Introduction to Waves & Sound

Big Ideas

1. Sound can "characterized" by a <u>wave</u>.

2. Waves can be used to "represent" any periodic or repeating motion.

3. Waves have physical properties (that can be measured) such as length, height, velocity, energy,

What is Periodic Motion

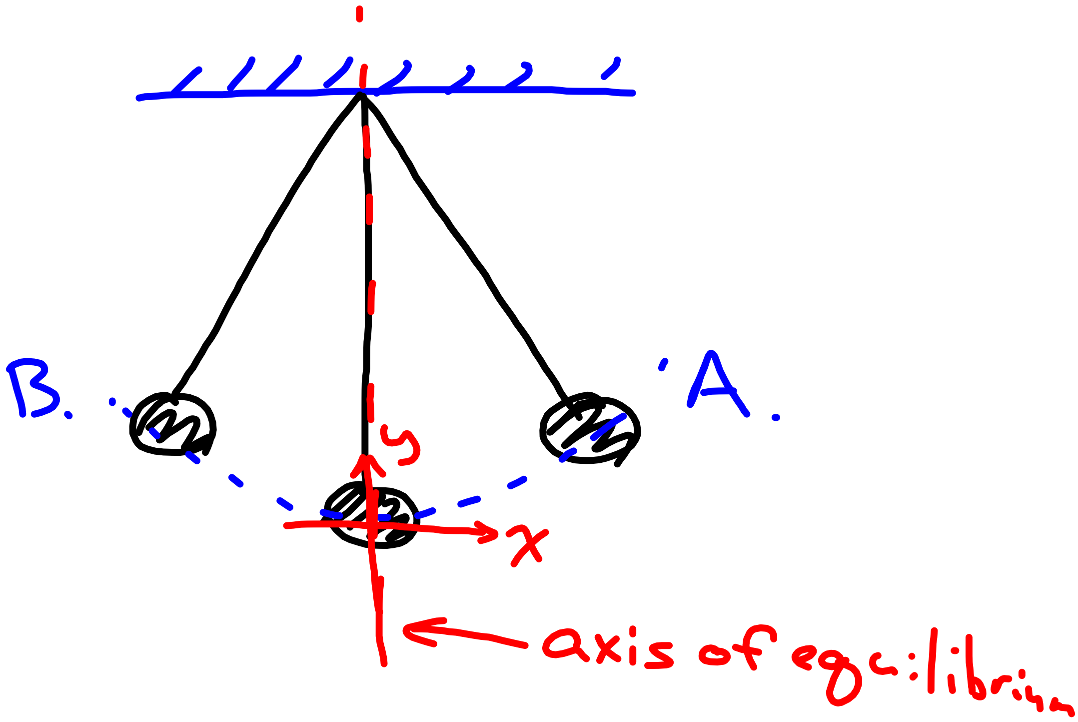
periodic motion is .. when the motion of an object repeats itself on a regular basis.

→ the vibration or oscillation is repeated in regular time intervals.

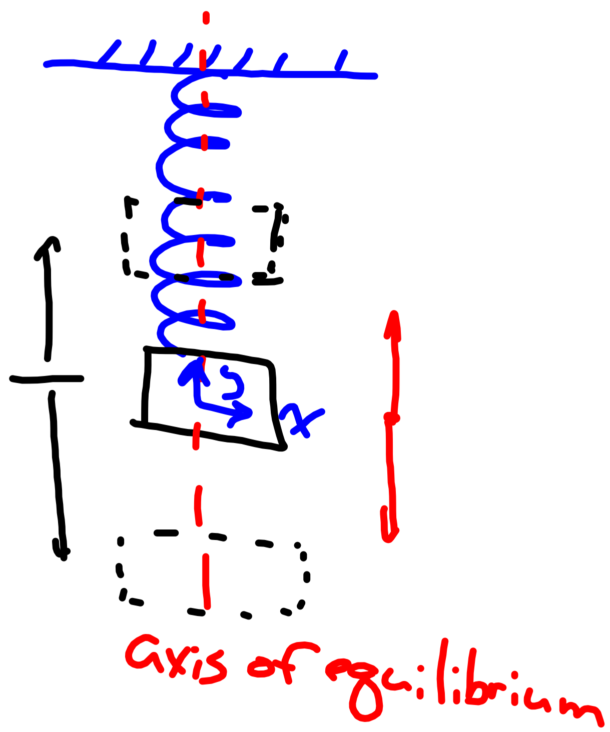
examples: daily routine
: tides
: orbit of earth
: flapping of humming bird's wings

Two Experiments

1. Pendulum

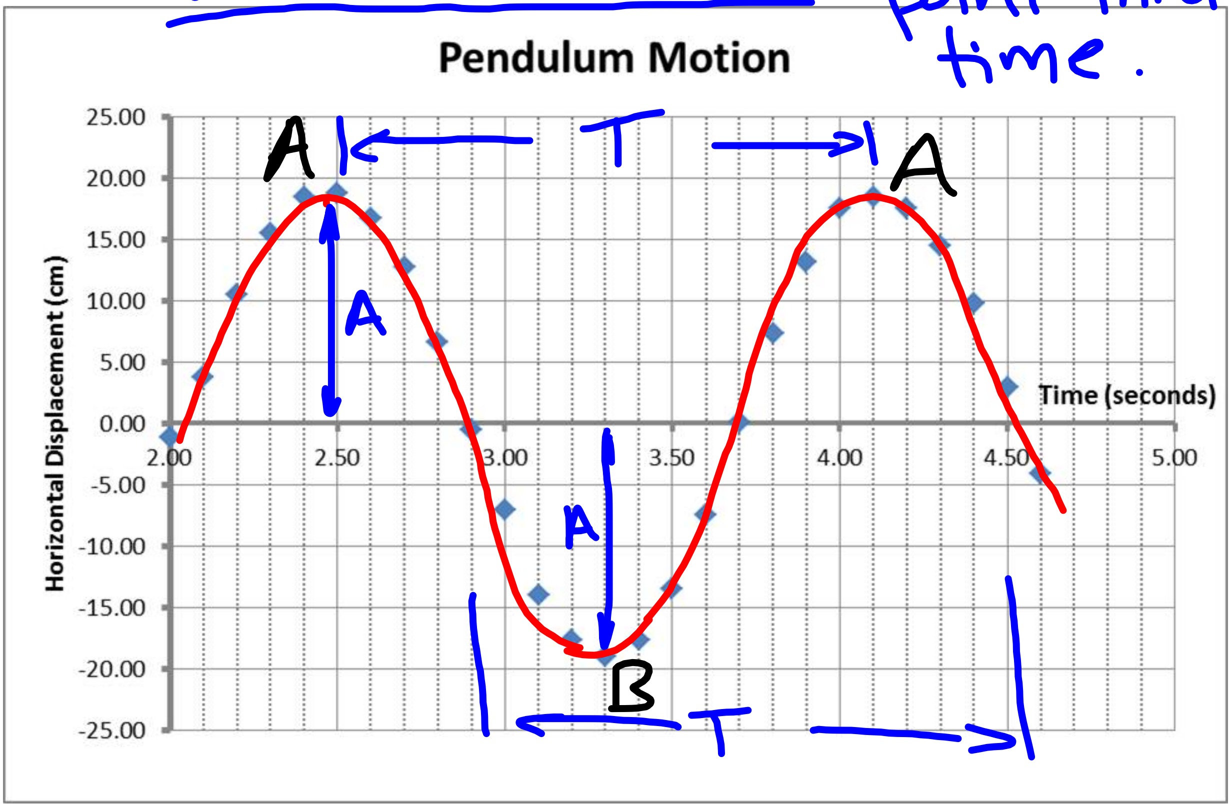


2. Bouncy Weight



VIBRATION GRAPH

tracks one point thru time.

