Hooke's Law

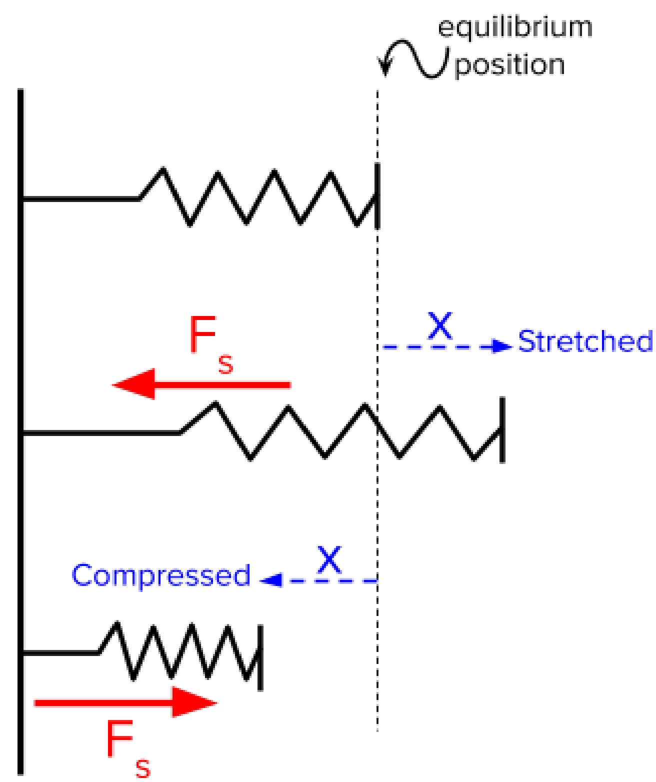
What does Hooke's Law mean?

Hooke's Law says that the force exerted by an "ideal" spring is proportional to the amount the spring is stretched or compressed from its equilibrium.

The equilibrium position of a spring is the location of the end of the spring when it is sitting at its natural length with no forces applied.

$$F_s = kx$$

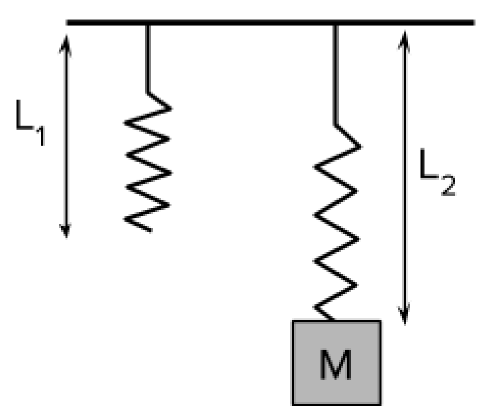
F_s = magnitude of the spring force
k = spring constant
x = amount that the spring is stretched or compressed



Example Question:

Question: An ideal spring is hanging from a ceiling at rest and has an unstretched length L_1. When a mass M is hung from the spring the stretched length of the spring is L_2. What is the spring constant of the spring?

A. mg/L_1
B. mg/L_2
C. $mg/(L_2 - L_1)$
D. $mg/(L_1 + L_2)$



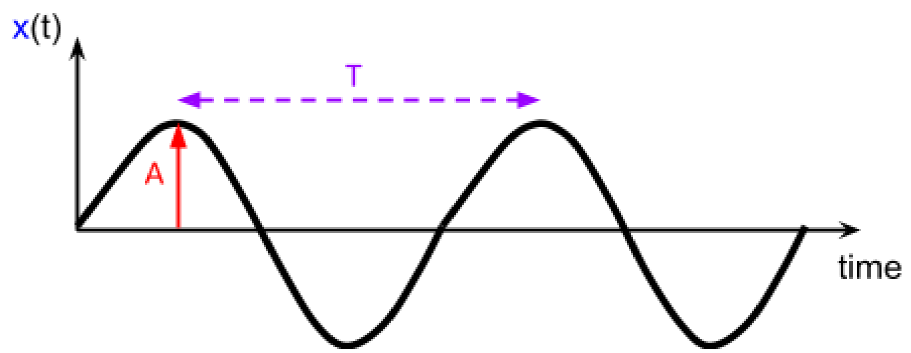
Simple Harmonic Motion

What does Simple Harmonic Motion mean?

We say that a variable x is a “simple harmonic oscillator” if the variable changes according to a sine or cosine function.

$$x(t) = A\sin(2\pi f\, t) = A\sin\left(\frac{2\pi}{T}\, t\right)$$

$x(t)$ = variable that’s oscillating
A = Amplitude
$\omega = \frac{2\pi}{T}$ = angular frequency
T = period of the motion



$$T_{\text{mass on spring}} = 2\pi\sqrt{\frac{m}{k}}$$

m = mass on the spring
k = spring constant

$$T_{\text{pendulum}} = 2\pi\sqrt{\frac{L}{g}}$$

L = length of the pendulum
g = acceleration due to gravity

Example Question:

Question: In a lab, a mass M on Earth can either be hung on a string of length L and allowed to swing back and forth with period $T_{pendulum}$, or hung on a spring of spring constant k and allowed to oscillate up and down with period T_{spring}. If a 2M mass were used instead, what would happen to the period of the two motions?

	$T_{pendulum}$	T_{spring}
A.	increases	decreases
B.	decreases	increases
C.	increases	doesn’t change
D.	doesn’t change	increases

Waves

What does the term Waves mean?

