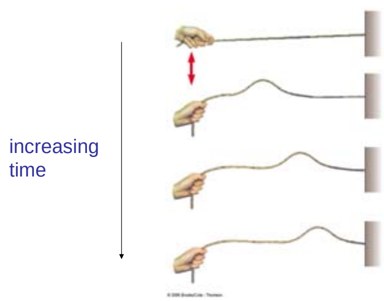
1.2 Waves

- Wave properties
  - speed
  - wavelength
- Example wave on a string
- Superposition of waves
- Reflection of waves at an interface

Waves

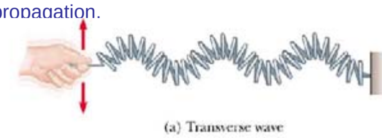
- A wave is a disturbance that propagates through distance with a certain speed. (traveling waves)
- The disturbance carries energy but does not carry mass.
- Mechanical Waves- water wave, sound – propagate through matter.
- Electromagnetic Waves – radio, x-ray, light – can propagate through a vacuum.

Wave on a string

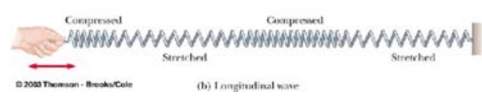


Transverse and Longitudinal Waves

Transverse Wave - The displacement is perpendicular to the direction of propagation – No displacement in direction of propagation.



Longitudinal Wave- The displacement is parallel to the direction of propagation –Pressure wave.



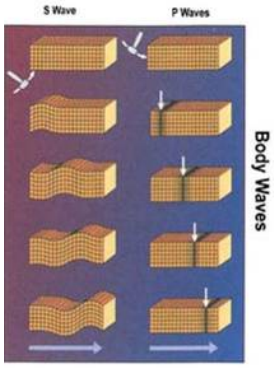
Transverse and Longitudinal Waves

- The transverse and longitudinal waves depend on different mechanical properties of the material.
- Two polarizations of transverse waves. Longitudinal waves are unpolarized.
- The speed of the transverse and longitudinal waves are different.
- Longitudinal waves but not transverse waves can propagate in a fluid.

Examples

- Transverse waves
  - Transverse wave on a string
  - Electromagnetic waves (speed = 3.00×10^8 m/s)
- Longitudinal waves
  - Sound waves in air (speed = 340 m/s)

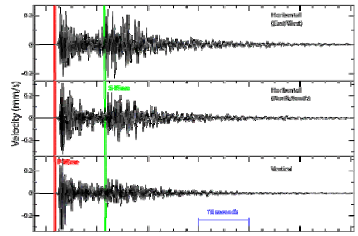
Seismic waves are transverse and longitudinal



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

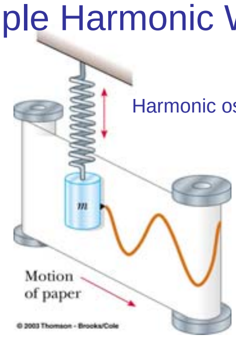
S waves – transverse
slower
v~ 3000 m/s (granite)

Seismograph record after an earthquake.



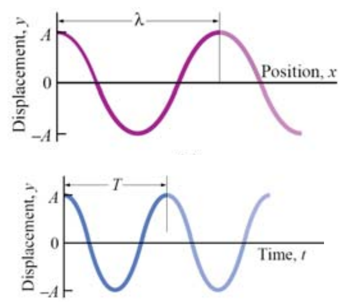
Time →

Simple Harmonic Waves



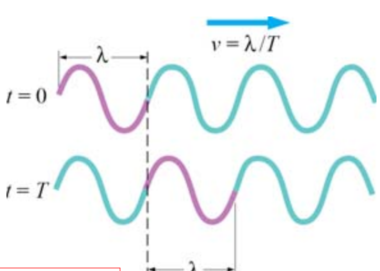
Periodic displacement vs distance

Wavelength - Spatial Period



Wave travels distance λ during one period T

Wave velocity



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

The wave travel at a velocity of one wavelength in one period.

