Phys 111: Lecture 27

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The 27th Day: "Guitar of Waves"

Homework Wk #14 Due Thursday

Today's Topics

1. Periodic Waves
2. Speeds of Waves
3. Wave nature of Sound

Motivation 1

How will the wave affect the fisherman and his boat?

Figure: 27.1 Wave through water[1]

[1] CJ Figure 16.1

Waves Introduction

All waves have the following two properties:

1. A wave is a traveling disturbance.
2. A wave carries energy from place to place.

Simple Types

1. Transverse: Wave disturbance perpendicular to travel direction.
2. Longitudinal: Wave disturbance parallel to travel direction.

Some Examples

- sound
- light
- wind waves (ocean)
- seismic (earthquakes)

Transverse Waves Spring Example

Common transverse waves are radio, visible light, micro, and primary-seismic waves.

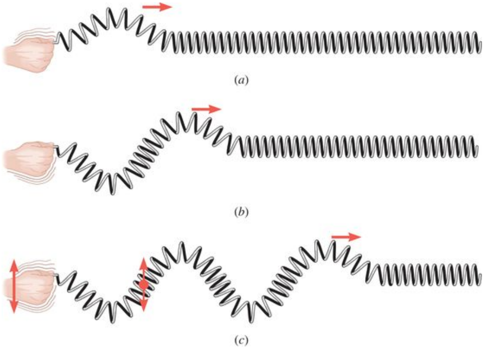

Figure: 27.2 Transverse wave through a slinky[2]

[2] CJ Figure 16.2

Longitudinal Waves Spring Example

Common longitudinal waves are sound, and secondary-seismic waves

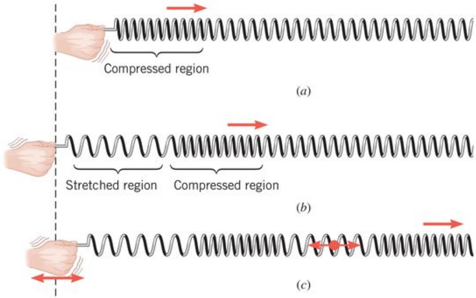

Figure: 27.3 Longitudinal wave through a slinky[3]

[3] C&J Figure 16.3

Waves

In general, waves are a combination or linear superposition of longitudinal and transverse waves.

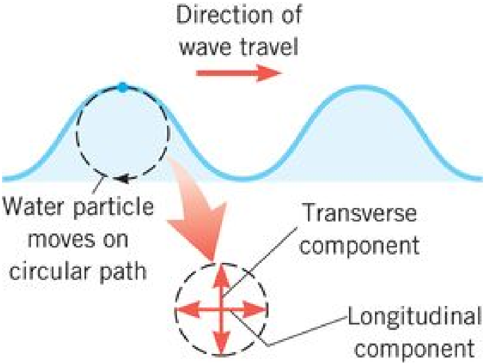

Figure: 27.4 Water waves are a combination of longitudinal and transverse waves[4]

[4] C&J Figure 16.4

Exercise # 1

How will the wave affect the fisherman and his boat?

Figure: 27.1 Wave through water[1]

[1] C&J Figure 16.1

Wave Basics Summary

A wave is a traveling disturbance that carries energy from place to place.

Simple Types

1. Transverse: Wave disturbance perpendicular to travel direction.
2. Longitudinal: Wave disturbance parallel to travel direction.

In general, any wave phenomena can be modeled as a complicated combination of many kinds and types of waves. See all of the types of seismic waves[5]

[5] https://en.wikipedia.org/wiki/Seismic_wave

Periodic Waves

Waves are called **periodic** if they consist of cycles or patterns that are produced over and over again by the source. Ideal data (minimal errors) would look like:

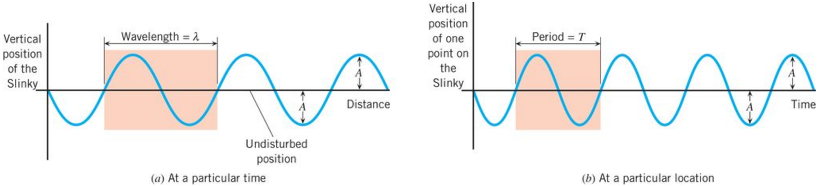

Figure: 27.5 Periodic wave graphs[6]

[6] C&J Figure 16.5

Parameters of Periodic Waves

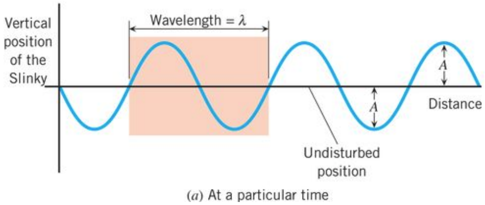

Figure: 27.6 Periodic wave spatial graph[6]

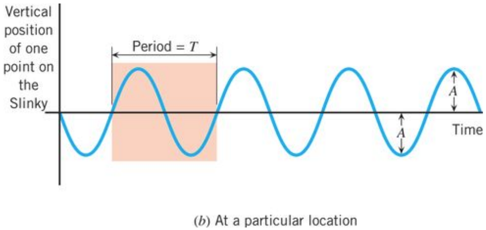

Figure: 27.7 Periodic wave temporal graph[8]

Wave Speed

Velocity is the rate at which something is changing position.