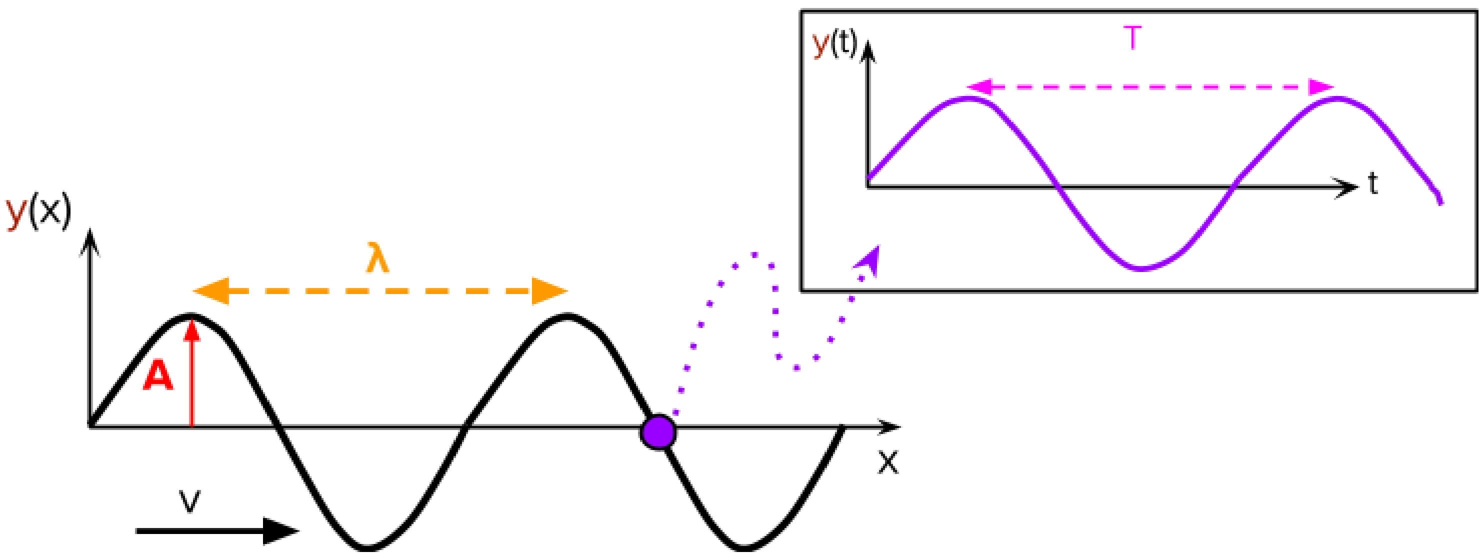
Mechanical waves are a disturbance in a medium (like water, air, or a string) that transfers energy and momentum over significant distances.

Transverse Waves: The oscillation of the medium is perpendicular to the wave velocity
Longitudinal Waves: The oscillation of the medium is parallel to the wave velocity

Wave speed v depends only on the **properties of the medium**, NOT on f, T, or A.

$$v = \lambda/T \qquad v = \lambda f \qquad \lambda = v/f$$

v = speed of the wave
f = frequency of wave
λ = wavelength of the wave
A = Amplitude of the wave
T = period of the oscillation



Example Question:

Question: A sound lab is being conducted in a lab room with total cubic volume V and temperature T. A speaker in the room is hooked up to a function generator and plays a note with frequency f and amplitude A. Which of the following would change the speed of the sound waves?

A. Increase the frequency f
B. Increase the temperature of the room T
C. Decrease the amplitude A
D. Decrease the volume of space in the lab room V

Wave Interference

<u>What does Wave Interference mean?</u>

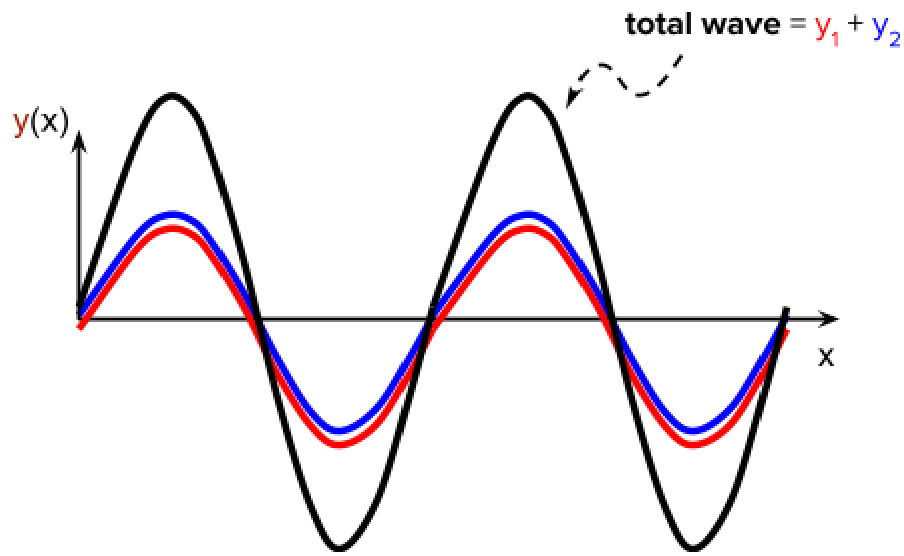
When two waves overlap, we say there is “wave interference”. While the waves are overlapping, they will combine to form a wave shape that is the sum of the two waves.

