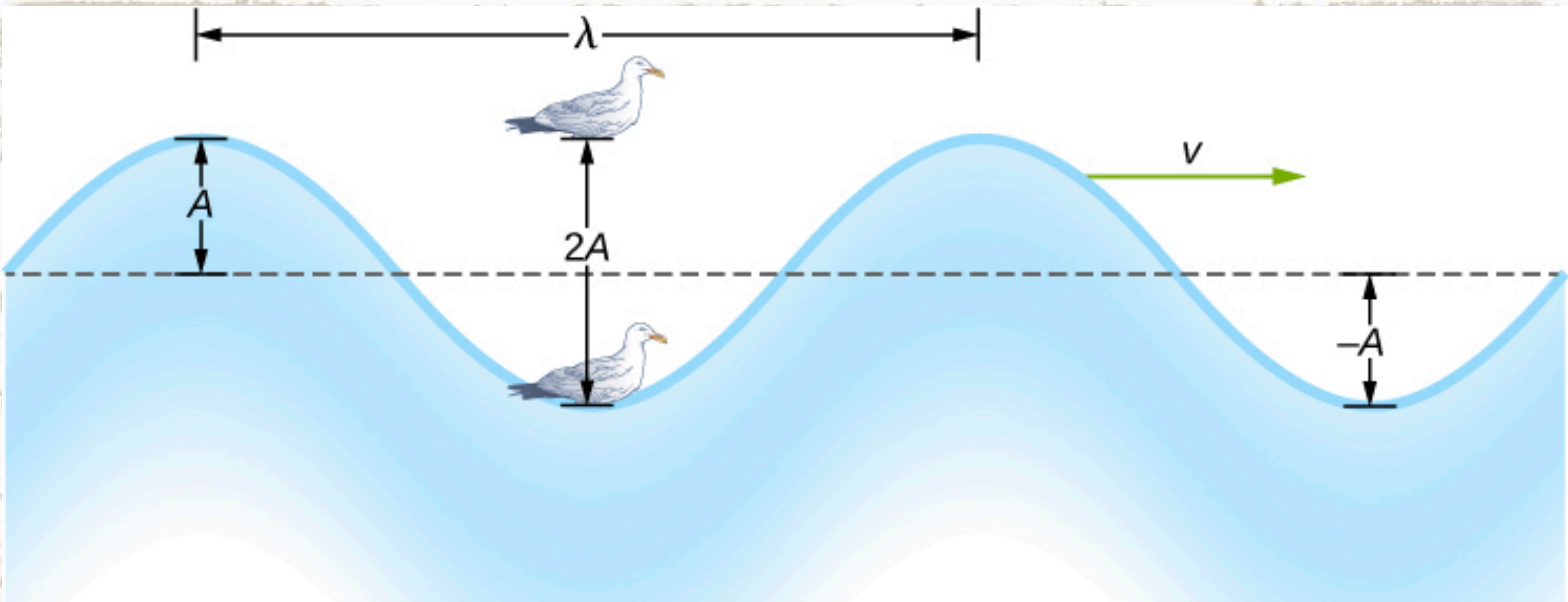
Waves

Chapter 16


Ocean waves are a common example of a wave

Types of Waves

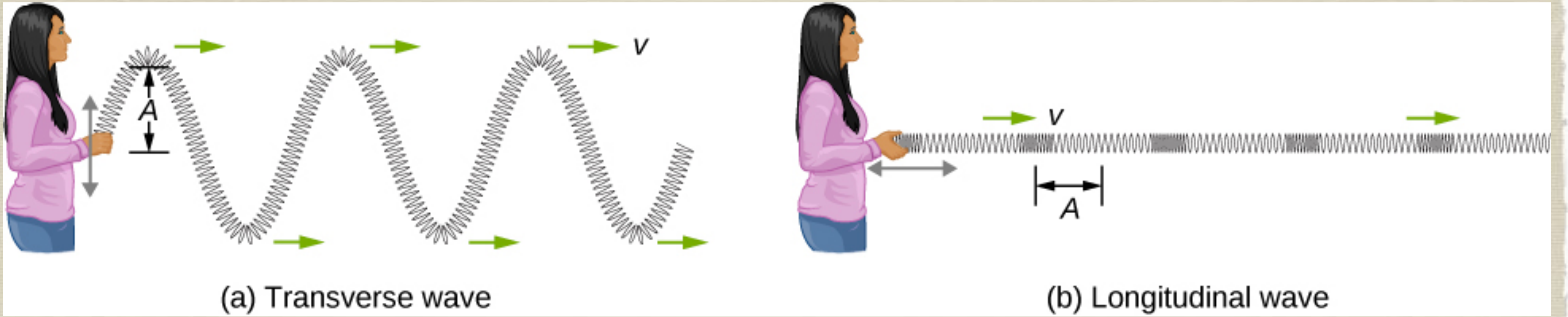
* In Physics there are 4 main types of waves:
* Mechanical waves travel through a medium and are governed by Newton's Laws. Mechanical waves transfer energy and momentum through the medium without transferring mass.
* Electromagnetic waves are caused by oscillations in electric and magnetic fields and do not require a medium. Electromagnetic waves are light as well as radio waves, gamma-rays, x-rays, and microwaves.
