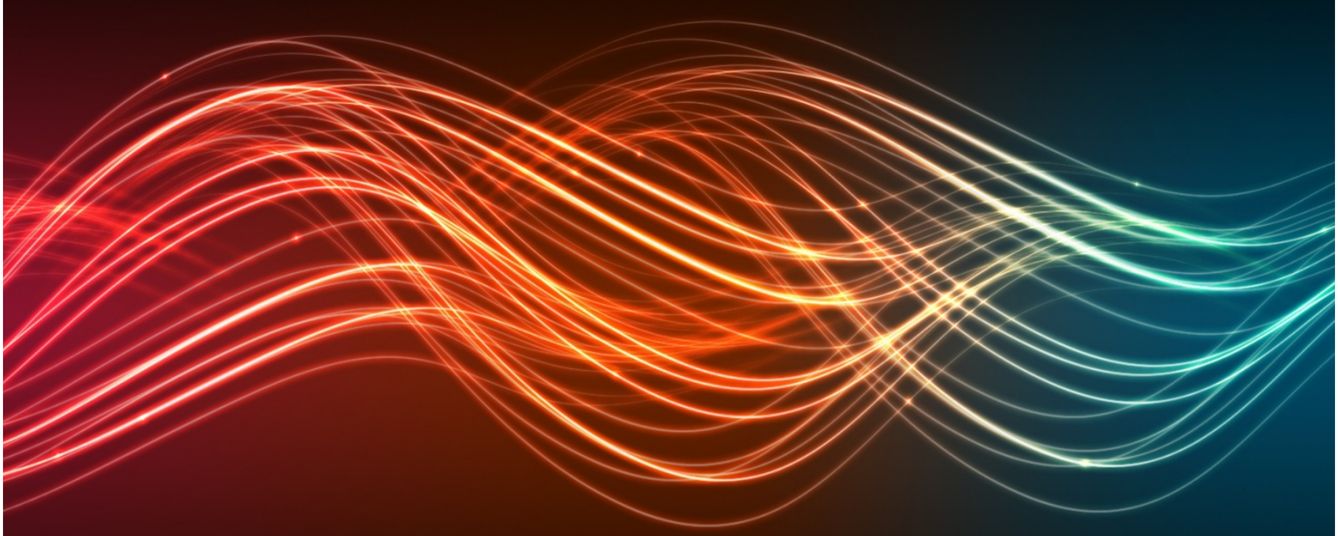
Waves & Sound



Outline

1. What are waves?

2. Properties of Waves

speed of a wave, reflection, interference, diffraction, refraction

3. What is Sound - sound waves, speed of sound

4. Human Hearing - pitch, intensity

1. WHAT ARE WAVES

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

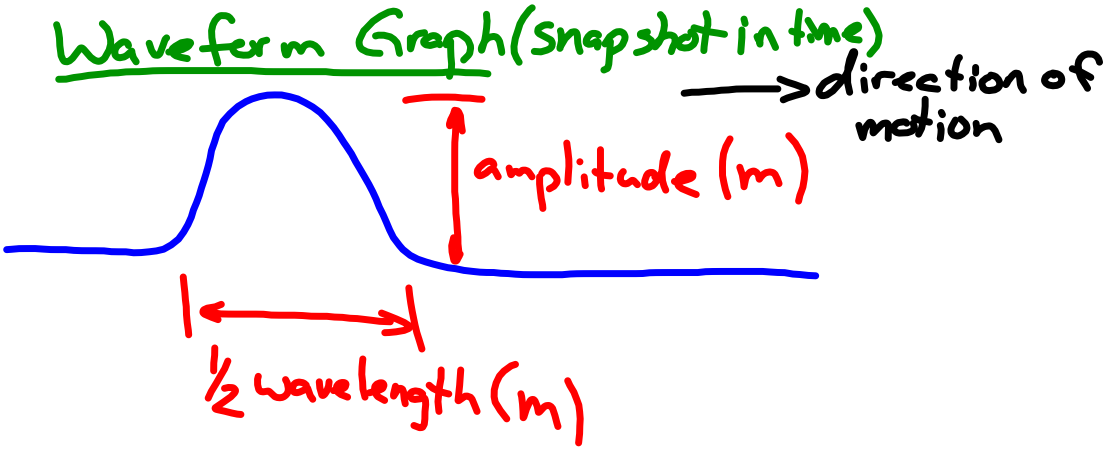
- Non-Mechanical Waves : do not require a physical medium to trav through