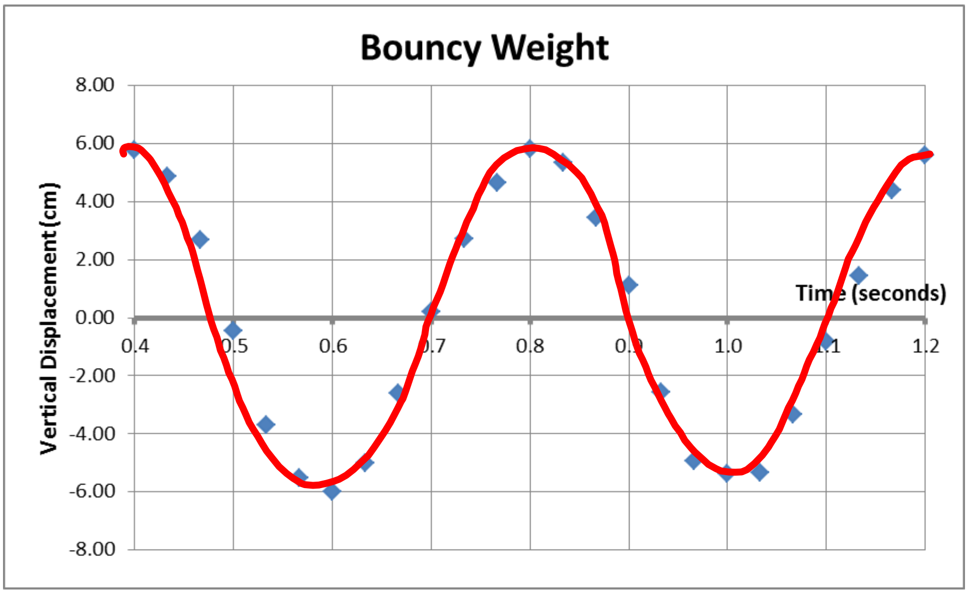


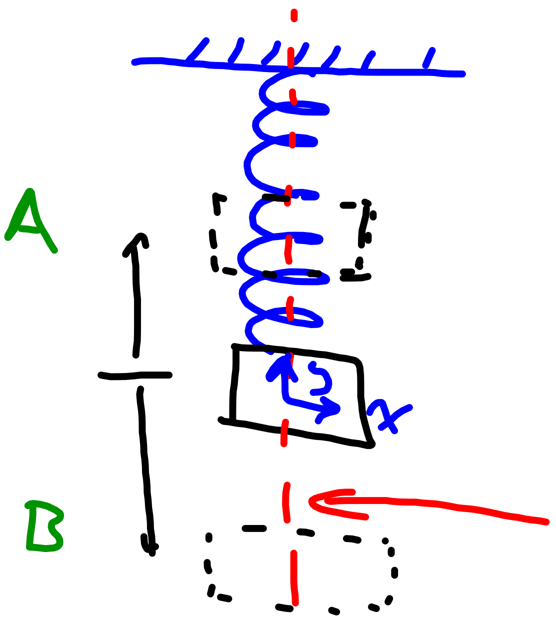
Amplitude = 19cm

Period = 1.6 s

Frequency = $\frac{1}{T}$ = 0.63 s^{-1}

= 0.63 Hz





A = 6cm

T = 0.4s

f = 2.5Hz

Characteristics of a Wave

Amplitude distance from equilibrium to max or min. A

Period time taken for one complete cycle T (secs/cycle)

Frequency inverse of period
→ # cycles completed per unit time.

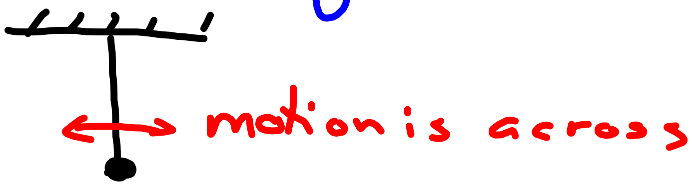
if period is in secs/cycle then frequency is in cycles/sec

1 cycle/sec = 1 Hz f

Types of Periodic Motion (Types of Waves)

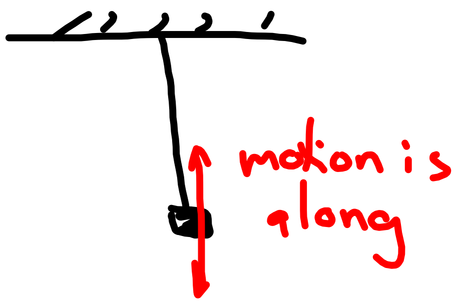
Transverse : when the motion is across (perpendicular) to the axis of equilibrium.

example: pendulum



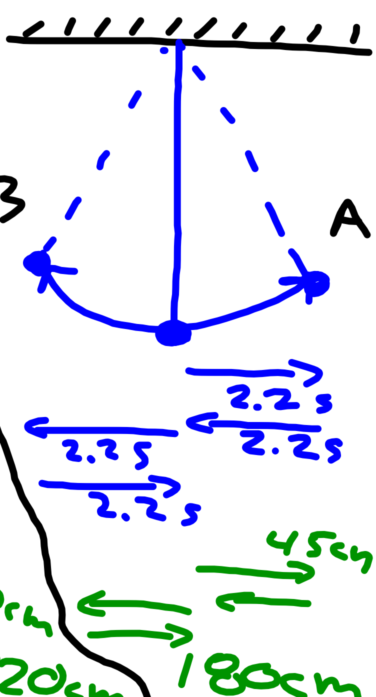
Longitudinal : when the motion is along (parallel) to the axis of equilibrium.

example: bouncy weight



Waves & Sound
Lesson 2&3 - The Wave Equation

Practice Problem #1:
A pendulum is set-up to have a horizontal amplitude of 45cm and can move this distance in 2.2 secs.
a. What is the period and frequency of this pendulum?
b. What total horizontal distance does the pendulum move in 4 cycles?



a. $T = 4 \times 2.2\,s = 8.8\,s$

$f = \frac{1}{T} = \frac{1}{8.8\,s} = 0.11\,Hz$

b. dist(1 cycle) $= 4 \times 45cm = 180cm$

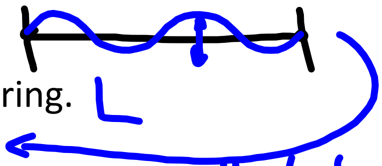
dist(4 cycles) $= 4 \times 180cm = 720cm$

Waves & Sound

Practice Problem #2 :

Write down the following 7 examples of periodic motion in your notes:

1. Swinging pendulum. T
2. Sound waves travelling down a clarinet. L
3. Vibrating guitar string. T
4. The sound produced from the vibrating guitar string. L
5. Waves in the ocean. T
6. Microwaves (yes the kind used to cook your food). T
7. Doing the wave at a football game. T



all electromagnetic waves are transverse.

Label the above examples of periodic motion as transverse or longitudinal.

Answers (T - transverse, L - Longitudinal)

1. Swinging pendulum. T

2. Sound waves travelling down a clarinet. L

3. Vibrating guitar string. T

4. The sound produced from the vibrating guitar string. L

5. Waves in the ocean. T

6. Microwaves (yes the kind used to cook your food). T

7. Doing the wave at a football game. T

WAVE MOTION

What is a Wave?

Definition:
A wave is a transfer of energy over a distance in the form of a disturbance. Most waves originate from a vibrating source.

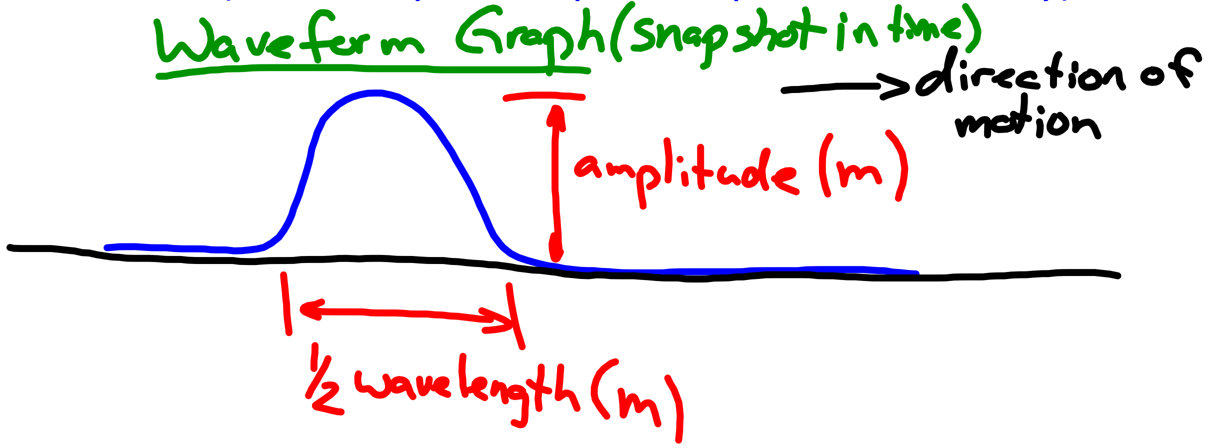
- Mechanical Waves : require a physical medium to travel through
  examples : waves on a slinky, sound waves

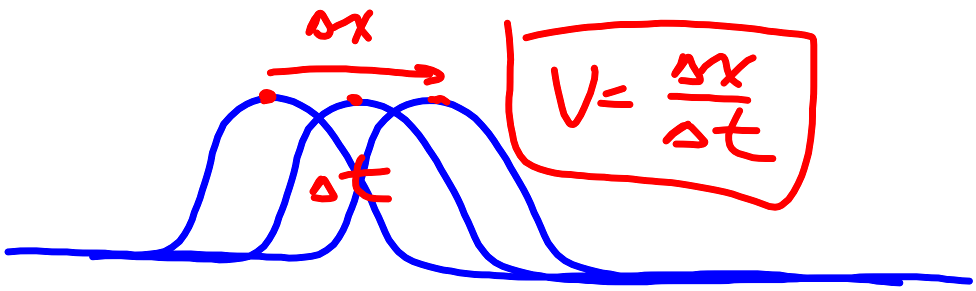
- Non Mechanical Wave: does not require any physical medium.
  - electromagnetic waves
  - gravity waves. (2016)

  → Transverse Waves.