* The wave function describes the quantum mechanical properties of matter. These matter waves are related to the uncertainty as to the location and velocity of objects in quantum mechanics.
* Gravity waves are part of the theory of general relativity. Why caused by accelerations of matter they are only detectable under extremely strong gravitational fields like neutron stars and black holes.



A wave can be described by its amplitude, A, wavelength, λ, and velocity v.

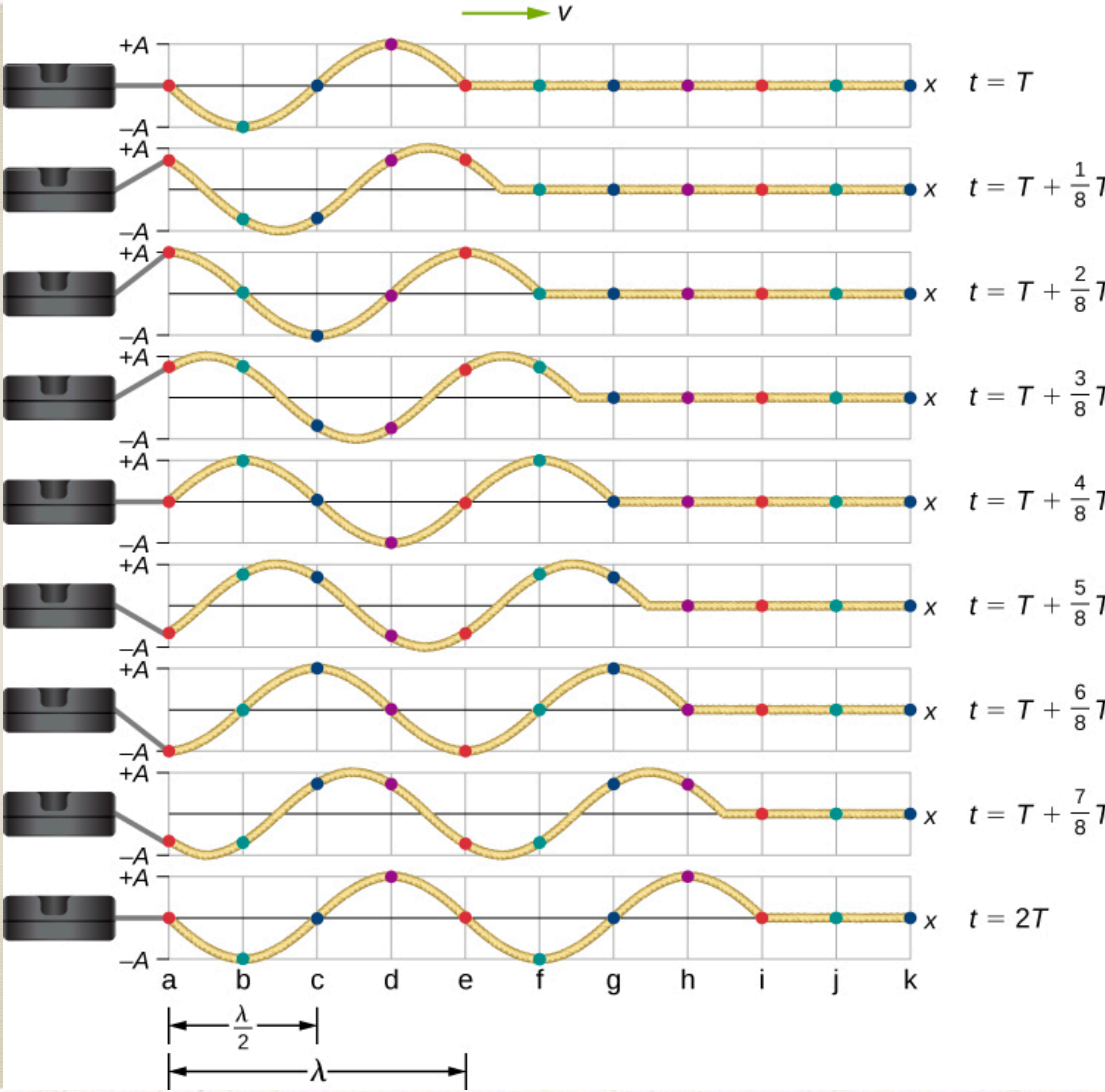
Also the wave has a period, T, or frequency, f. The velocity is related to the wavelength and frequency by:

