Physics 1501

Fall 2008

Mechanics, Thermodynamics, Waves, Fluids

Lecture 36: Wave motion

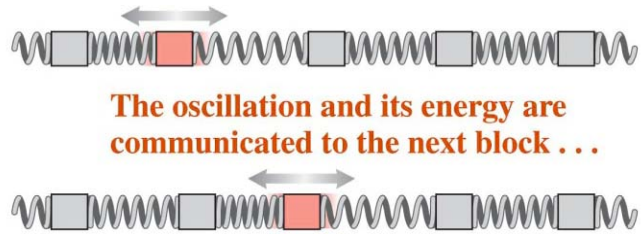
What’s a wave?

- A **wave** is a traveling disturbance that transports energy but not matter.
  - **Mechanical waves** are disturbances of a material medium.
    - The medium moves briefly as the wave goes by, but the medium itself isn’t transported any distance.
    - The wave propagates as the disturbance of the medium is communicated to adjacent parts of the medium.
  - **Electromagnetic waves**, including light, have no medium.
    - Nevertheless, they share many of the properties of mechanical waves.

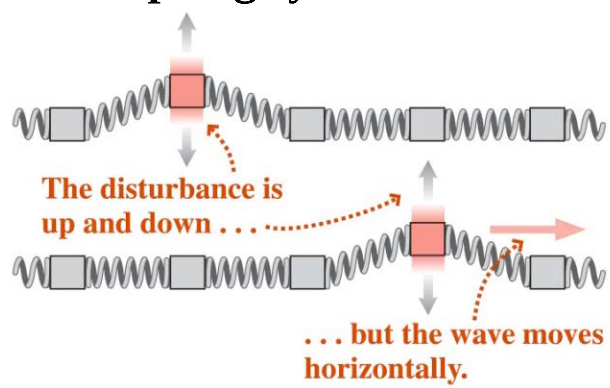
Longitudinal and Transverse waves

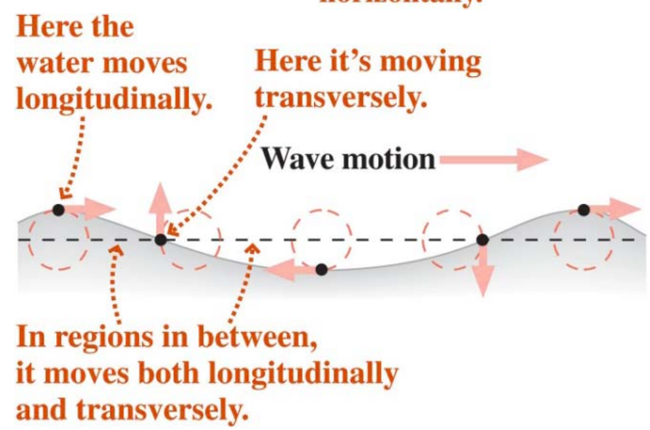
- In a **longitudinal wave**, the disturbance is parallel to the wave motion.
- In a **transverse wave**, the disturbance is perpendicular to the wave motion.
- Some waves, like surface waves on water, involve both longitudinal and transverse motions.

Longitudinal wave on a mass-spring system:



Transverse wave on a mass-spring system:

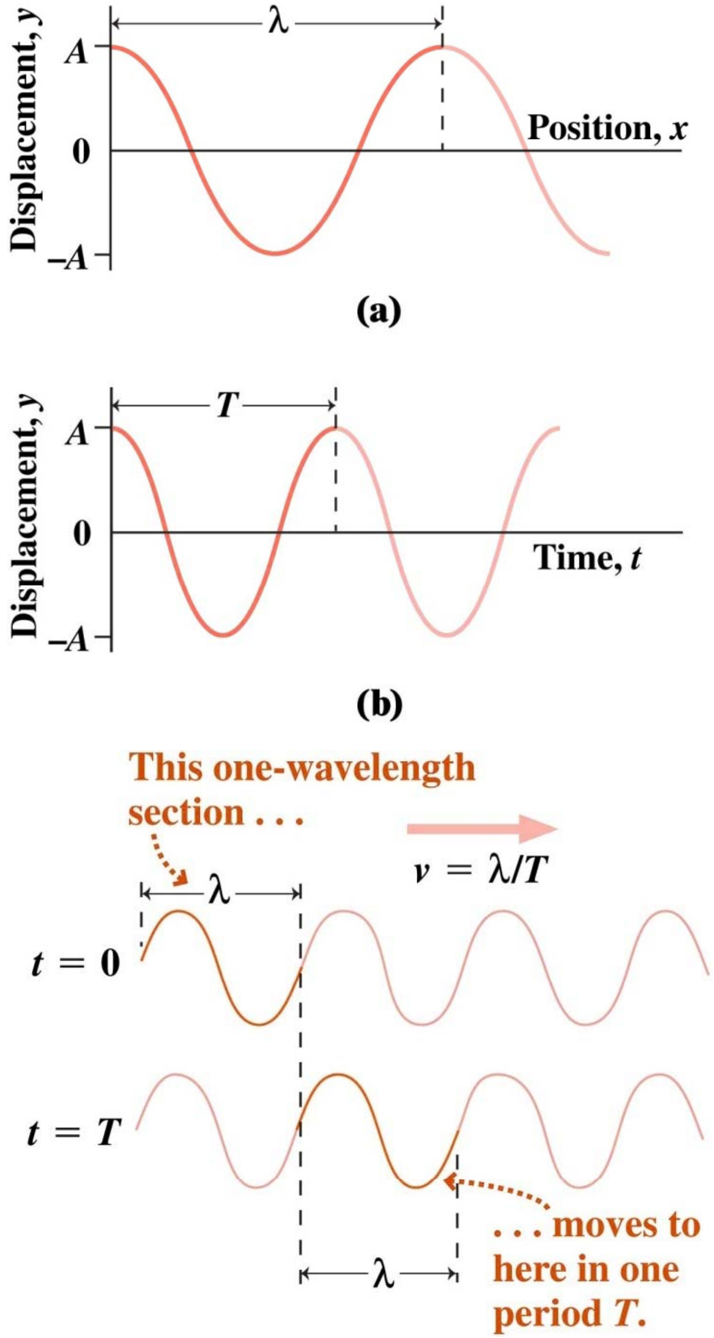




Properties of waves

- **Wavelength** λ is the distance over which a wave repeats in space.
- **Period** T is the time for a complete cycle of the wave at a fixed position:
  - **Frequency** $f = 1/T$
- **Amplitude** A is the peak value of the wave disturbance.
- **Wave speed** is the rate at which the wave propagates:

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

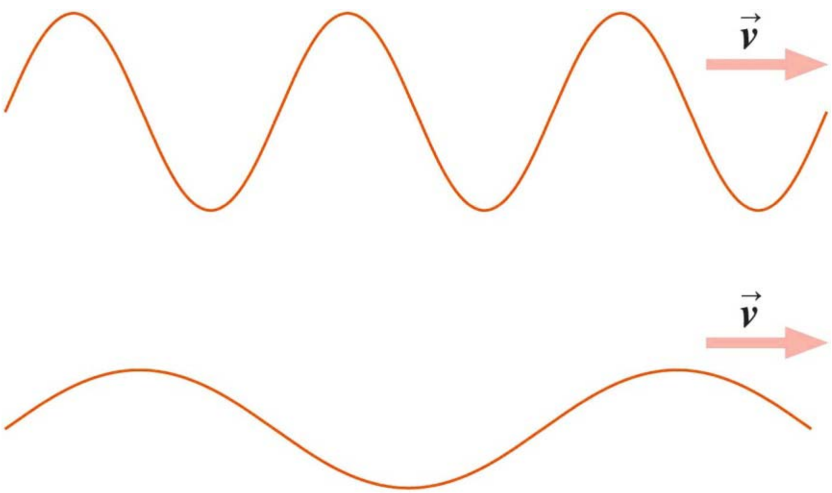


Simple harmonic waves

- **A simple harmonic wave** has a sinusoidal shape.
  - A simple harmonic wave is described by a sinusoidal function of space and time:

$$y(x,t) = A\cos(kx - \omega t)$$

    - *y* measures the wave disturbance at position *x* and time *t*.
    - $k = 2\pi/\lambda$ is the **wave number**, a measure of the rate at which the wave varies in *space.*
    - $\omega = 2\pi f = 2\pi/T$ is the **angular frequency**, a measure of the rate at which the wave varies in *time.*
    - The wave speed is $v = \lambda f = \omega/k$.