If the waves cancel to form a smaller wave we call it **“destructive interference”**.
If the waves combine to form a larger wave we call it **“constructive interference”**.

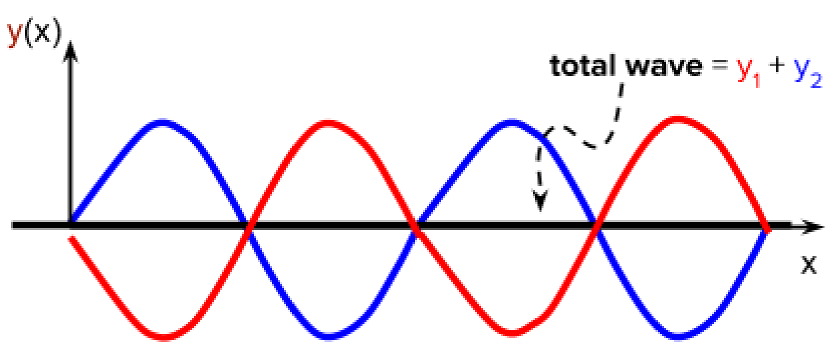
To find the value of the total wave at a point, just add up the values of each wave at that point

$$y_{total} = y_1 + y_2$$

Constructive Interference:
Waves combine to form a larger wave

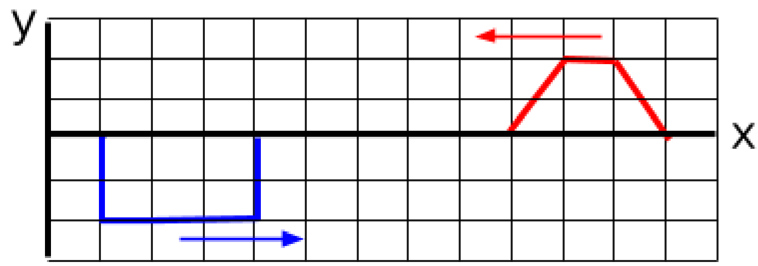


Destructive Interference:
Waves cancel each other to form a smaller wave

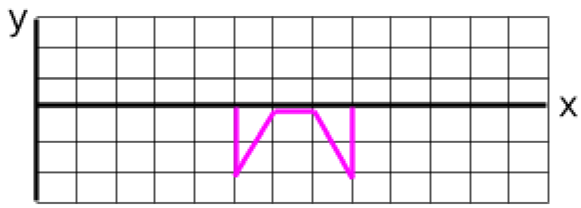


Example Question:

Question: Two wave pulses on a string head toward each other as seen to the right. What will be the shape of the wave when the wave pulses overlap?



A.



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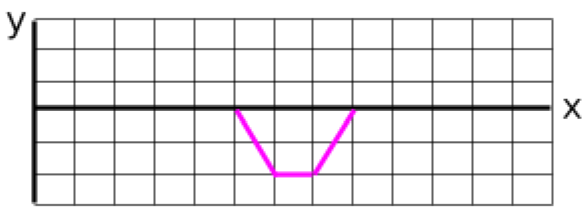
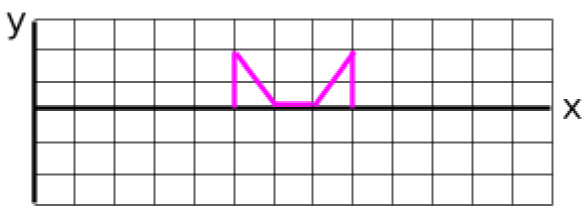
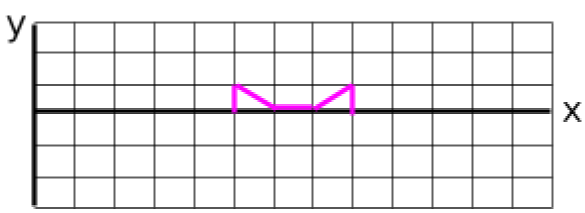


C.



D.