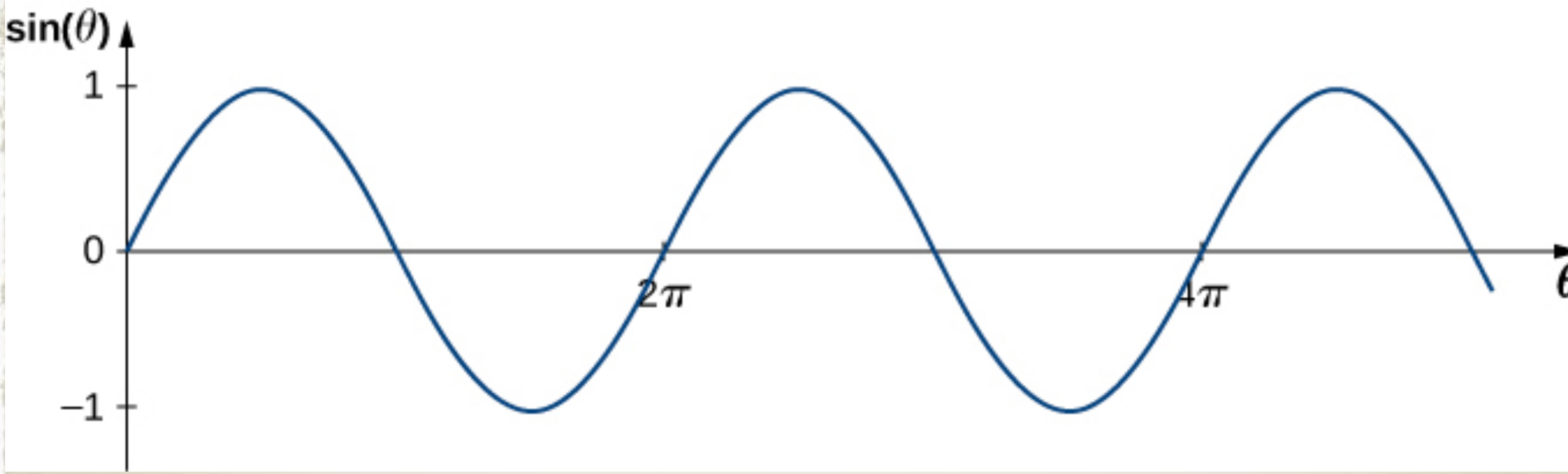
$$v = \lambda f$$



Mechanical waves can be of two types, transverse or longitudinal. These distinctions refer to how the amplitude is oriented compared to the velocity. If the oscillation is perpendicular to the velocity that is a transverse wave. If it is in the same direction that is a longitudinal wave. Waves can also be a combination of both types, water waves are an example of this.

