1.2 Waves

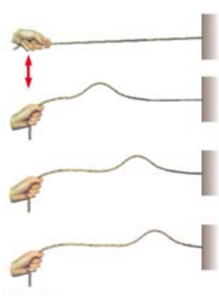
- Wave properties
  - speed
  - wavelength
- Example wave on a string

Waves

- A wave is a disturbance that propagates through distance with a certain speed. The disturbance carries energy but does not carry mass. (called traveling waves)
- Mechanical Waves- water wave, sound – propagate through matter.
- Electromagnetic Waves – radio, x-ray, light – can propagate through a vacuum.

Wave on a string

increasing time

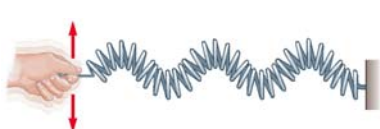


Transverse and Longitudinal Waves

Transverse Wave - The displacement is perpendicular to the direction of propagation

Longitudinal Wave- The displacement is parallel to the direction of propagation

One dimensional wave



wave on a string

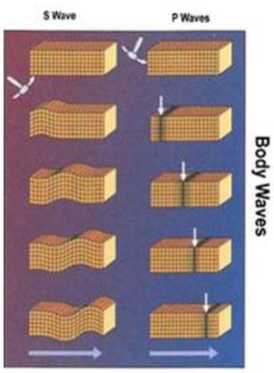
Two dimensional wave

Three dimensional wave

Transverse and Longitudinal Waves

- The transverse and longitudinal waves depend on different mechanical properties of the material.
- The speed of the transverse and longitudinal waves are different.
- Example. earthquakes

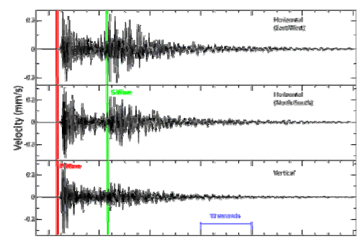
Seismic Waves



P waves- longitudinal
faster
v~ 5000 m/s (granite)

S waves – transverse
slower
v~ 3000 m/s (granite)

Seismograph record



Time →

Time difference Δt ~ 10 s.

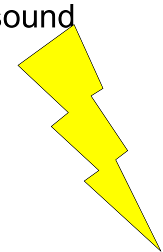
distance from earthquake = KΔt where K~8 km/s

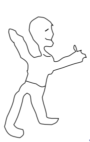
d ~ 80 km

Speed of waves
Light and sound

Speed of light =3.0x10^8 m/s

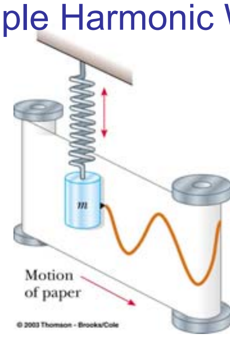
Speed of sound (air) = 300 m/s





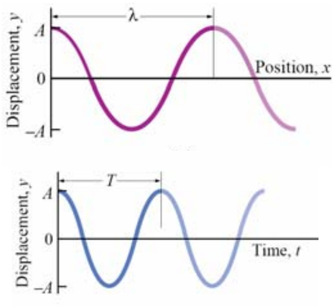
Distance from lightning is about
1 mile per 5 s difference between
the sight of lightning and sound of thunder.

Simple Harmonic Waves



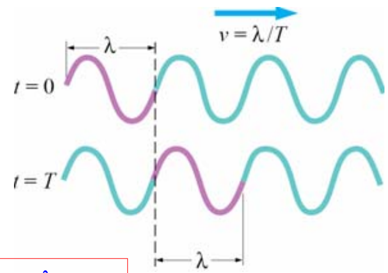
Periodic displacement vs distance

Wavelength - Spatial Period



Wave travels distance λ during one period T

Wave velocity



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

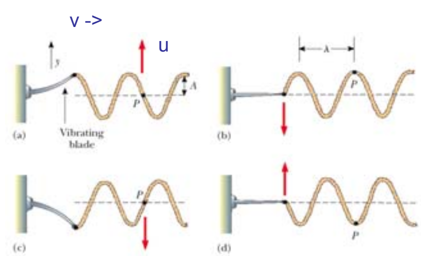
Example

A radio station transmits at a frequency of 100 MHz. Find the wavelength of the electromagnetic waves. (speed of light $=3.0\text{x}10^8$ m/s)

$$v = \lambda f$$

$$\lambda = \frac{v}{f} = \frac{3.0\text{x}10^8}{100\text{x}10^6} = 3.0\text{m}$$