Doppler effect

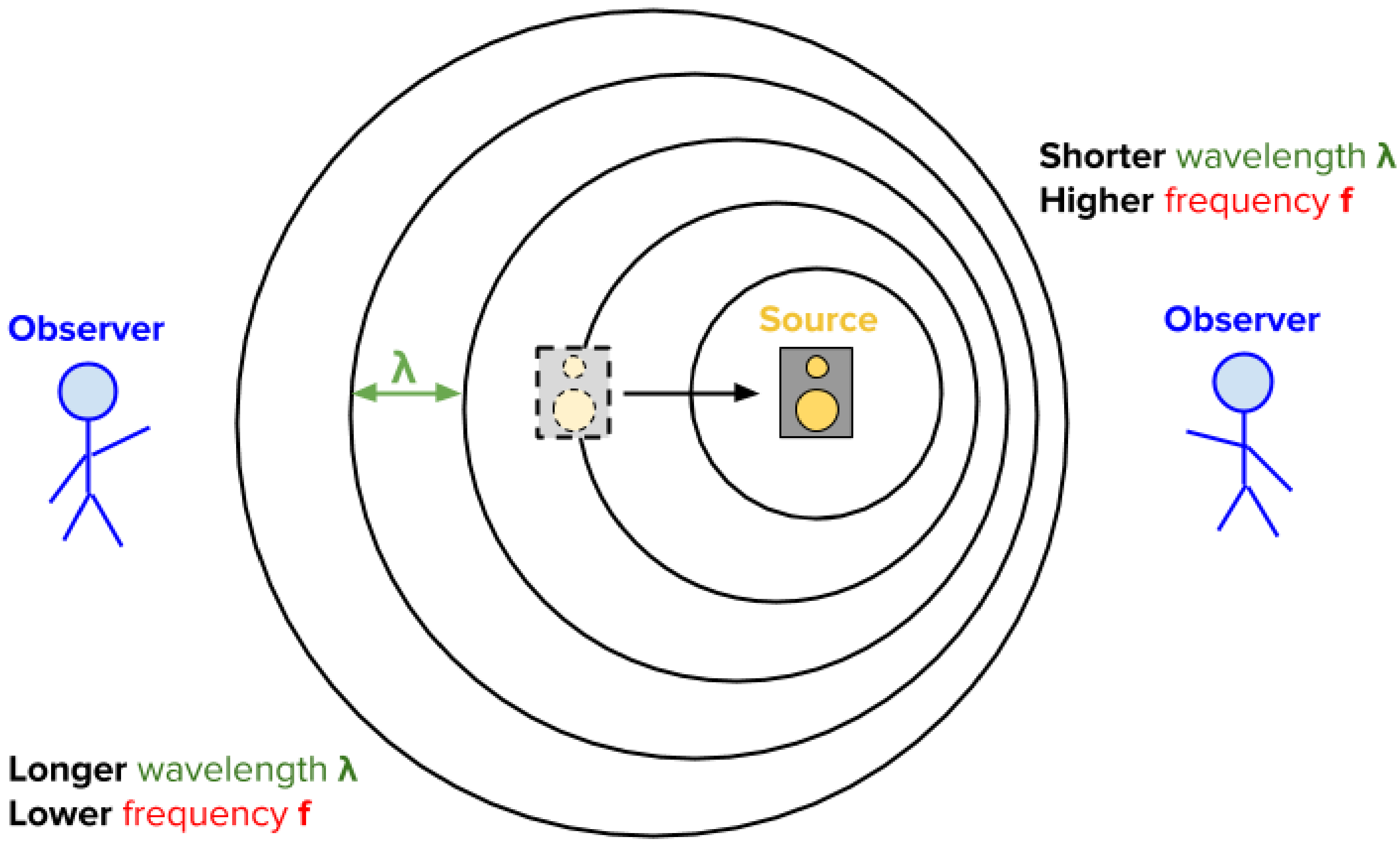
What does Doppler effect mean?

When a speaker (or wave source) moves relative to you, the perceived frequency **f** will be different from the frequency **f** coming out of the speaker. This phenomenon is called the “Doppler effect”.

If the source and observer are moving...

Toward each other → wavelength **λ** **decreases** and frequency **f** **increases**

Away from each other → wavelength **λ** **increases** and frequency **f** **decreases**



Example Question:

Question: The driver of a car sees that they are heading straight toward a person standing still in the crosswalk, so they continuously honk their horn and emit a sound of frequency $\mathbf{f_{horn}}$. The driver of the car also simultaneously slams on the brakes and skids to a stop right in front of the person standing in the crosswalk. What would the person standing in the crosswalk hear during the car's skidding motion?

A. $\mathbf{f_{horn}}$ the entire time since the person is at rest
B. First a higher frequency than $\mathbf{f_{horn}}$ that eventually becomes the same as $\mathbf{f_{horn}}$
C. First a lower frequency than $\mathbf{f_{horn}}$ that eventually becomes the same as $\mathbf{f_{horn}}$
D. First they hear $\mathbf{f_{horn}}$ that eventually becomes higher than $\mathbf{f_{horn}}$