The speed of a wave (v_w) is most easily calculated by measuring wavelength (λ) and the period (T):

$$v_w = \frac{\lambda}{T}$$

Recall the relationship for period and frequency (f)

$$f = \frac{1}{T}$$

Wave Speed cont'd

For **all** waves the net wave speed, v_w is

$$v_w = f\lambda$$

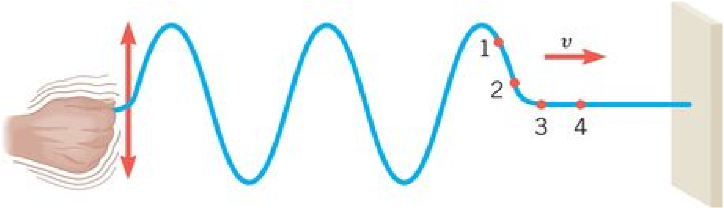

Figure: 27.8 Wave speed of a string attached to a wall [9]

[9] C&J Figure 16.7

Exercise #2

C&J 16.1 Light is an electromagnetic wave and travels at a speed of $3.00 \times 10^8\ m/s$. The human eye is most sensitive to yellow-green light, which has a wavelength of $5.45 \times 10^{-7}\ m$. What is the frequency of this light?

Exercise #2 Translation

C&J 16.1 Calculate the frequency of yellow-green light in vacuum that travels at the speed of light $c = 3.00 \times 10^8\ m/s$ with a wavelength of $\lambda = 5.45 \times 10^{-7}\ m$.

Need to know that wave speed is

$$v_w = f\lambda$$

Exercise #2 Answer

C&J 16.1 $c = 3.00 \times 10^8\ m/s$, $\lambda = 5.45 \times 10^{-7}\ m$

$$v_w = f\lambda$$

$$f = \frac{v_w}{\lambda}$$

$$f = \left(\frac{3.0 \times 10^8\ m/s}{5.45 \times 10^{-7}\ m}\right)$$

$$f = 5.50 \times 10^5\ GHz$$

Waves on Strings

For strings fixed at one or both ends, there are two parameters that you need to determine the wave speed.

1. tension force (F)
2. linear mass density (m/L)

$$v_w = \sqrt{\frac{F}{m/L}}$$

For waves on strings

$$f\lambda = \sqrt{\frac{F}{m/L}}$$

Exercise #3

C&J 16.13 The middle C string on a piano is under a tension of $944\ N$. The period and wavelength of a wave on this string are $3.82\ ms$ and $1.26\ m$, respectively. Find the linear density of the string.

Exercise #3 Translation

C&J 16.13 Calculate m/L for a middle C string under a tension of $F = 944\ N$. For this string $T = 3.82\ ms$ and $\lambda = 1.26\ m$.

$$v_{st} = \sqrt{\frac{F}{m/L}}$$

Remember that

$$v_w = f\lambda = \frac{\lambda}{T}$$

Exercise #3 Work

C&J 16.13 Calculate m/L for a middle C string under a tension of $F = 944\ N$. For this string $T = 3.82\ ms$ and $\lambda = 1.26\ m$.

$$\frac{\lambda}{T} = \sqrt{\frac{F}{m/L}}$$

$$\left(\frac{\lambda}{T}\right)^2 = \frac{F}{m/L}$$

$$\frac{m/L}{F} = \left(\frac{T}{\lambda}\right)^2$$

$$m/L = F\left(\frac{T}{\lambda}\right)^2$$

Exercise 3 Answer

C&J 16.13 Calculate m/L for a middle C string under a tension of $F = 944\ N$. For this string $T = 3.82\ ms$ and $\lambda = 1.26\ m$.

$$m/L = F\left(\frac{T}{\lambda}\right)^2$$

$$m/L = (944\ N)\left(\frac{3.82 \times 10^{-3}\ s}{1.26\ m}\right)^2$$

$$m/L = 8.68\ g/m$$

$$m/L = 8.68\ kg/km$$

Sound

Sound is a longitudinal wave that is created by a vibrating object.

Sound can be created or transmitted only in a medium, such as a gas, liquid, or solid. Moreover, sound cannot be created in a vacuum.