Wave Pulse

A wave pulse is created by <u>one</u> half oscillation of the source (for example an upwards pulse on a slinky)

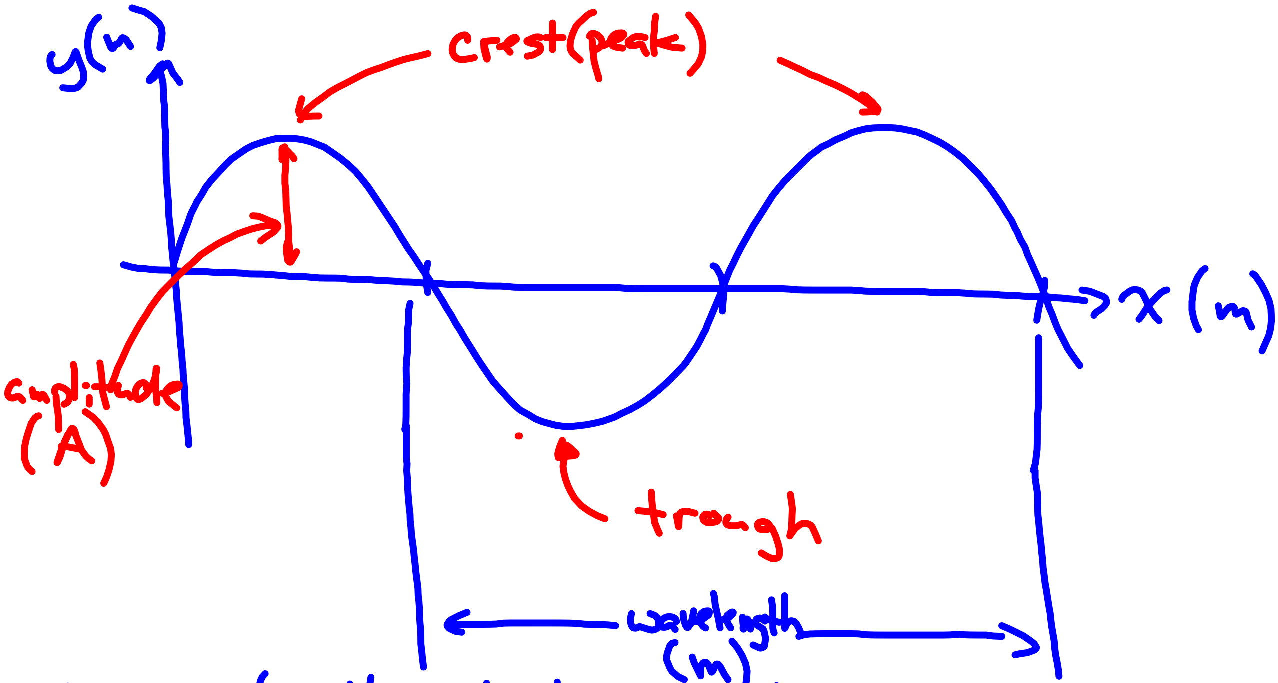




Periodic WAVES

Periodic waves originate from periodic vibrations (oscillations).

Waveform Graph (snapshot in time)

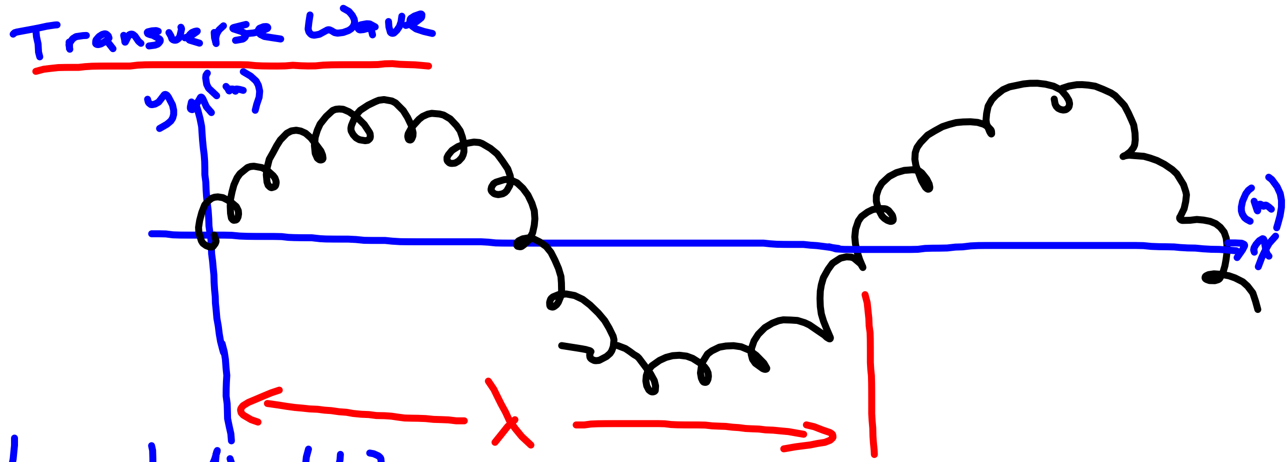


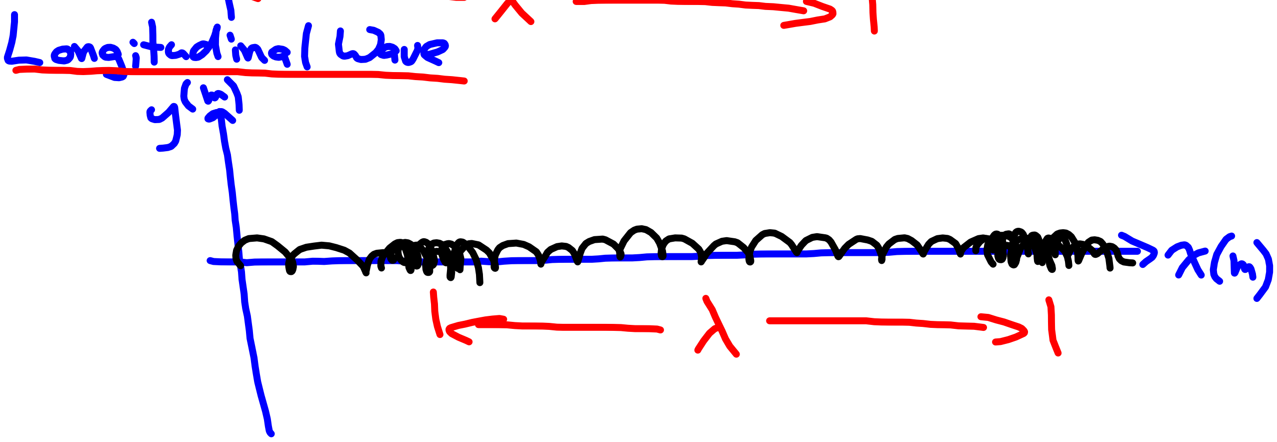
1 wavelength = distance between successive points on a waveform graph.

Symbol for wavelength → lambda

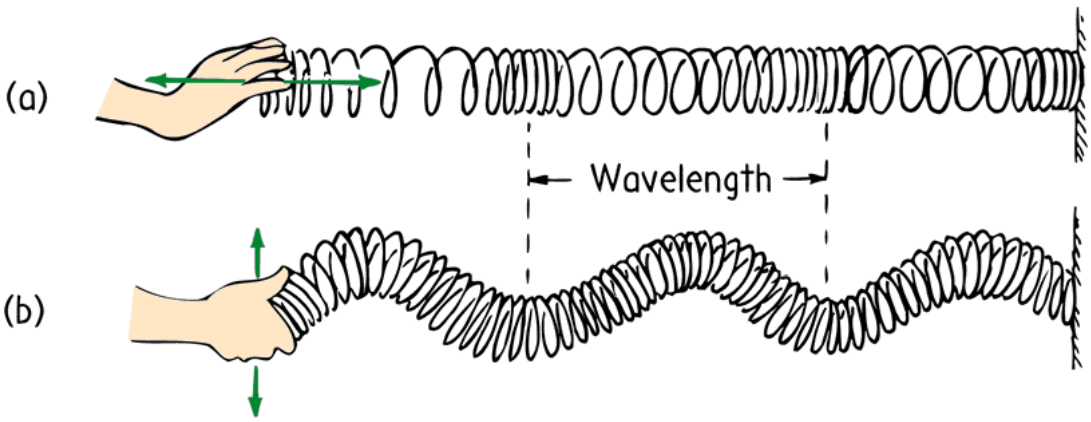
λ - units (m)