Standing Waves on Strings

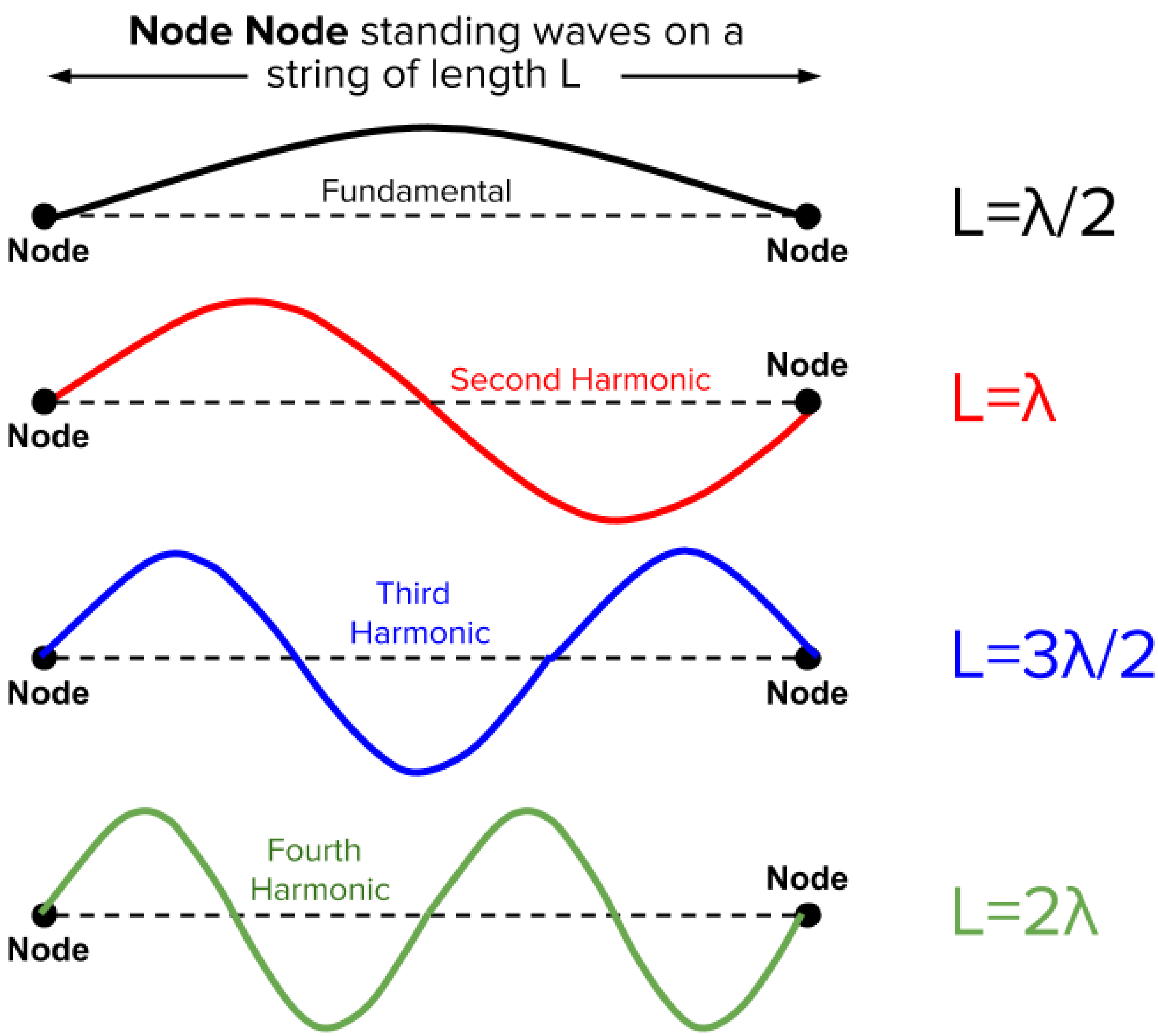
What does Standing Waves on Strings mean?

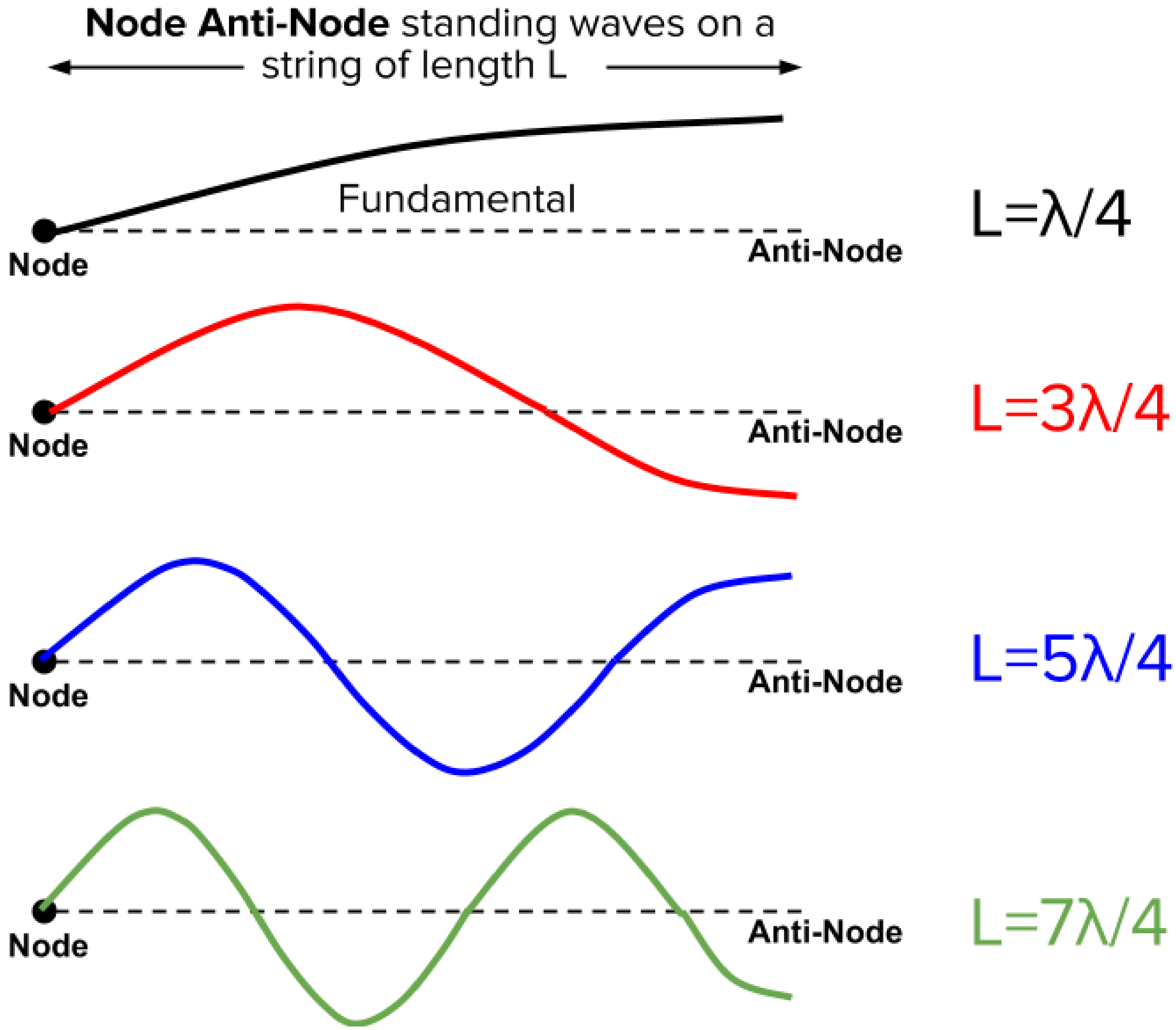
If two waves overlap while going in opposite directions you can create a standing wave. The **length L** of and **boundaries** of the medium determine the allowed wavelengths.