Imagine a string where one end is oscillated by a machine. At every 1/8 of a period each position just advances in the x. However, the actual matter only oscillates up and down, never forward. This motion can be described by a sin wave.





We can see that one wavelength is 2π in angle or

$$\theta = \frac{2\pi}{\lambda}x$$

$$y(x) = A\sin(\frac{2\pi}{\lambda}x)$$

As we just saw the x value moves as vt so

$$y(x) = A\sin(\frac{2\pi}{\lambda}(x - vt))$$

This is often written as

$$y(x) = A\sin(kx \mp wt + \phi)$$

where k is called the wave number and ω the angular frequency and are defined as

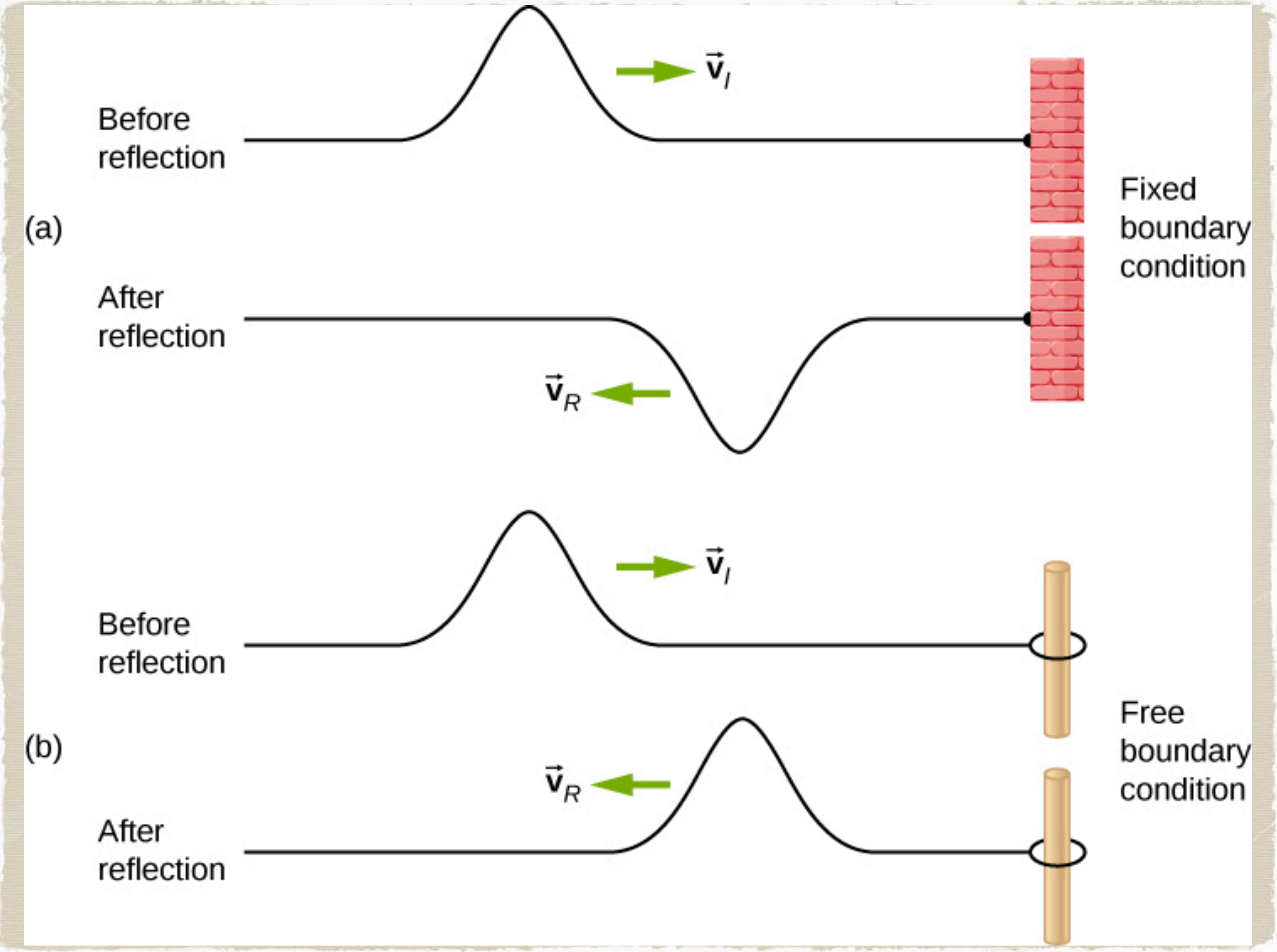
$$k \equiv \frac{2\pi}{\lambda} \qquad \omega \equiv \frac{2\pi}{T}$$

