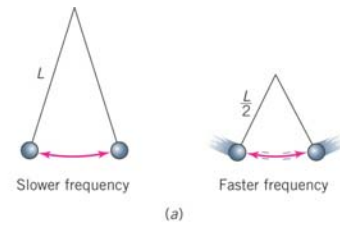
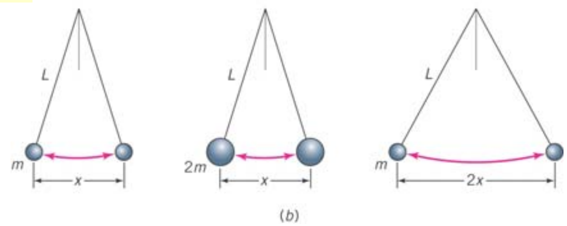
Chap 14 Vibrations and Waves

Vibration of a Pendulum

Period increases with length, but is largely independent of amplitude and mass.



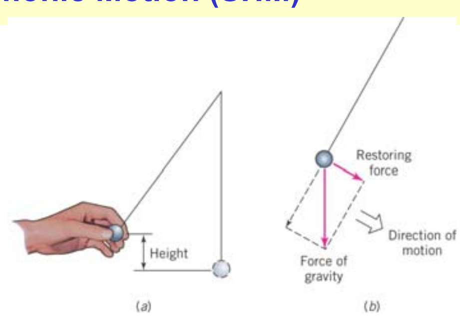
(a)



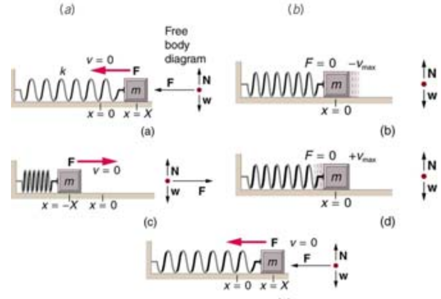
(b)

Simple Harmonic Motion (SHM)

SHM is marked by a restoring force that is proportional from the departure from the equilibrium point.



Another example of SHM is that displayed by the motion of a mass attached to the end of a spring.



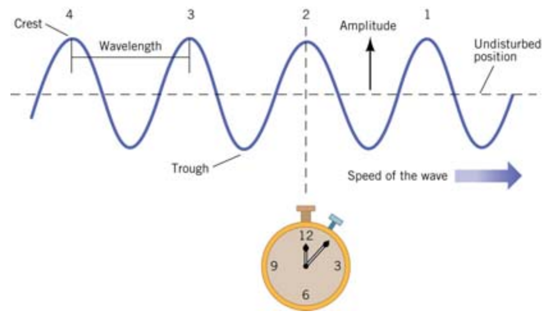
Properties of Waves

Wavelength (λ)

Frequency (f)

Velocity (v)

Amplitude (A)



Velocity of Wave

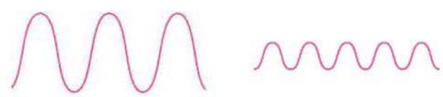
The speed of a wave is equal to the wavelength of the wave times the number of waves that pass by each second (frequency)

$$v = f \times \lambda$$

Examples

1. Jim and Gina are swinging on adjacent, equal length swings at the school playground. Jim weighs about twice as much as Gina. Who, if either, will take less time to swing back and forth? What, if anything, will change if Jim swings while standing on the seat of his swing?

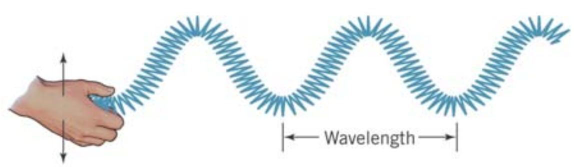
3. Two waves that travel through the same medium are sketched in the figure. Which one has the longer wavelength? Which one has the smaller amplitude? Which one has the higher frequency? Which one has the shorter period?