The ends of a string could be **fixed** or **loose**:

Fixed ends of a string act as displacement **nodes** (no string displacement)

Loose ends of a string act as displacement **anti-nodes** (maximum string displacement)




Node Anti-Node standing waves on a
string of length L
Fundamental
L=λ/4
Node
Anti-Node
L=3λ/4
Node
Anti-Node
L=5λ/4
Node
Anti-Node
L=7λ/4
Node
Anti-Node

Example Question:

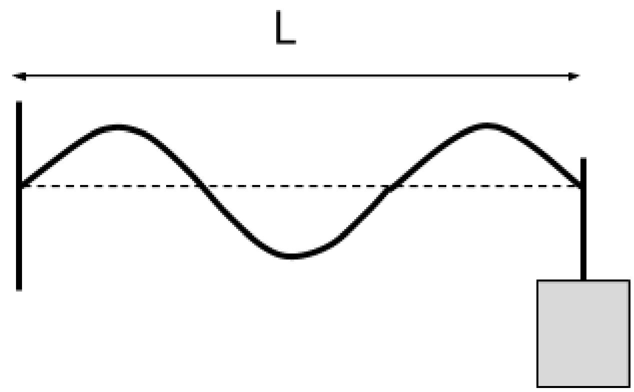
Question: One end of a string of length L is attached to the wall and the other end is attached to a vibrating rod. A student finds that the string sets up a standing wave as seen below when the frequency is set to f_o. What is the speed of waves on the string?