and ϕ is the phase angle that accounts for when we start t. It is + or - because we take ω as always positive. Note that v can be written as

$$v = \frac{\omega}{k}$$

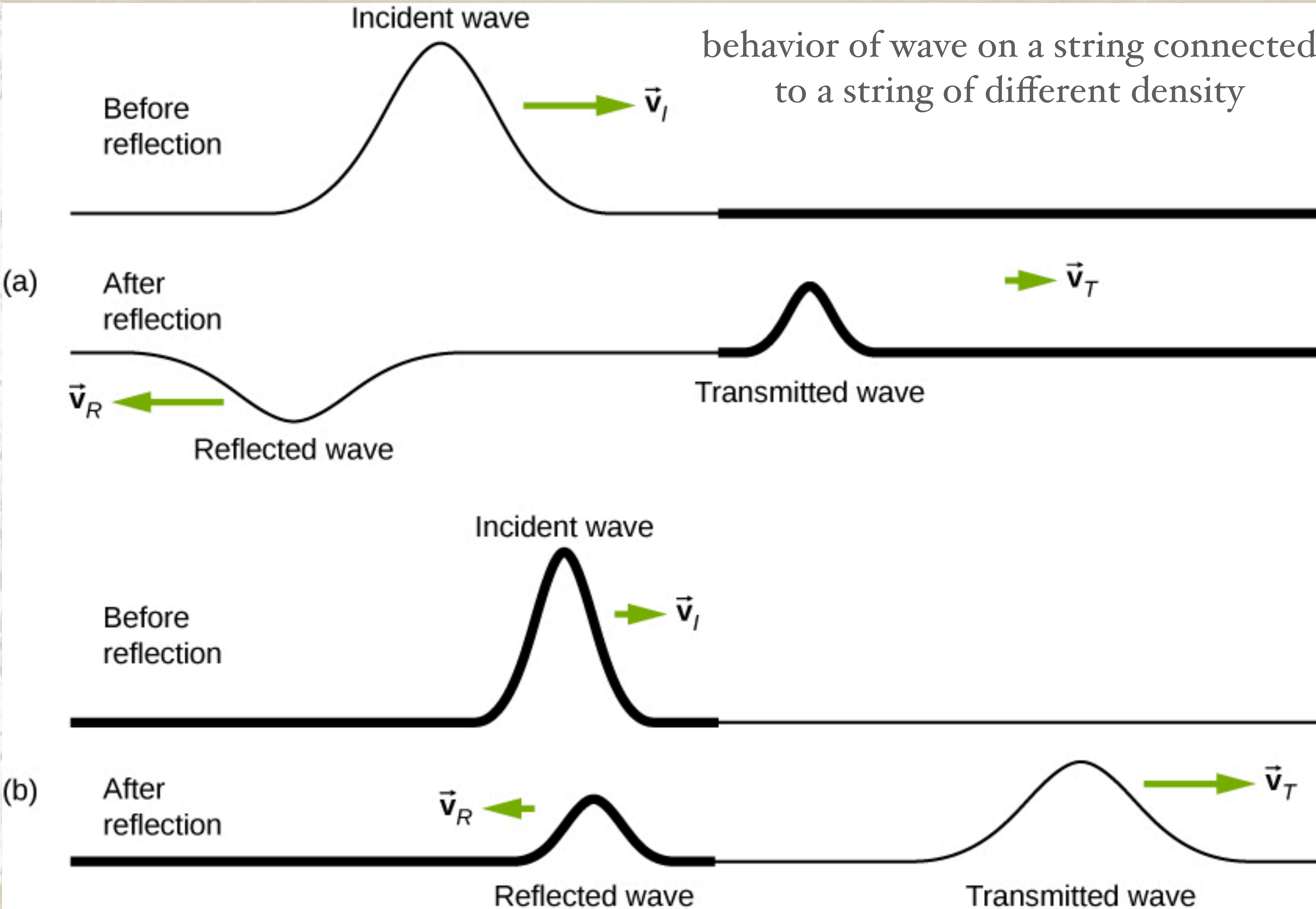
Wave Behaviors

* Waves exhibit a number of behaviors that are unique to them.
    * Reflection - waves will bounce off of a boundary
    * Transmission - part of the wave can continue past a change of medium
    * Interference - when two waves interact the amplitude can increase and decrease in different places