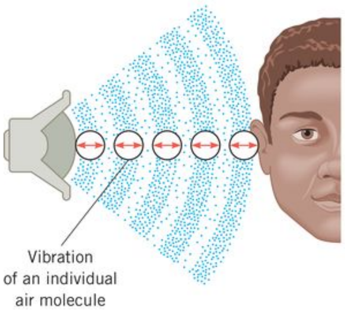

Figure: 27.9 Wave speed of a string attached to a wall [10]

[10] C&J Figure 16.13

Producing Sound with a Slinky

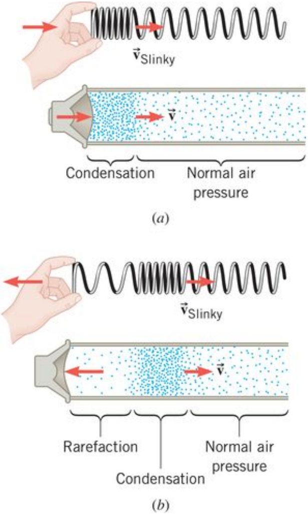

Figure: 27.10 Wave speed of a string attached to a wall [10]

[10] C&J Figure 16.11

Visualizing Sound Waves

If you look along any one line of sound in the previous image you can visualize the sound as below.

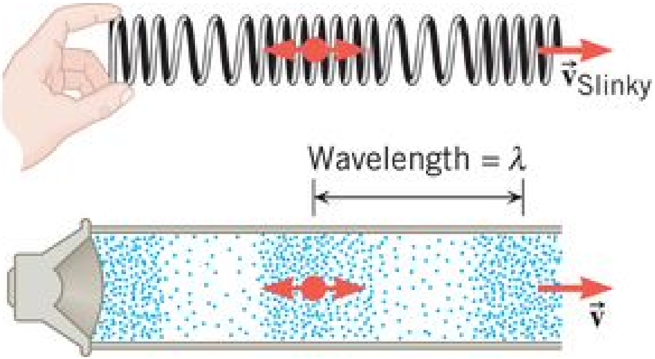

Figure: 27.10 Components of sound[11]

[11] C&J Figure 16.12

Pressure Analysis of Sound

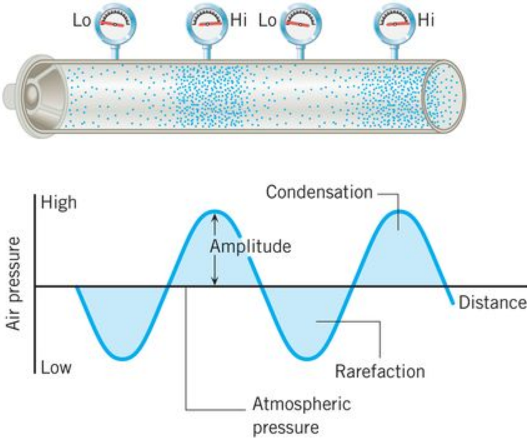

Figure: 27.11 Pressure of sound[12]

[12] C&J Figure 16.17

Puretones and Telephones

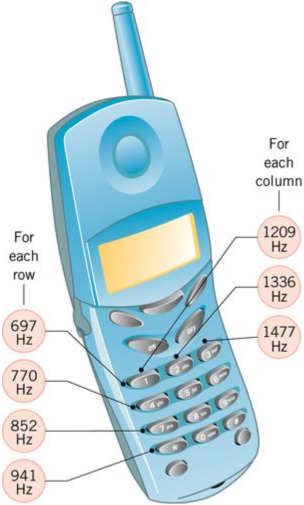

Figure: 27.12 Application of frequency analysis for telephones[13]

[13] C&J Figure 16.14

Ultrasonic Rulers

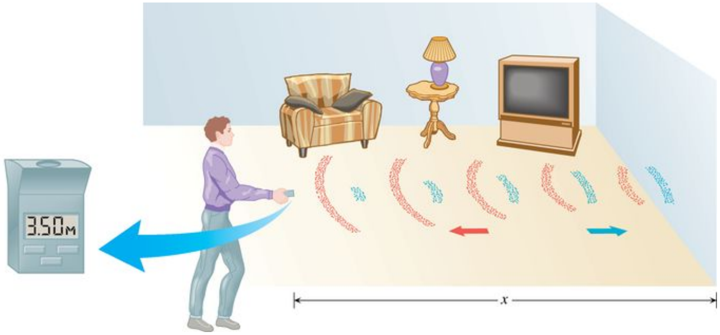

Figure: 27.13 Application of wave speed[14]

[14] C&J Figure 16.18

Sound Basics Summary

Sound

- is a longitudinal wave ($v_w = f\lambda$).
- can have transverse or longitudinal sources.
- can't travel in vacuum.
- travels faster in denser mediums.
- propagates through pressure differences.
- is used extensively throughout society.
- can be digitally stored[15]

[15] http://hyperphysics.phy-astr.gsu.edu/hbase/Audio/fourier.html