A. $2L f_o$

B. $\frac{3L fo}{2}$

C. $L f_o$

D. $\frac{2L fo}{3}$

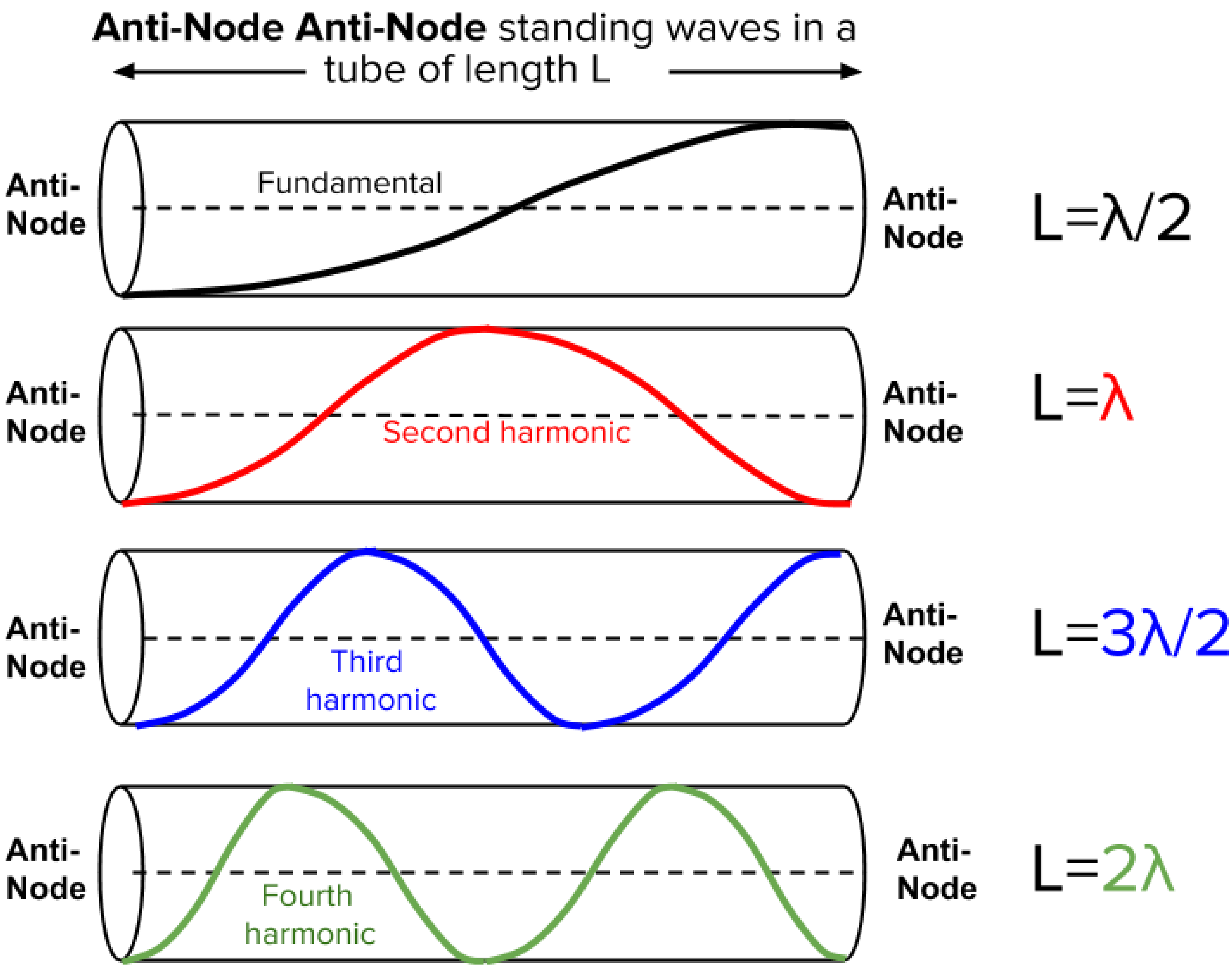


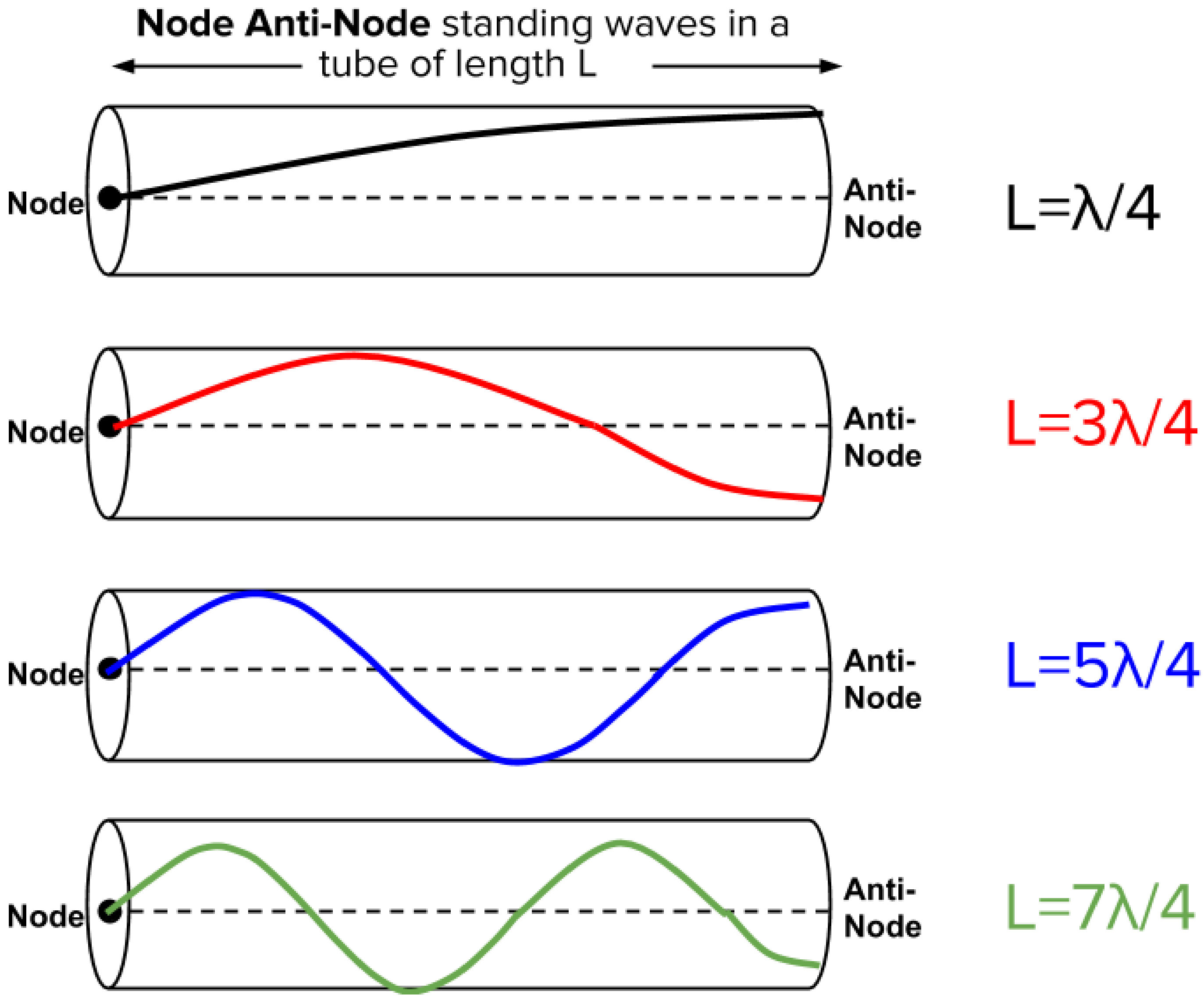
Standing Waves in Tubes

<u>What does Standing Waves in Tubes mean?</u>

Just like standing waves on a string, the wavelengths of standing waves in a tube are determined by the length of the tube and the boundary conditions.

The ends of the tube could be **closed** or **open**:
Open ends of the tube act as displacement **anti-nodes** (maximum air disturbance)
Closed ends of the tube act as displacement **nodes** (no air disturbance)





Example Question:

Question: When blowing over the top of a tube that is open at both ends, it resonates with a frequency f_o. The bottom of the tube is covered and air is again blown over the top of the tube. What is the frequency heard if the tube is blown over again?