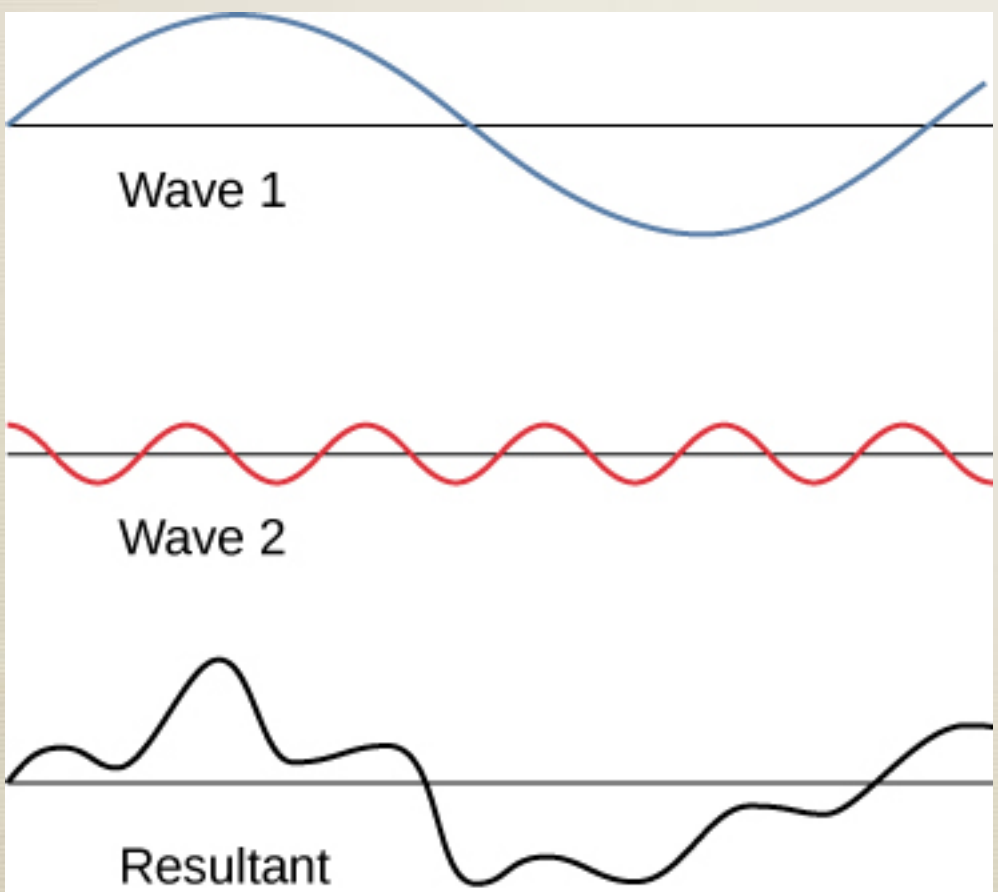


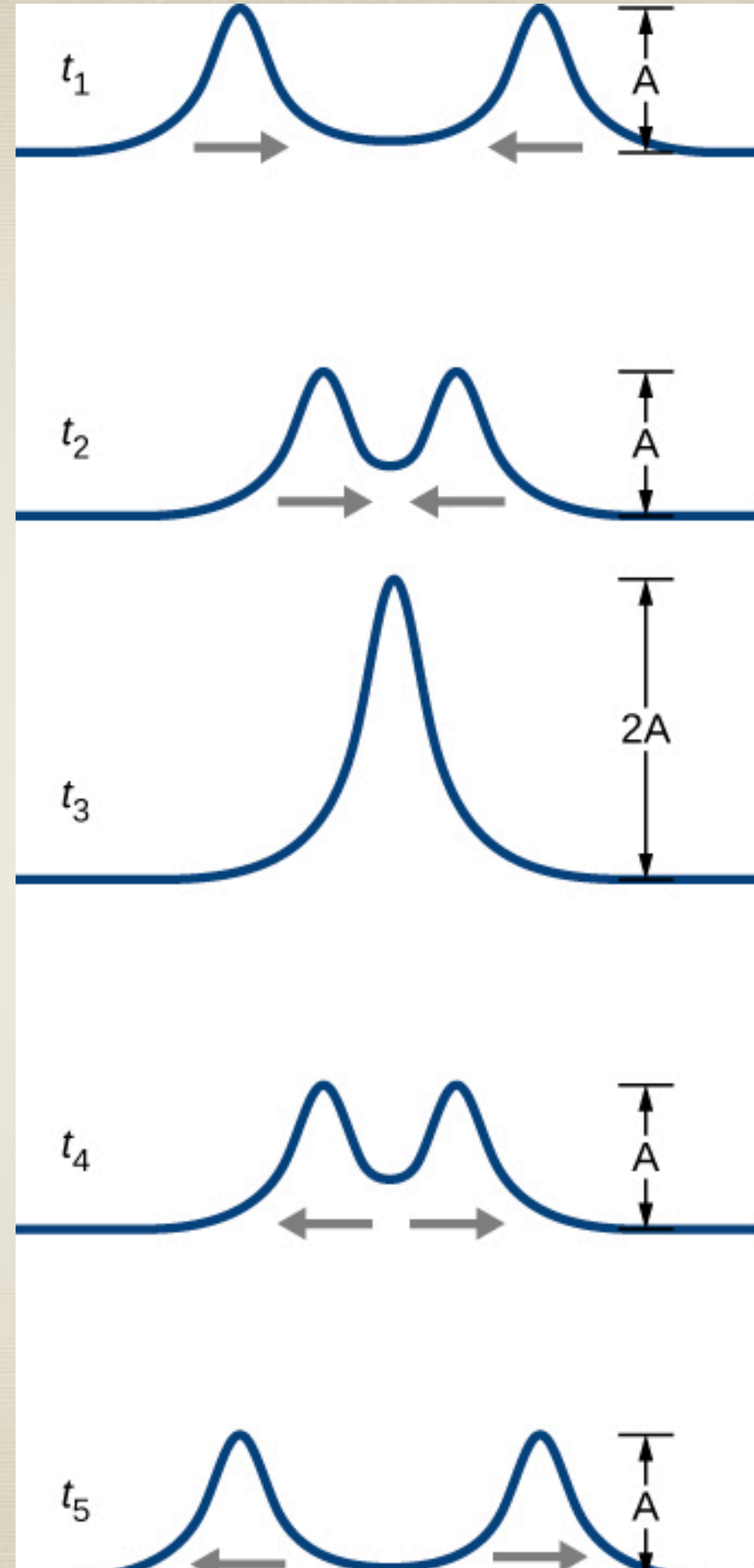
Before reflection
$\vec{v}_I$
(a)
After reflection
$\vec{v}_R$
Fixed boundary condition
Before reflection
$\vec{v}_I$
(b)
After reflection
$\vec{v}_R$
Free boundary condition

behavior of wave on a string connected to a string of different density



When two waves interact you add the y value of each wave at that point. Since the y value can be positive or negative this can give you a higher or lower amplitude and even no amplitude at all.