Transverse vs Longitudinal Wave

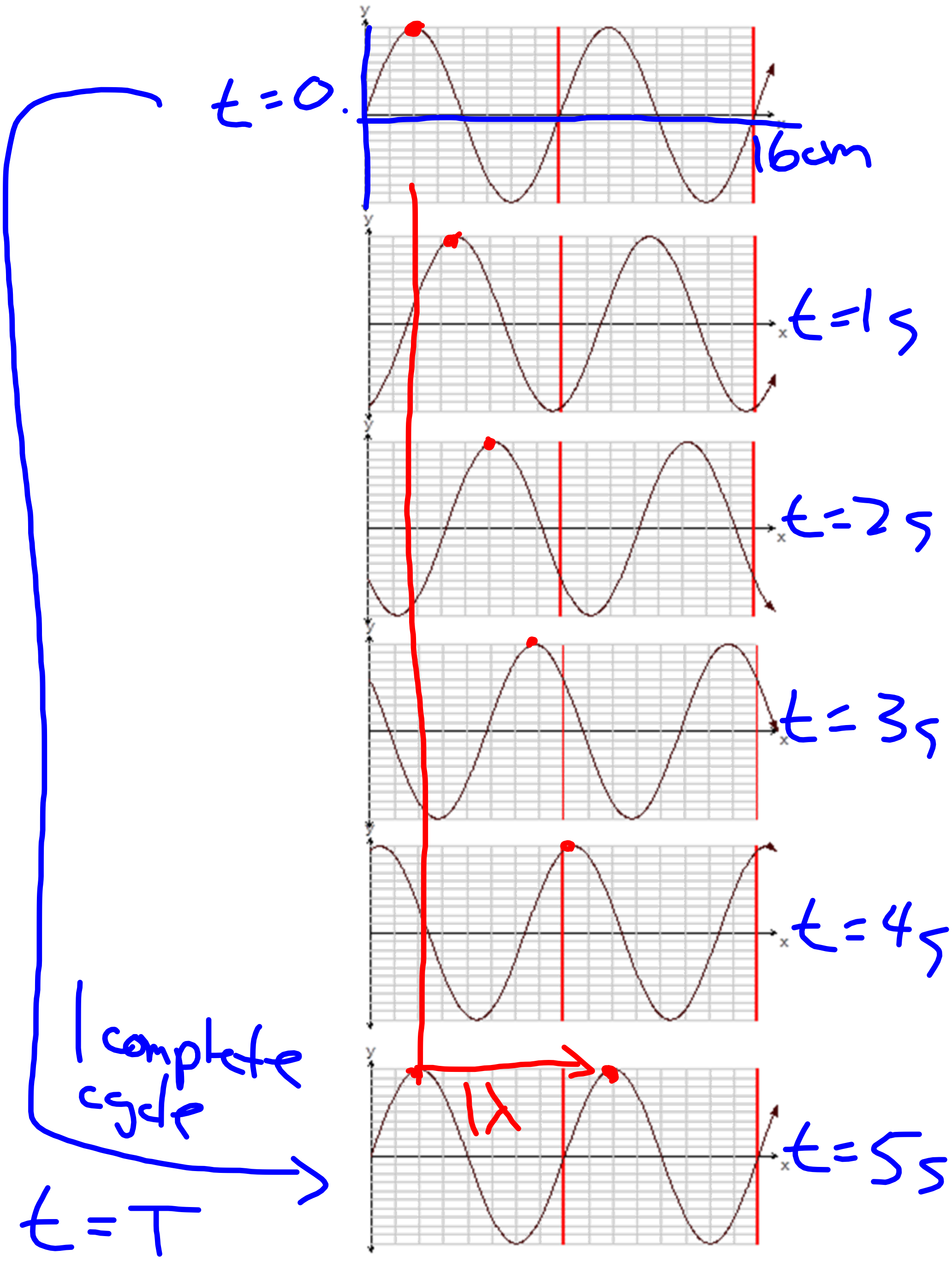




see pages 205, 206 in your text book



Wave Propagation (i.e. how fast does a wave travel?)



in 1 period wave travels 1 wavelength.

$$* \text{ speed} = \frac{\text{distance}}{\text{time}} = \frac{8\text{cm}}{5\text{s}}$$

$$= 1.6\text{cm/s}$$

Universal Wave Equation

f - Hz (s^{-1})

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

$$V = f\lambda$$

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

Factors affecting the speed of wave

The speed of a waves is ***NOT*** affected by:

- The frequency of vibration (or wavelength)
- The amplitude of vibration

The only factor affecting the speed of a wave is the medium transmitting the wave (i.e. the properties of the slinky or the properties of air for sound waves).

Practice Problems

1. A ruby-throated hummingbird beats its wings at a rate of about 70 wing beats per second.
a. What is the frequency in Hertz of the sound wave?
b. Assuming the sound wave moves with a velocity of 350 m/s, what is the wavelength of the wave?

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

a. 70 beats per second.

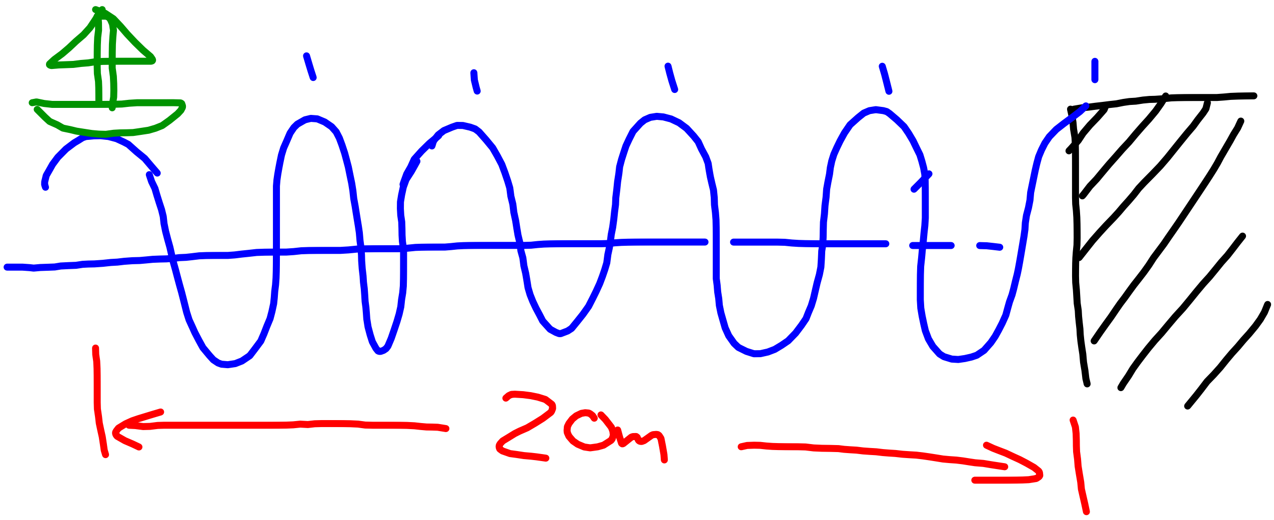
$f = 70 Hz$ $\left(T = \frac{1}{f} = \frac{1}{70} s\right)$

b. $\lambda = \frac{V}{f} = \frac{350 m/s}{70 Hz}$ $Hz \rightarrow /s$

$= 5 m$

Practice Problems

2. A large crest of water requires 8 seconds to travel from a fishing boat to the pier which is 20m away. While sitting on the boat, the fishermen notice that 15 crests pass the boat in 24 seconds. What is the wavelength of the waves?



$$V = f\lambda$$

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

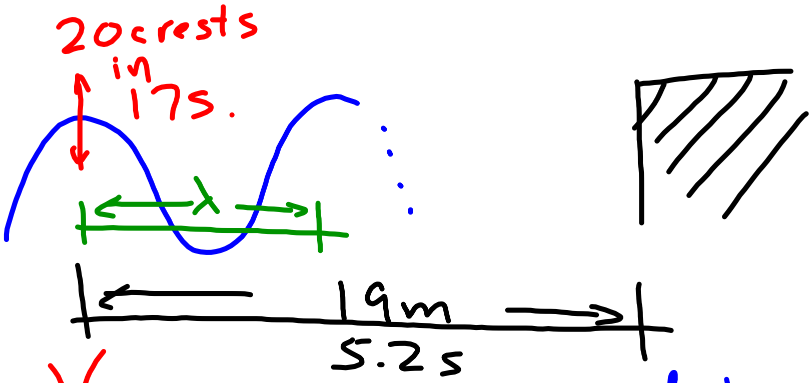
$$v = \frac{dist}{time} = \frac{20m}{8s} = 2.5 \, m/s$$

$$f = \frac{crests}{sec} = \frac{15 \, crests}{24 \, sec} = 0.625 \, Hz$$

$$\lambda = \frac{2.5 \, m/s}{0.625 \, Hz} = 4m$$

Homework Review :Page 211 #2-8

#4



$$\lambda = \frac{V}{f} = \frac{3.65\,m/s}{1.176\,Hz} = 3.1\,m$$

$$f = \frac{cycles}{sec} = \frac{20\,cycles}{17\,s} = 1.176\,Hz$$

$$V = \frac{dist}{time} = \frac{19\,m}{5.2\,s} = 3.65\,m/s$$

units $\frac{m/s}{/s} = m$

#8

$f = 102\,MHz$ M $\times 10^6$

$V = 3.00 \times 10^8\,m/s$

$$\lambda = \frac{V}{f} = \frac{3.00 \times 10^8\,m/s}{102 \times 10^6\,Hz} = 2.9\,m$$

Velocity, c = 3/0x10^8 m/s (this is the speed of light)

Practice Problem

A speaker has a woofer with diameter of 55cm and a tweeter with diameter of 4 cm. What is the frequency of the sounds that have wavelengths equal to these diameters if the speed of sound is 344 m/s?

