; (c) the second harmonic; (d) the third harmonic.

$\lambda_n = 2L/n$ [Wavelength of normal n^{th} normal mode of oscillation]

$f_n = (n/2L)\,(T/\mu)^{1/2}$ [Natural frequencies for standing waves]

$= n\, f_1$

18.4 Resonance (*descriptive*)

An oscillating system is in resonance with some driving force whenever the frequency of the driving force matches one of the natural frequencies of the system.

Resonance frequency of the string :

$f_n = (n/2L)\,(T/\mu)^{1/2}$ [natural frequencies for standing waves]

Standing wave patterns

Only frequencies that correspond to natural frequencies will persist, and other frequency components will die quickly.