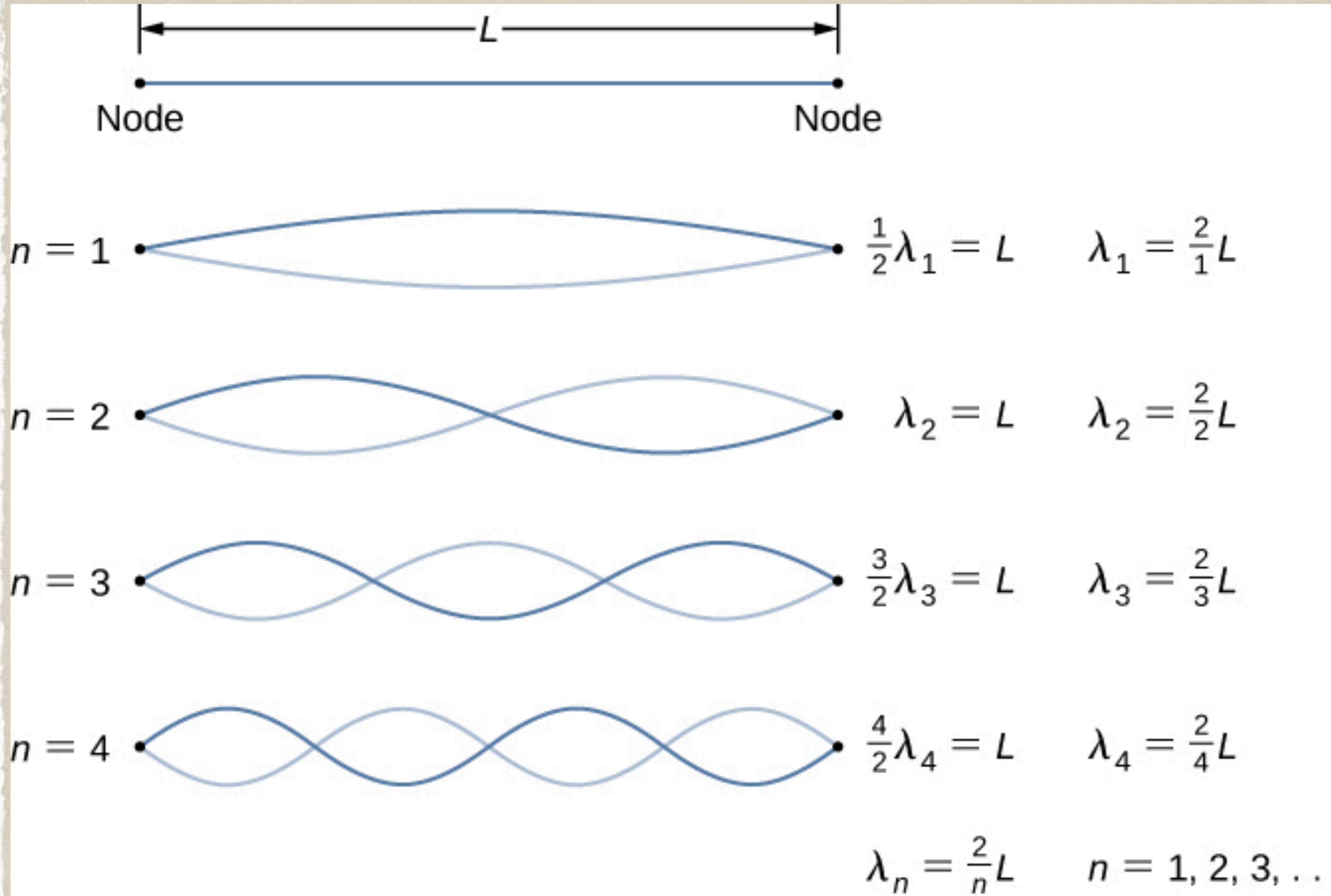
Standing Waves

* Standing waves can occur if two waves are traveling such that they interfere in a way that doesn't change with time.

* This is common when waves are traveling back and forth in a closed container.

* Then there will be a longest possible wave and higher harmonics that are related by integers.

Standing waves in a bowl of milk sitting on a box fan



Standing waves when both ends are fixed.