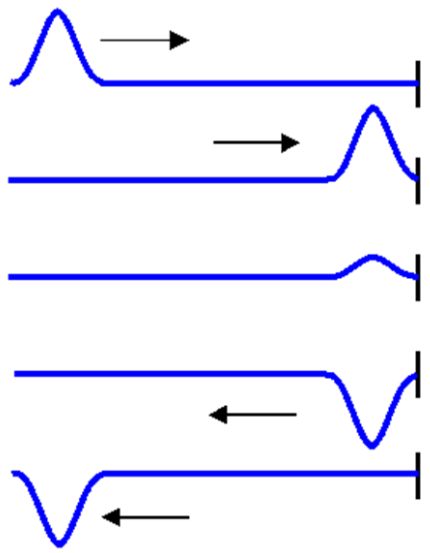
$$f = \frac{v}{\lambda} = \frac{344\,m/s}{.55\,m} = 625\,Hz$$

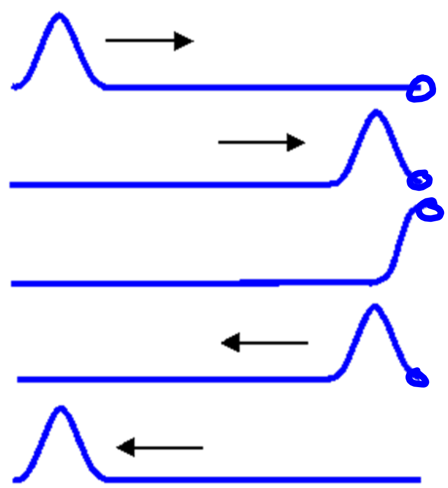
$$f = \frac{v}{\lambda} = \frac{344\,m/s}{.04} = 8600\,Hz$$