Units

$$v = \frac{\lambda(\text{meters})}{T(\text{seconds})}$$ meters/second

$$v = \lambda(\text{meters}) f(1/\text{seconds})$$ meters/second

$$f = \frac{1}{T} = \frac{v(\text{meters/second})}{\lambda(\text{meters})}$$ 1/seconds

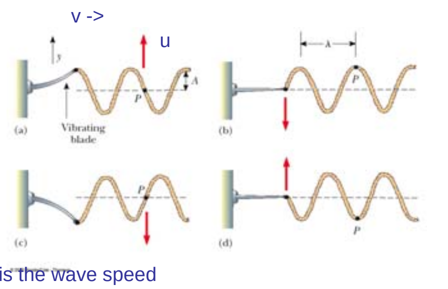
Example

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.

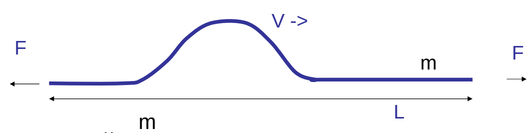
Transverse wave simulation

transverse wave simulation

http://www.surendranath.org/applets/waves/twave01a/twave01aapplet.html

For a transverse wave each segment undergoes simple harmonic motion.

Speed of the transverse wave on a string.

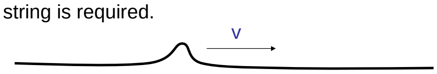


$$\mu = \frac{m}{L}$$ mass density

$$v = \sqrt{\frac{F}{\mu}}$$ 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 string. If the string has a length of 5.0 m and a mass of 0.060 kg, what tension on the string is required.

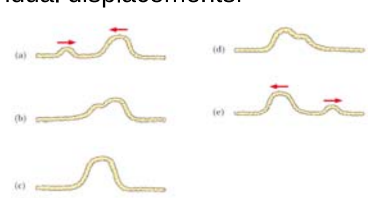


$$v = \sqrt{\frac{F}{m/L}}$$

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

Superposition Principle

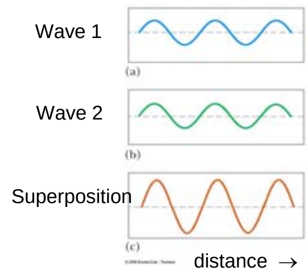
- When two waves overlap in space the displacement of the wave is the sum of the individual displacements.



Interference

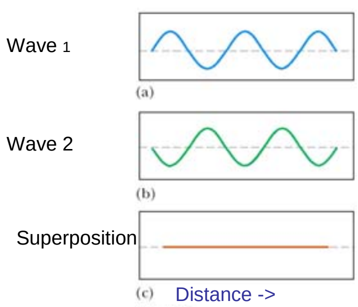
- Superposition of harmonic waves depends on the relative phase of the two waves
- Can lead to
  - – Constructive Interference
  - – Destructive Interference

Constructive Interference



The two waves have the same phase

Destructive Interference



The two waves are out of phase (by 180°, or π)

Other Interference Effects

Many other effects arise from superposition of harmonic waves – discussed later.

Standing waves. two waves traveling in opposite directions.

Beats. two waves with different frequencies.

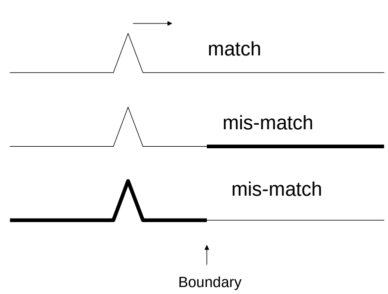
Diffraction. Interference in wave patterns in space.

Reflection and Transmission.

- When a wave reaches a boundary, part of the wave is reflected and part of the wave is transmitted.
- The amount reflected and transmitted depends on how well the media is matched at the boundary.
- The sign of the reflected wave depends on the "resistance" at the boundary.

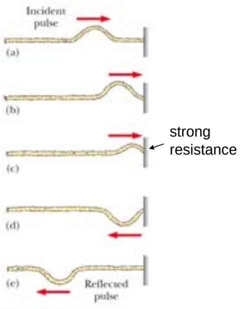
Mis-match at the boundary

part of the wave will be reflected at the boundary

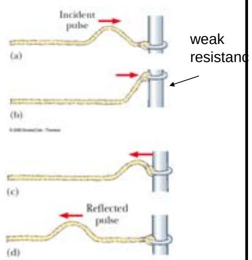


Reflection

Fixed End-
Inversion



Free End-
No Inversion



Question

A wave on a string goes from a thin string to a thick string. What picture best represents the wave some time after hitting the boundary?