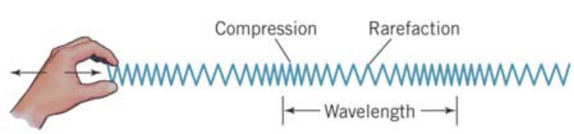
(*a*) (*b*)

4. Two waves have the same speed. The first has twice the frequency of the second. Compare the wavelengths of the two waves.

Longitudinal and Transverse Waves



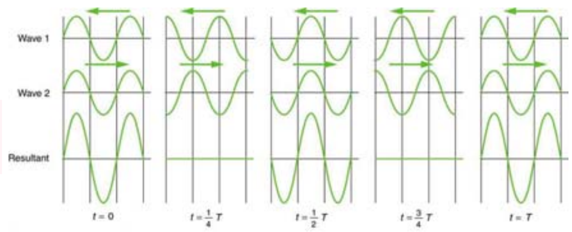
(*a*) Transverse wave

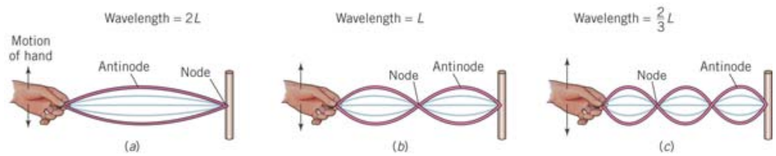


(*b*) Longitudinal wave

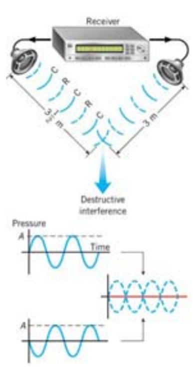
Interactions of Two or More Waves

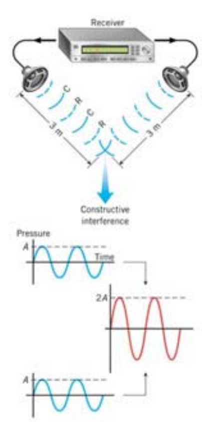
Interference and Standing Waves

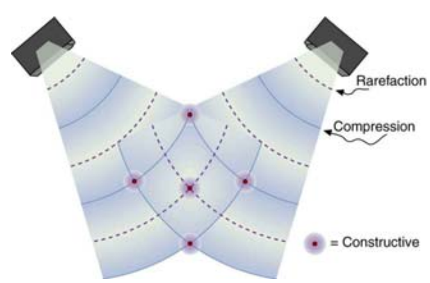




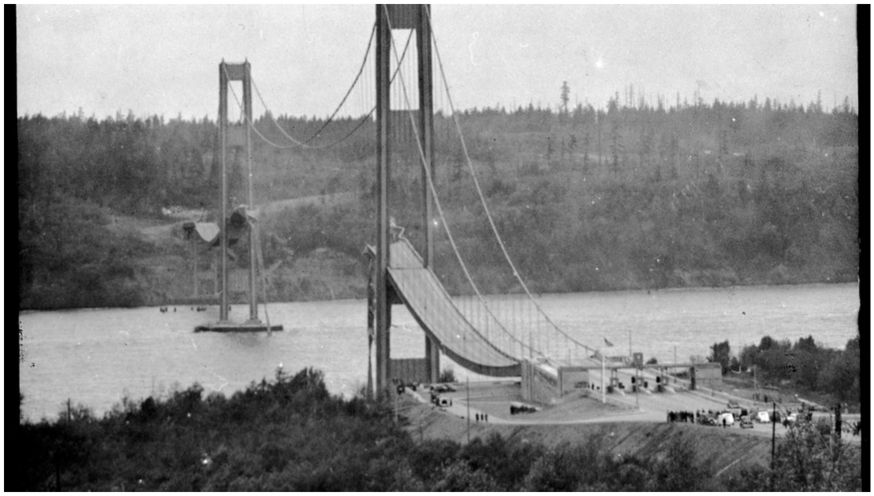
Constructive and Destructive Interferences





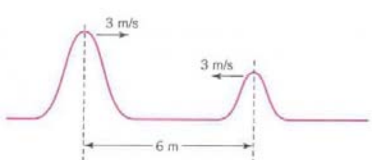


Resonance

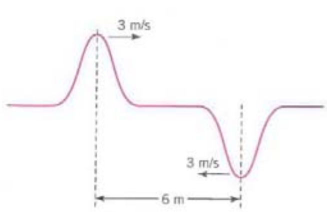


Examples

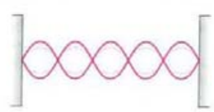
11. Two waves on a string travel toward each other as shown in the figure. They are 6 meters apart and traveling at 3 meters per second. Sketch the situation 1 second later. Sketch the situation 2 seconds later.