Reflections

From a fixed end
- reflected pulse is inverted

From a free (or loose end)
- reflected pulse is not inverted

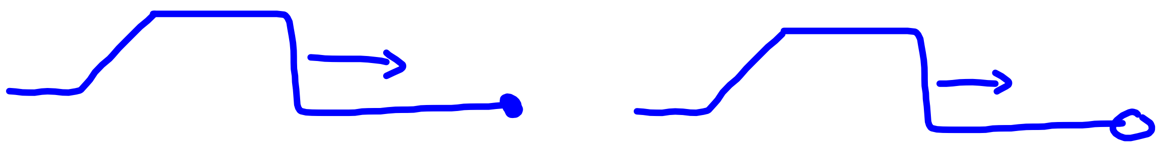


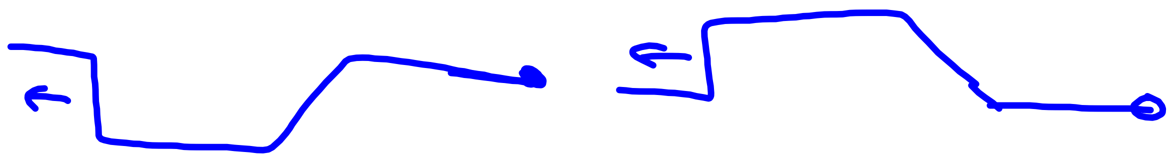


Other Examples

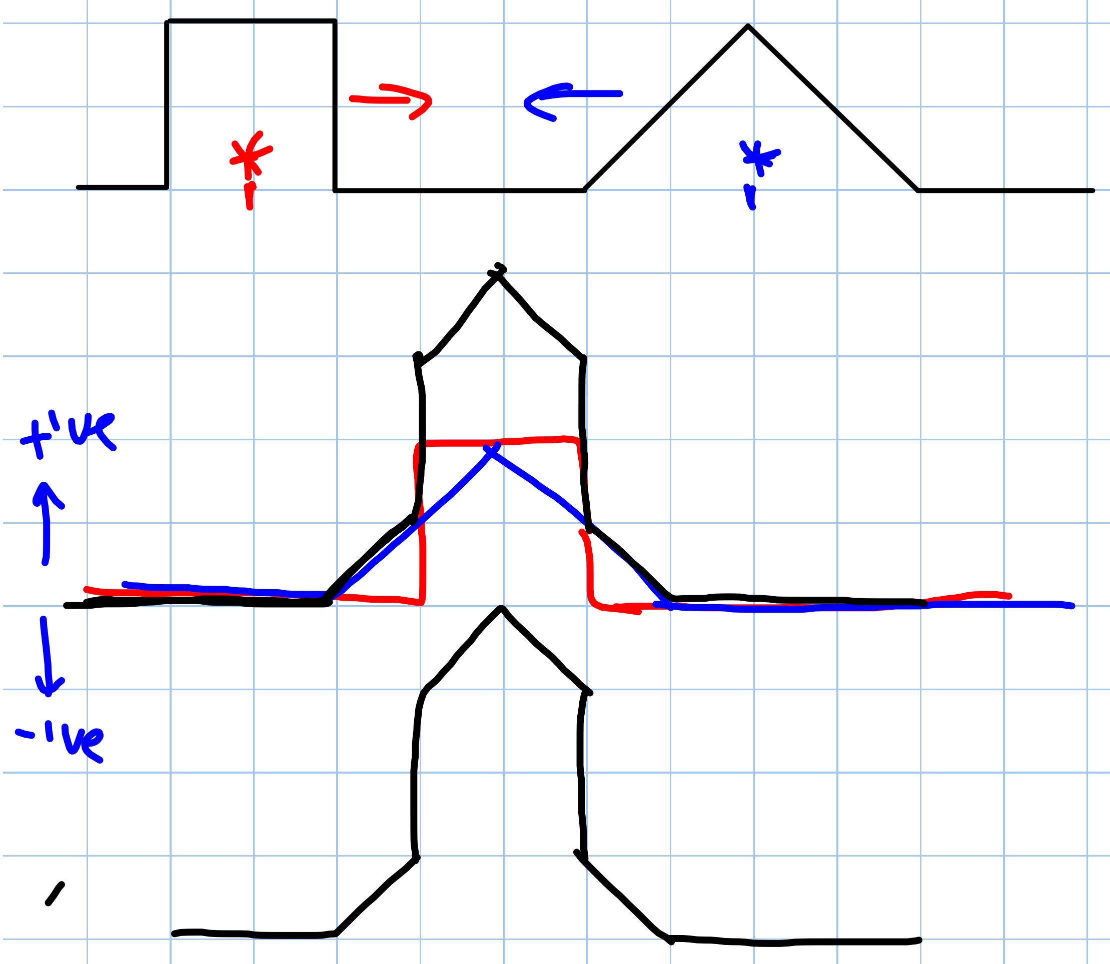
Fixed

Open

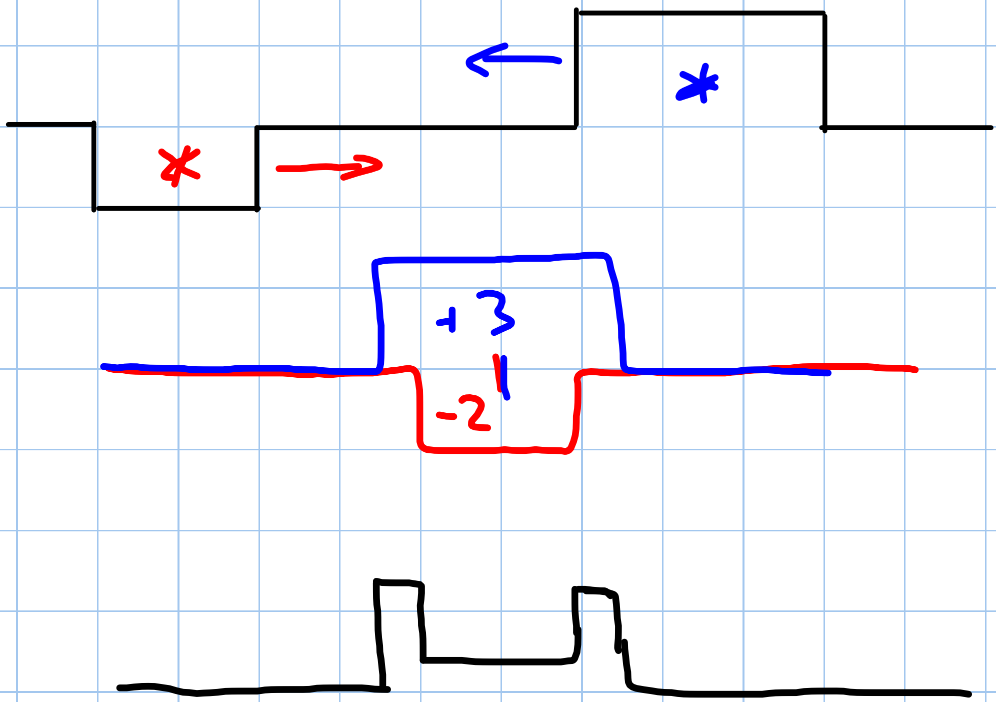


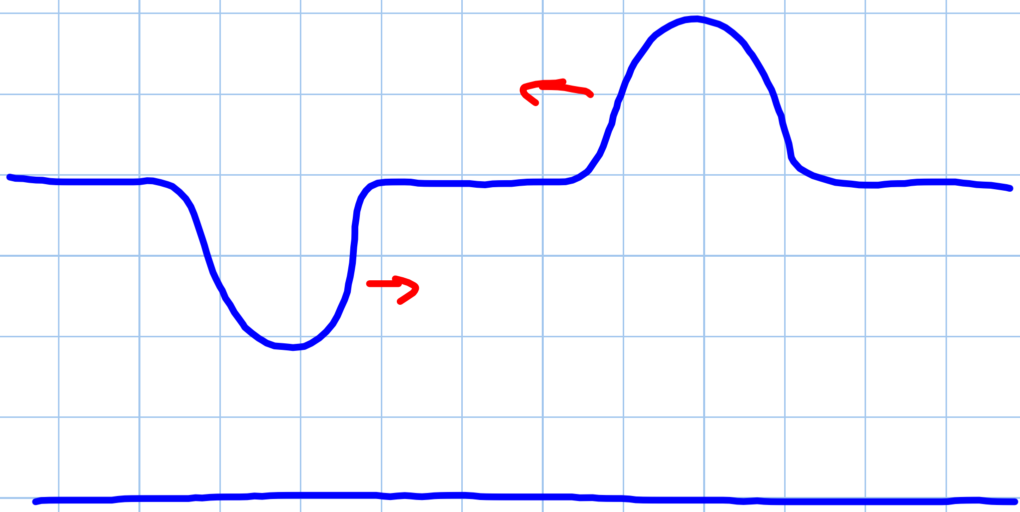


Constructive Interference



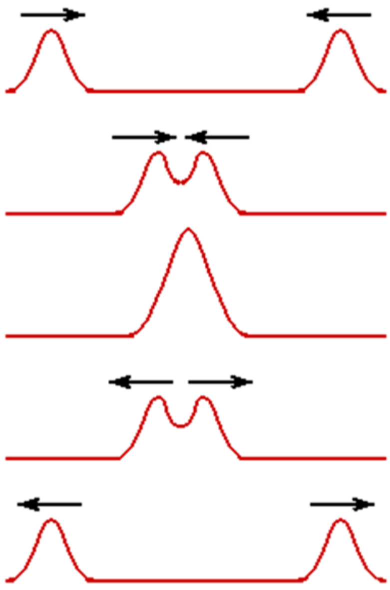
Destructive Interference.





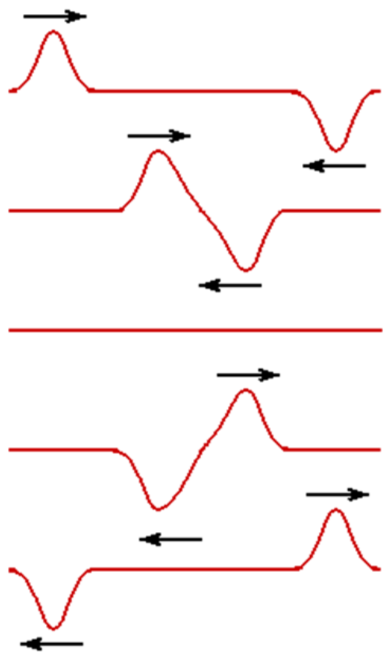
Constructive Interference

when two positive or two negative amplitude pulses add together.



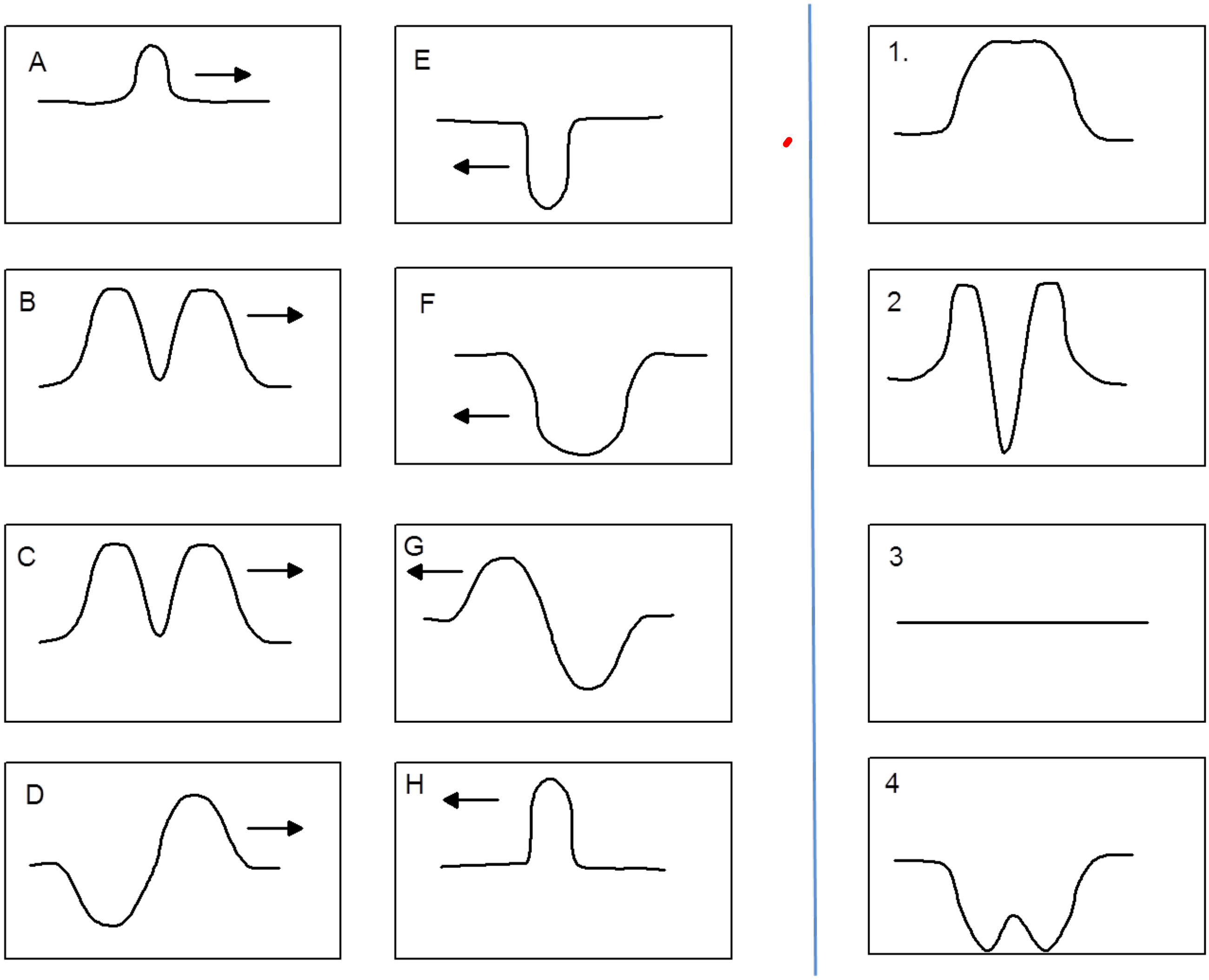
Destructive Interference

when a positive & a negative pulse interfer with each other.