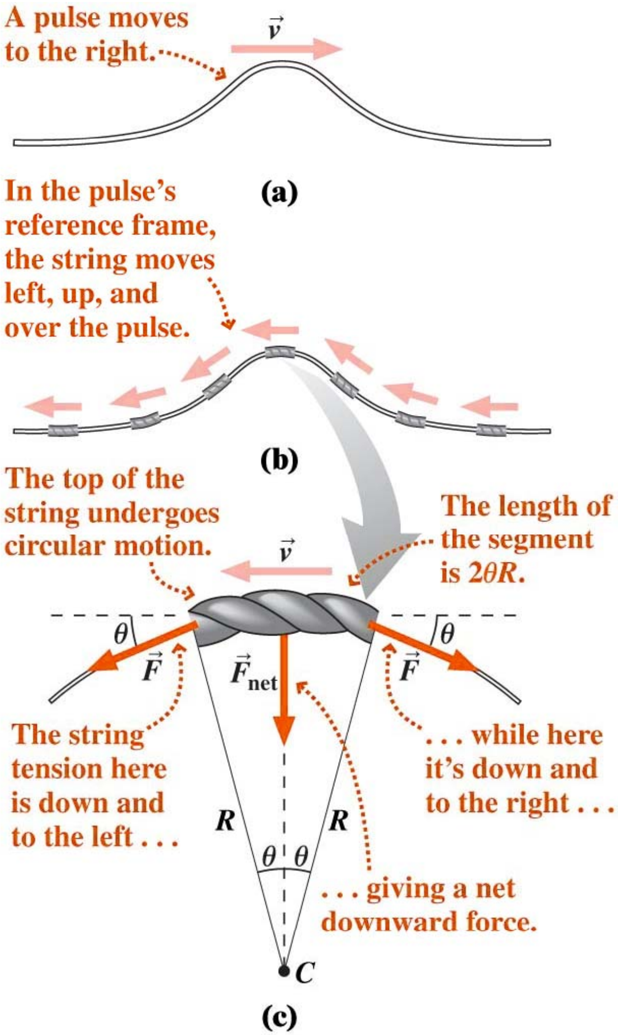
These two waves have the same speed. How do their wavenumbers, angular frequencies, and periods compare?

Waves on strings

- On strings, fibers, long springs, cables, wires, etc., tension provides the restoring force that helps transverse waves propagate.
  - The speed of such waves is

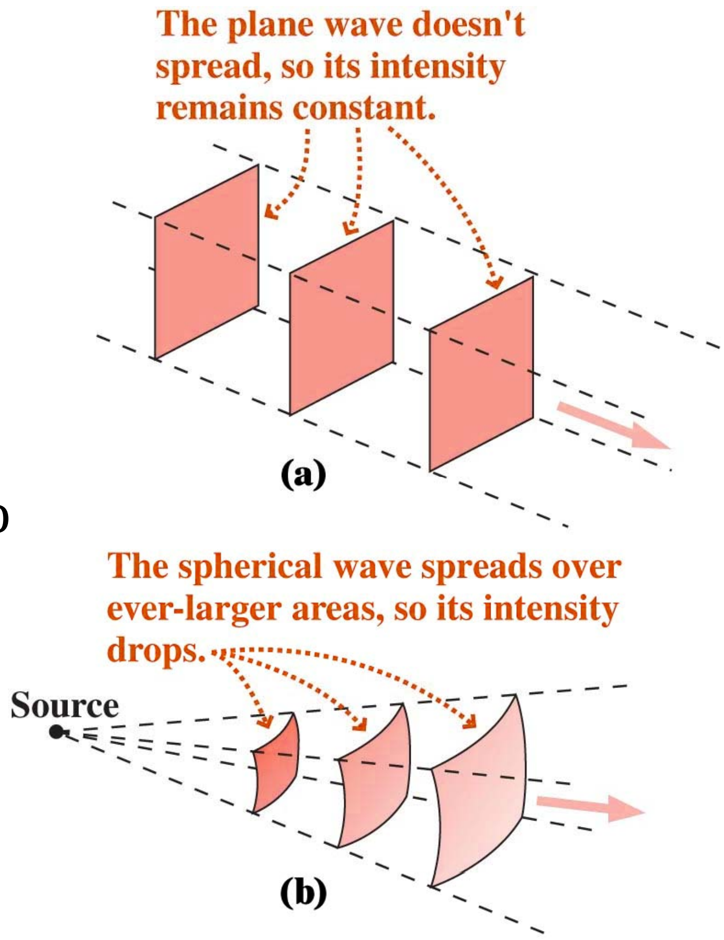
$$v = \sqrt{\frac{F}{\mu}}$$

where F is the tension and μ is the mass per unit length.



Wave power and intensity

- The power carried by a wave is proportional to the wave speed and to the square of the wave amplitude.
  - Details depend on the type of wave; for waves on a string, the average power is $\overline{P} = \frac{1}{2}\mu\omega^2 A^2 v$.
- Wave intensity is the power per unit area.
  - In a plane wave, the intensity remains constant.
    - The plane wave is a good approximation to real waves far from their source.
  - A spherical wave spreads in three dimensions, so its intensity drops as the inverse square of the distance from its source: $I = \frac{P}{A} = \frac{P}{4\pi r^2}$



question

Two identical stars are different distances from Earth. The intensity of light from the more distant star is only 1% that of the closer star. How far away is the more distant start compared with the closer star?

A. **100 times farther away**

B. **10 times farther away**

C. $\sqrt{10}$ **times farther away**

D. **twice as far away**