A. $2f_o$
B. f_o
C. $\frac{fo}{2}$
D. $\frac{fo}{4}$

Beat Frequency Units: **Hz (1/sec)** Vector? **No**

What does Beat Frequency mean?

When two waves overlap with **different frequencies**, the interference of the waves at a given point in space goes from **constructive** to **destructive** to constructive and so on.

This will be perceived by a person as a “wobble” in the loudness of the sound.

The rate at which the interference “wobbles” (i.e. goes through a cycle of constructive to destructive back to constructive) is called the “**beat frequency**”.

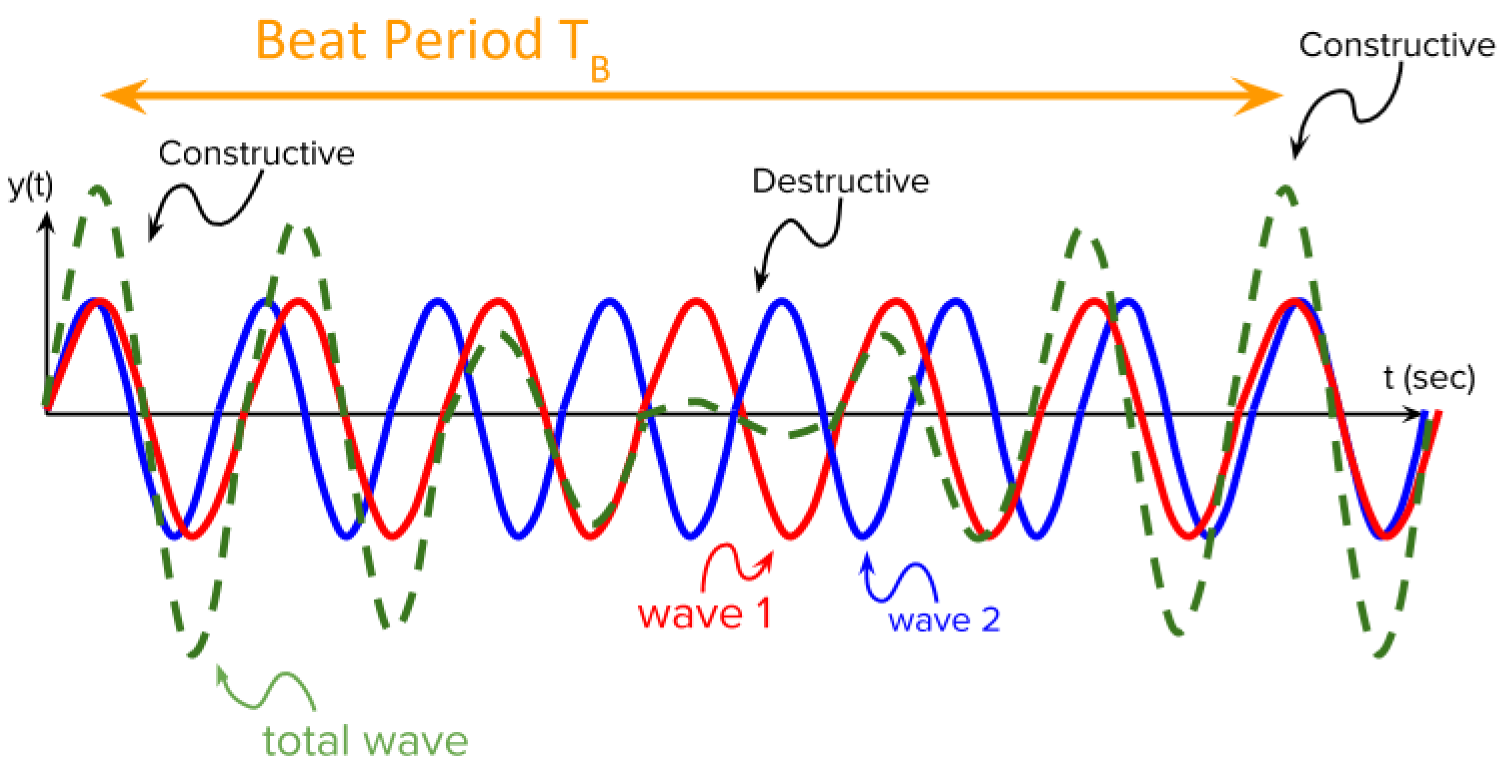
$$f_{beat} = |f_1 - f_2| = \frac{1}{T_B}$$

f_{beat} = beat frequency

f_1 = frequency of wave 1

f_2 = frequency of wave 2

T_B = beat period = time to go from constructive to destructive back to constructive



Example Question:

Question: A tuning fork is struck with a mallet and at the same time an electronic tone generator plays an unknown frequency, after which a beat frequency of 3Hz is heard. The frequency of the sound emitted by the tone generator is increased by 2Hz, after which a beat frequency of 5Hz is heard. What can be said for sure?

A. The frequency emitted by the tone generator is higher than the tuning fork.
B. The sound emitted by the tone generator is louder than the tuning fork.
C. The frequency emitted by the tone generator is lower than the tuning fork.
D. The sound emitted by the tone generator is softer than the tuning fork.

Example Question:

Question: Two wave generators create overlapping waves and their displays look as follows. What is the beat frequency observed?

A. 0.25 Hz
B. 0.50 Hz
C. 2.00 Hz
D. 4.00 Hz