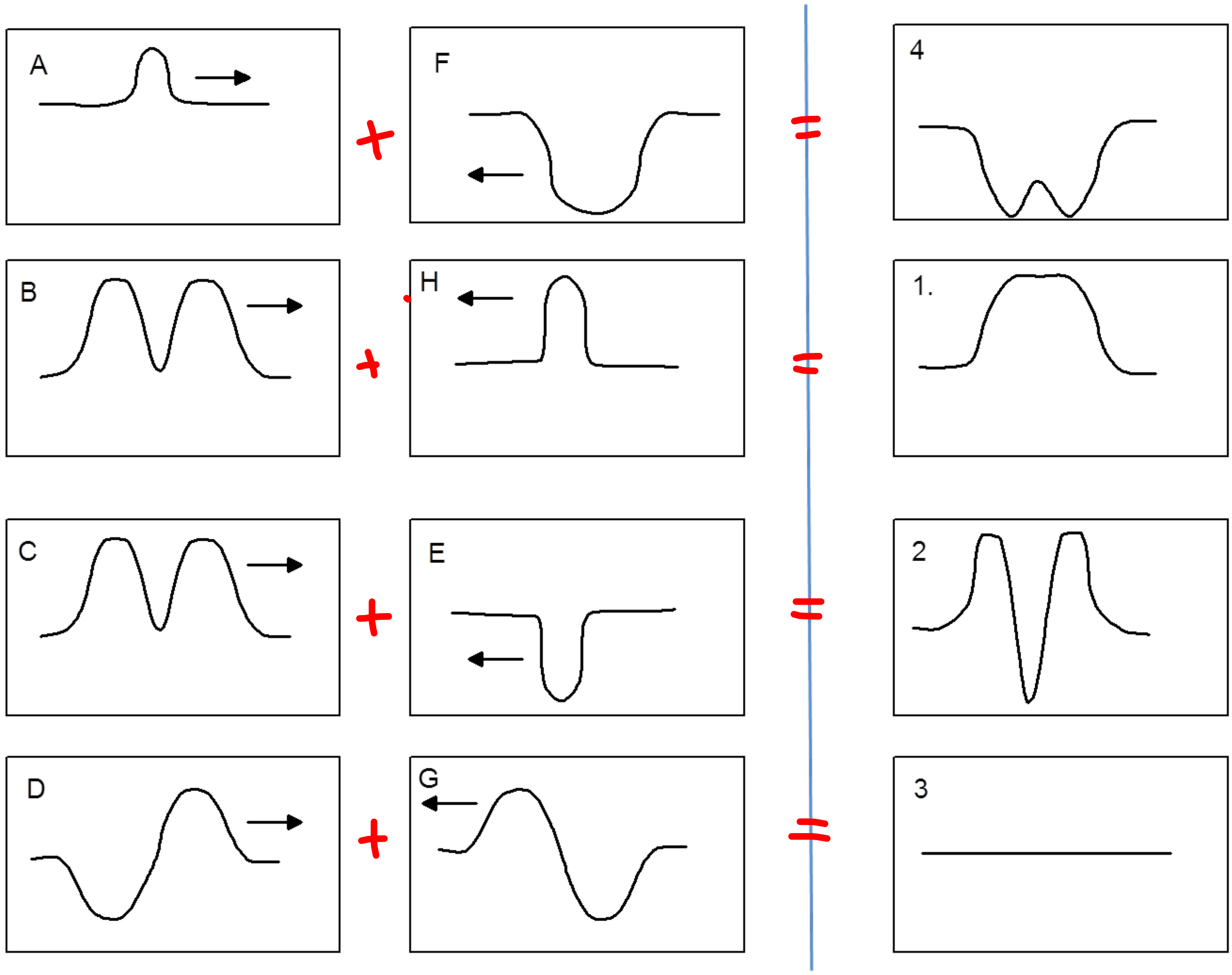


Interference Practice

determine which waves add up to waves #1, 2, 3 or 4.



Answers

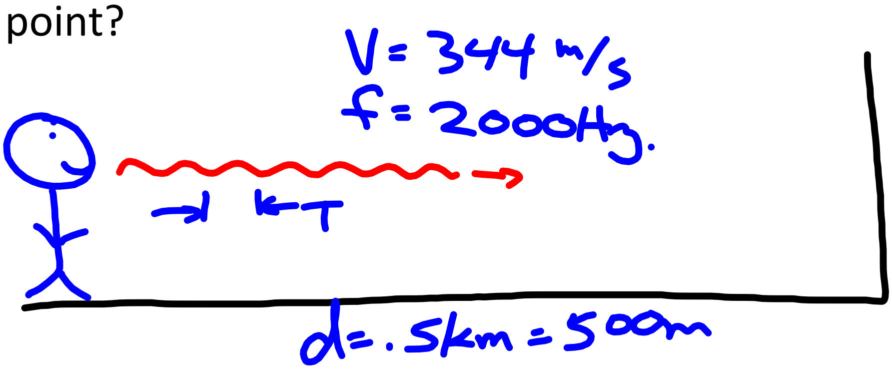


Warm-Up

A sound wave is travelling at 344 m/s and has a frequency of 2,000 Hz. The sound wave travels across a canyon 0.5km wide and bounces back (i.e. echoes).

a. what is the wavelength of the sound wave?

b. how long does it take for the echo to return to it's starting point?



a. $V = f\lambda \Rightarrow \lambda = \frac{V}{f} = \frac{344 \text{ m/s}}{2000 \text{ Hz}} = 0.172 \text{ m}$

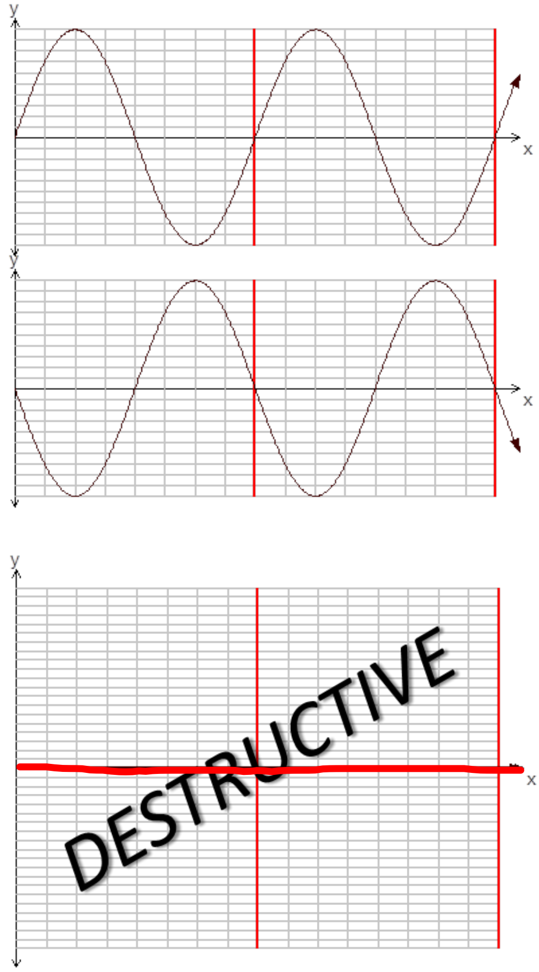
b. $T = \frac{1}{f} = \frac{1}{2000} = 0.0005$

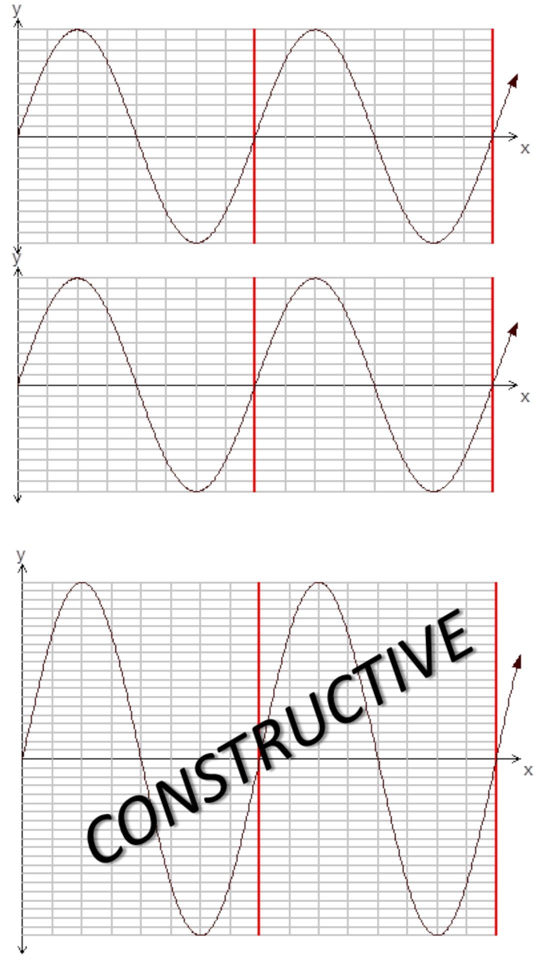
$V = \frac{\text{dist}}{\text{time}}$

$\text{time} = \frac{\text{dist}}{V} = \frac{500 \text{ m}}{344 \text{ m/s}} = 1.45 \text{ s}$

$\therefore$ total time to reach canyon wall & back $= 2 \times 1.45 \text{ s}$
$= 2.9 \text{ s}$.