12. Two waves on a string travel toward each other as shown in the figure. They are 6 meters apart and traveling at 3 meters per second. Sketch the situation 1 second later. Sketch the situation 2 seconds later.



14. How many nodes and antinodes are there in the standing wave pattern shown?



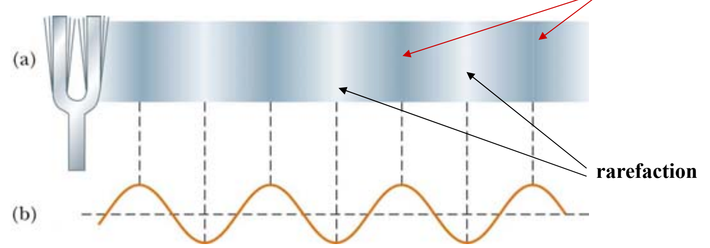
15. A police siren emits a 500-Hz tone. If the police car is chasing you, but catching up, how does that affect the sound you hear? What if you are pulling away?

17. Suppose your car desperately needs shock absorbers, so that the coil or leaf springs are essentially supporting the weight of the car. You are driving down a long stretch of road that has equally spaced bumps in it. At one particular speed, but not others, your car bounces violently in reaction to driving over the bumps. What is happening?

18. If the speed of a wave doubles while the wavelength remains the same, what happens to the frequency?

Chapter 15 Sound

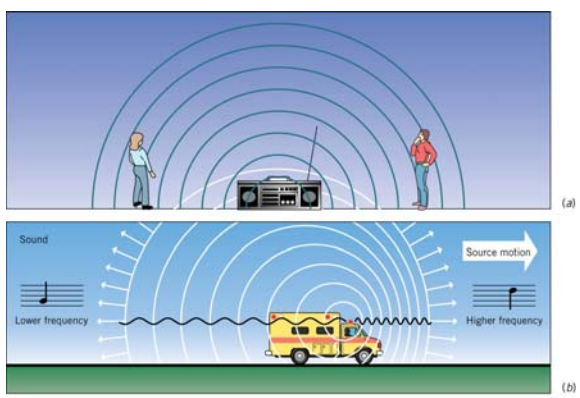
Sound waves are longitudinal waves traveling through a medium, such as air. The vibration of an object (drum, tuning fork, etc.) leads to alternate regions of high molecular density (compression) and low molecular density (rarefaction), propagating outward. This is how sound waves are generated.



Audible waves have frequencies in the 20 Hz to 20,000 Hz range. Ultrasound waves have frequencies higher than 20 kHz.