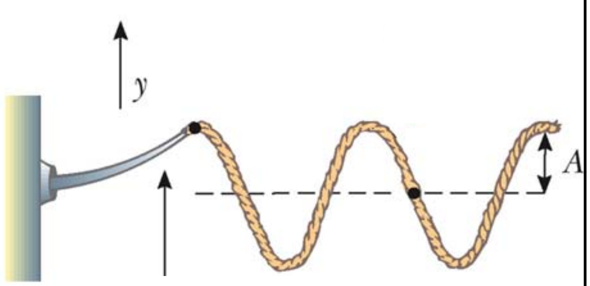
Transverse wave on a string

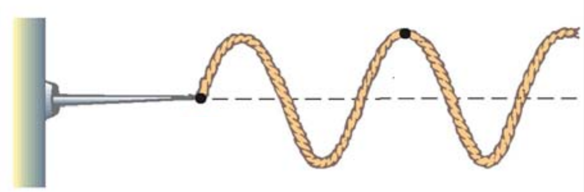


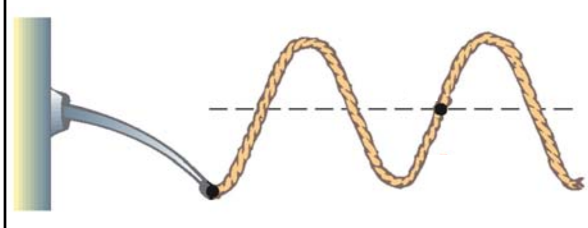
v is the wave speed

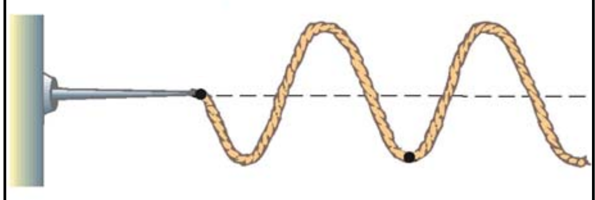
u is the speed of the string perpendicular to direction of v.

The mass at P undergoes simple harmonic motion.

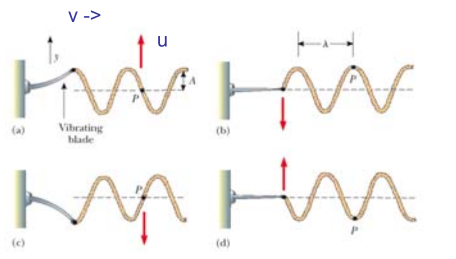








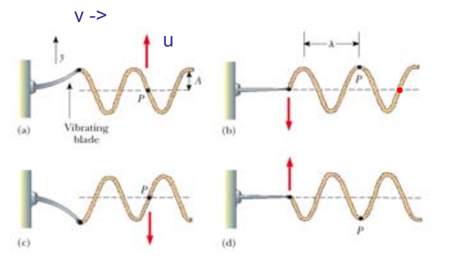
Transverse wave on a string



In going from a) to b) how much time has elapsed?

a) T
b) T/2
c) T/3
d) T/4 √

Transverse wave on a string



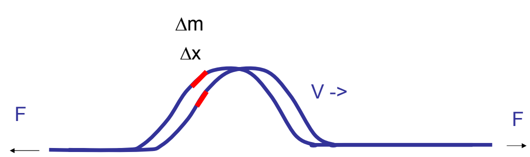
In going from a) to b) how far has the wave traveled?

a) λ
b) $\lambda/2$
c) $\lambda/4$ √
d) 0

Speed of a mechanical wave

- Dependent on a force component
- Dependent on an inertial (mass) component.

Speed of the transverse wave on a string.



$$\mu = \frac{\Delta m}{\Delta x}$$ mass density

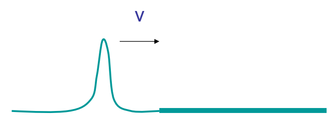
$$v = \sqrt{\frac{F}{\mu}}$$ speed of transverse wave on a string depends on the tension on the string and the mass density

Example

A transverse wave with a speed of 50 m/s is to be produced on a stretched spring. If the string has a length of 5.0 m and a mass of 0.060 kg, what tension on the string is required.

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

$$F = \frac{v^2 m}{L} = \frac{(50\,m/s)^2(0.060\,kg)}{5.0\,m} = 30\,N$$



When a wave on a string goes from a thin string to a thick string. The speed of the wave will:

a) increase

b) decrease

c) remain the same

d) can either increase or decrease