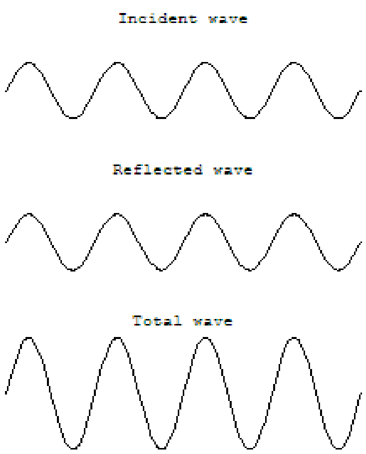
Interference Practice





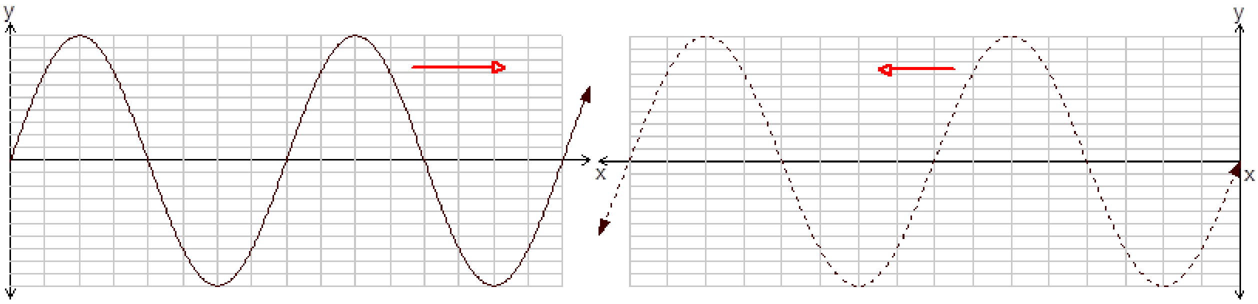
Reflections - wave pulses

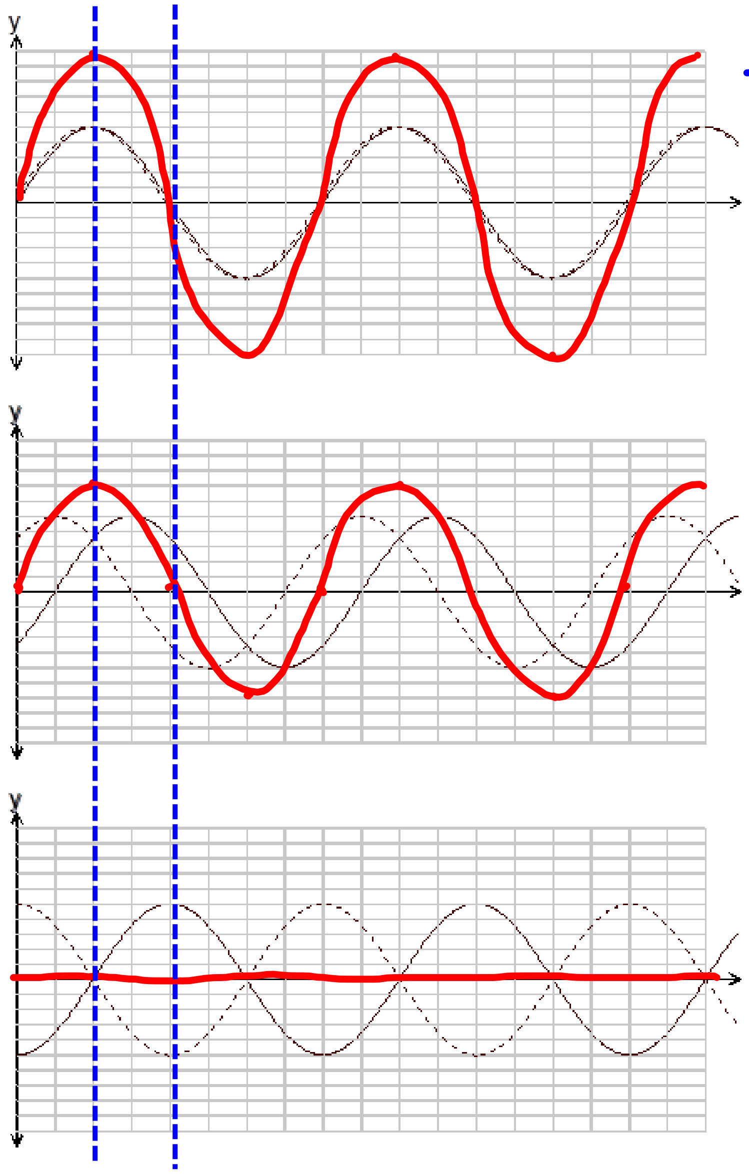
What happens if a periodic wave reflects off a surface?



resources:
- Phet Website
- Justin S. Flash Video File

Standing Waves (handout)

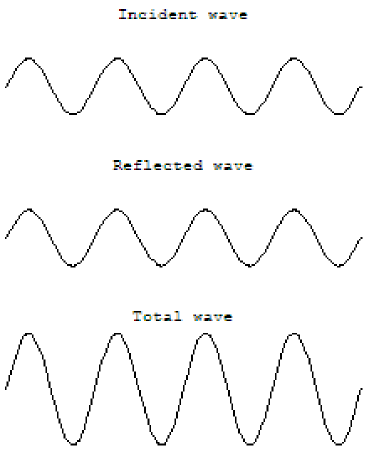


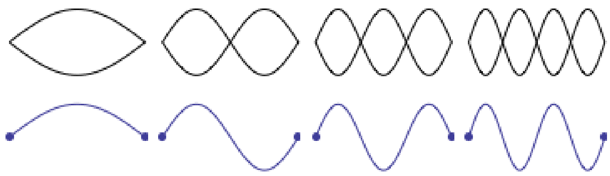


- Amplitude doubles
- λ stays same

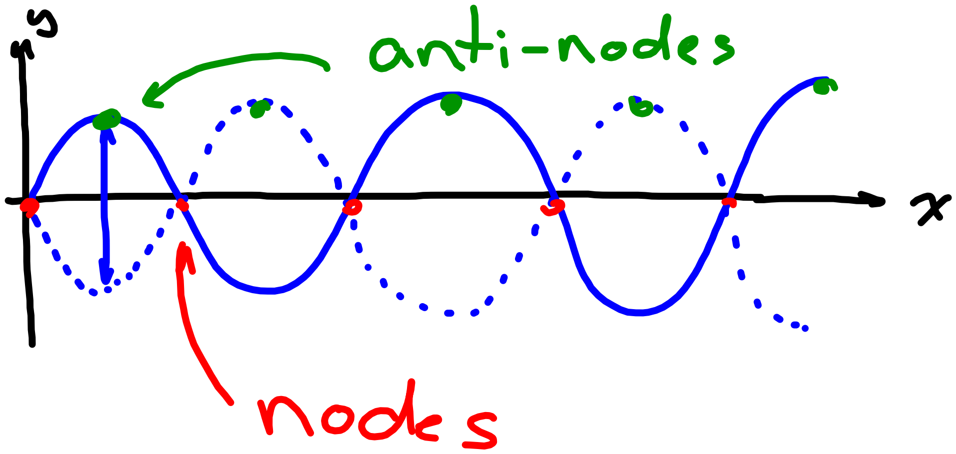
- Amplitude increases
- λ stays same

Standing Transverse Waves (i.e. slinky, string)





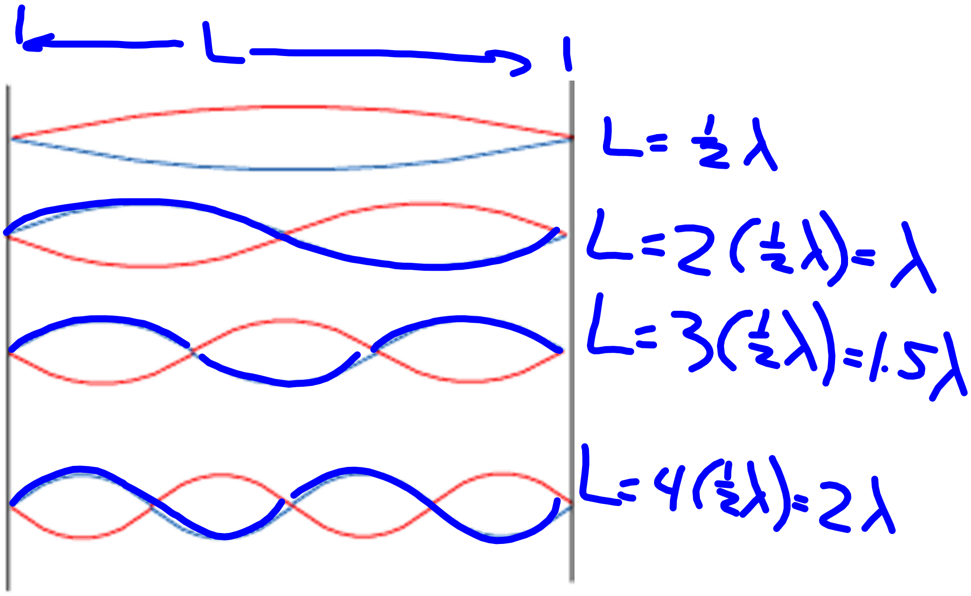
Standing Waves



are special cases of interference that occur when waves moving in opposite directions with same wavelength (& frequency) interfere.

distance between
nodes = $\frac{1}{2}\lambda$
anti-nodes = $\frac{1}{2}\lambda$

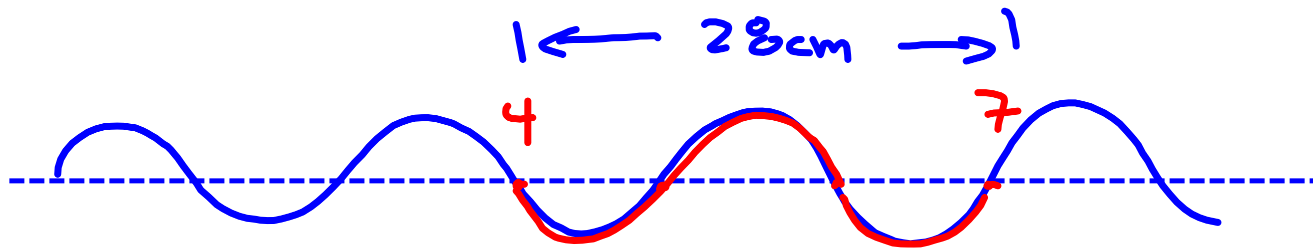
Necessary Conditions for Standing Waves



- Wavelength and Frequency must be the same for the interfering waves.
- The length of the medium (rope, slinky) etc must be integer half lengths of the wavelength (assuming both ends are fixed).

practice

The distance between the 4th and 7th nodes in a standing wave is 28cm. What is the wavelength of the waves? What is the speed of the waves if the source has a frequency of 16Hz?



$\lambda = ?$

$V = ?$

$1\frac{1}{2}\lambda = 28cm$

$1.5\lambda = 28cm$

$\lambda = \frac{28cm}{1.5} = 18.7cm$

$V = f\lambda$

$= 16Hz \times 18.7cm$

$= 300\ cm/s \quad (\sim 3\ m/s)$

Textbook Practice Problems

Page 198 #1-7

page 211 #2-8

Page 222 #1,2

Page 229 #1-3

(#1 - answer is wrong in book - should be 4.75cm)