Generating Longitudinal Waves

Doppler Effect



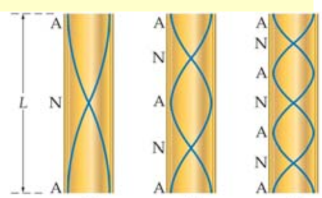
Examples

1. Rank the following media from slowest to fastest in terms of the speed with which a sound wave travels through them: air at 40°C, steel, air at 0°C, water.
2. Rosa and Jon were asked by their physical science teacher to determine the speed of sound. While walking to their dormitories after class, Jon clapped his hands, which Rosa and Jon heard a moment later as an echo. The echo bounced off a building that was 300 ft away. They knew that they could not measure the brief time for a single clap to return, so they had a brilliant idea. Jon clapped and then started to clap as soon as he heard the echo, and he then continued this synchronized clapping so that Rosa could measure the frequency. Rosa counted 56 of Jon's claps in one-half minute.
   a. What is the frequency of Jon's clapping?
   b. What is the speed of sound as determined by Rosa and Jon?
   c. How does this speed compare with the speed of sound at room temperature (about 340 m/s)?
3. Rosa and Jon decided to test their results, so they walked an additional 100 ft away from the wall. Using their calculated sound speed in Problem 2, answer the following.
   a. Predict their new clapping frequency. Will it be greater than, equal to, or less than the frequency determined in Problem 2?
   b. What is the new time between successive claps?
   c. How many claps will Jon have to make in one-half minute?

Standing Waves in Air Columns

Sound waves exiting the open end of a tube are reflected back. However, the standing wave set up inside the tube has an antinode, rather than a node, on the location of the open end. This means that the standing wave frequencies for a tube of length L, with two open ends, are

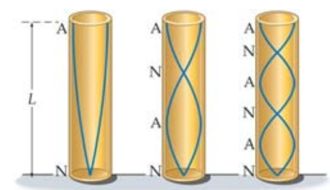
$f_n = n v / (2 L)$ n= 1, 2, 3, ...



(a) First harmonic (fundamental) (b) Second harmonic (c) Third harmonic

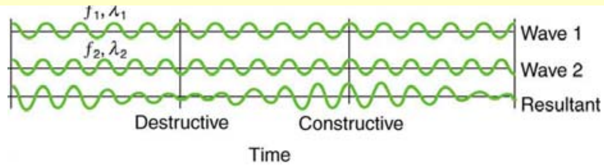
If the tube of length L is sealed on one end. A node is forced to be present at the sealed end, while an antinode exists at the open end. Thus, the natural resonant frequencies are

$f_n = n v / (4 L)$ n = 1, 3, 5, ...



(a) First harmonic (fundamental) (b) Third harmonic (c) Fifth harmonic

Beats



Two oscillations close in frequency leads to periods of approximate constructive interference and destructive interference. The volume of the sound appears to flip between "large" and "small", forming "beats".

What is the beat frequency?

Suppose at time t=0, the two primary sounds are "in phase" (maximum). We want to know the next time when the two sounds are again "in phase". The time elapsed, T_{beat}, is then obviously the "period" of the beats. This happens when the sound with the higher frequency (f_1) has gone one full cycle more than the slower wave (f_2).

Beats

$$f_1 T_{beat} - f_2 T_{beat} = 1$$
$$T_{beat} = (f_1 - f_2)^{-1}$$
$$f_{beat} = f_1 - f_2$$

$$f_{beat} = | f_1 - f_2 |$$

Examples

6. A. Assume that the speed of a sound wave produced by an elephant at 20°C is 344 m/s and the frequency is around 25 Hz.

a. What is the wavelength of this wave?
b. Can you tell the amplitude or the intensity/loudness of the sound from this information? Why?
c. Do you expect the wavelength of sound to be shorter or longer for higher-frequency sounds? Why?
d. Consider the compression and rarefaction pattern of a sound wave and identify each of the following terms in the context of the elephant's sound wave: wavelength, frequency, and amplitude.

6. B. Repeat the calculations in part a for a high-frequency sound of 150,000 Hz that might be produced by a bat in order to confirm your answer in part c. Would a human hear this sound?

10. If the length of a flute open at both ends is 0.4 m, wh the longest possible wavelength that could be produce this instrument?

11. Calculate the fundamental frequency of a 4-meter o pipe that is open at both ends. Calculate the same quency for a pipe that is open at one end and closed at end. Assume that the temperature is 20°C and the s of sound is 344 m/s.

12. A stringed instrument has a maximum string lengt 0.3 m and is tuned so that a wave travels along the s at 120 m/s.

a. What is the string's fundamental frequency at length and wave speed?
b. What are some of the overtones or harmonics as ated with this fundamental frequency?
c. Is each of the fundamental waves and its overton standing wave?
d. Do overtones enrich a sound or take away from What role does wave interference play in producing final sound you hear? Explain your answer.