Wave: A disturbance that transports energy in space without transporting matter.
16 Traveling Waves

IN THIS CHAPTER, you will learn the basic properties of traveling waves.

What is a wave?
A wave is a disturbance traveling. In a **transverse wave**, the displacement is perpendicular to the direction of travel. In a **longitudinal wave**, the displacement is parallel to the direction of travel.

What are some wave properties?
A wave is characterized by:
- **Wave speed**: How fast it travels through the medium.
- **Wavelength**: The distance between two neighboring crests.
- **Frequency**: The number of oscillations per second.
- **Amplitude**: The maximum displacement.

LOOKING BACK Sections 15.1–15.2 Properties of simple harmonic motion

Are sound and light waves?
Yes! Very important waves.
- **Sound waves** are longitudinal waves.
- **Light waves** are transverse waves.

The colors of visible light correspond to different wavelengths.

Do waves carry energy?
They do. The rate at which a wave delivers energy to a surface is the **intensity** of the wave. For sound waves, we'll use a logarithmic **decibel** scale to characterize the loudness of a sound.

What is the Doppler effect?
The frequency and wavelength of a wave are shifted if there is relative motion between the source and the observer of the waves. This is called the **Doppler effect**. It explains why the pitch of an ambulance siren drops as it races past you.

How will I use waves?
Waves are literally everywhere. Communications systems from radios to cell phones to fiber optics use waves. Sonar and radar and medical ultrasound use waves. Music and musical instruments are all about waves. Waves are present in the oceans, the atmosphere, and the earth. This chapter and the next will allow you to understand and work with a wide variety of waves that you may meet in your career.
Mathematically

Snapshot (fixed x)

$y(x,t)$

get $\lambda$, $k = \frac{2\pi}{\lambda}$

"Wavenumber"

(A)

History (fixed t)

$y(x,t)$

get $T$, $f = \frac{1}{T}$, $\omega = 2\pi f$

Which graph could you get $\lambda$ from?

(A)

Wave speed $V = \lambda f = \frac{\omega}{k}$

$y(x,t) = A \cos [\frac{\lambda x}{L} + \omega t + \phi]$}

Waves on Strings:

$V = f \lambda$

* I can't change $V$ by changing for $\lambda$*

$V = \sqrt{\frac{T}{\mu}}$

-- tension in string

$\frac{mass}{length}$
The following is a snapshot at $t=0$ for a transverse wave traveling \textbf{to the right} with velocity 2 m/s. Which of the following equations is correct for this wave?

1. $y(x,t) = 2 \sin \left[ \frac{\pi}{2} x - \left( \frac{\pi}{2} \right) t \right]$
2. $y(x,t) = 2 \sin \left[ \pi x - \left( \frac{\pi}{2} \right) t \right]$
3. $y(x,t) = 2 \sin \left[ \frac{\pi}{2} x - \pi t \right]$
4. $y(x,t) = 2 \sin \left[ \pi x - \pi t \right]$
5. None of the above.

The following is a history at $x = 0$ meter of a transverse wave traveling \textbf{to the left} with velocity 2m/s. Which of the following equations is correct for this wave?

1. $y(x,t) = 2 \sin \left[ \frac{\pi}{2} x + \left( \frac{\pi}{2} \right) t \right]$
2. $y(x,t) = 2 \sin \left[ \frac{\pi}{2} x + \pi t \right]$
3. $y(x,t) = 2 \sin \left[ \pi x + \left( \frac{\pi}{2} \right) t \right]$
4. $y(x,t) = 2 \sin \left[ \pi x + \pi t \right]$
5. None of the above.
A transverse wave is traveling to the right with velocity 2m/s and wave length 4m. What will the wave (shown on the right, at t = 0 sec.) look like at t =1.5 seconds?

\[ d = vt \]

\[ v = \lambda f \]
\[ f = \frac{1}{T} \]
\[ T = \frac{\lambda}{v} \]

A transverse wave is traveling to the right with velocity 2m/s and wave length 4m. The following graph describes how the particle at x=3m vibrates. Draw a snap shot of the wave at t=1 second.
A transverse wave is traveling to left with velocity 2m/s and wave length 4m. The following is a snap shot at t=0 seconds. Which of the following graphs best describes the vibration at x = 2m?

![Graph 1]

![Graph 2]

![Graph 3]

![Graph 4]

ANS: 4

Two strings with different unit mass are tied in the center and attached with a tension of 1000N to two walls, as shown. What is the ratio of the wave’s speed in the two strings?

The wave speed in a wire is $v = \sqrt{\frac{T}{\mu}}$

![String diagram]

1. $v_1 / v_2 = 9/25$
2. $v_1 / v_2 = 3/5$
3. $v_1 / v_2 = 5/3$
4. $v_1 / v_2 = 25/9$
5. $v_1 / v_2 = 1$

ANS: 2

See Sec. B for explanation!
Two strings with different unit mass are tied in the center and attached with a tension of 1000N to two walls, as shown. What is the ratio of the wave’s frequencies in the two strings?

\[ \frac{f_1}{f_2} = \frac{9}{25} \]

\[ \frac{f_1}{f_2} = \frac{3}{5} \]

\[ \frac{f_1}{f_2} = \frac{5}{3} \]

\[ \frac{f_1}{f_2} = \frac{25}{9} \]

\[ \frac{f_1}{f_2} = 1 \]

Two strings with different unit mass are tied together as shown. What will the waves look like in the two strings? Ignore reflections that might occur at the knot.

A. [Wave pattern image]
B. [Wave pattern image]
C. [Wave pattern image]
D. [Wave pattern image]
$A \cos[kx - wt]$... Why is the minus sign if the wave is moving in the $+\hat{x}$-direction?

Here's a graph of $A \cos[kx]$: 

If we want to shift it to the right, we replace $f(x) \rightarrow f(x-a)$
[remember this from math]

e.g., if $q = \frac{2}{4} = \frac{\pi}{2k}$, then

$A \cos[k(x-a)] = A \cos[kx - ka]$

$= A \cos[kx - 90^\circ]$

Note the converse as well: $A \cos[kx + wt]$ describes a wave traveling in the $-\hat{x}$-direction!