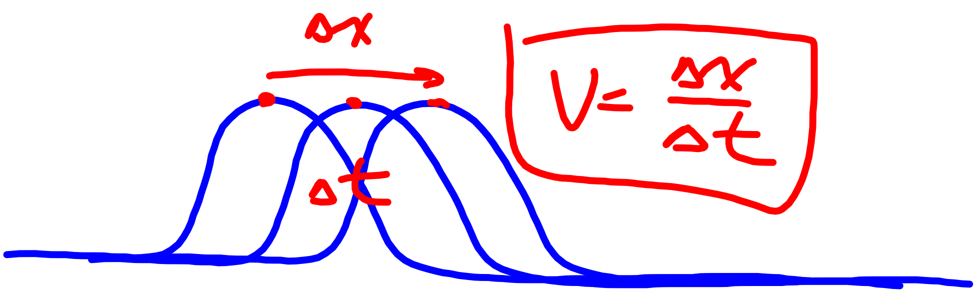
  examples : electromagnetic waves, gravitational waves

Wave Pulses vs Continuous Waves

Wave Pulses

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

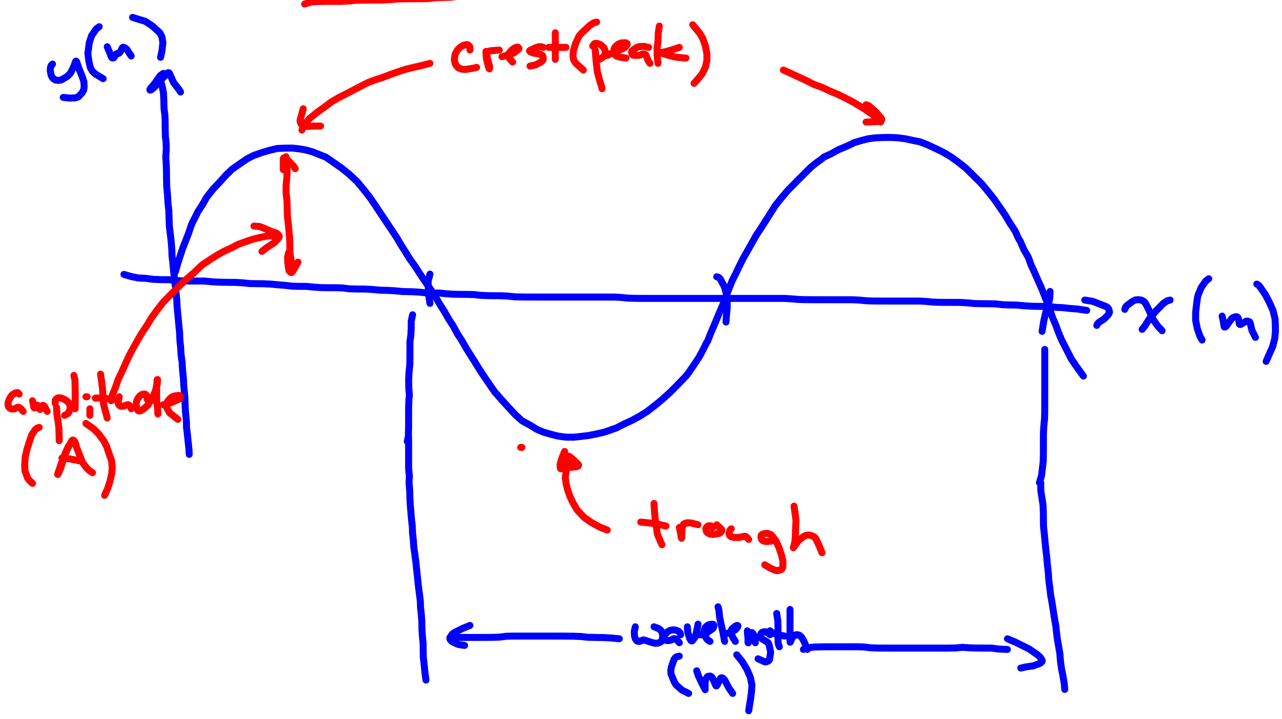




Continuous (Periodic) Waves

Continuous waves originate from periodic vibrations (oscillations).

Waveform Graph (snapshot in time)



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

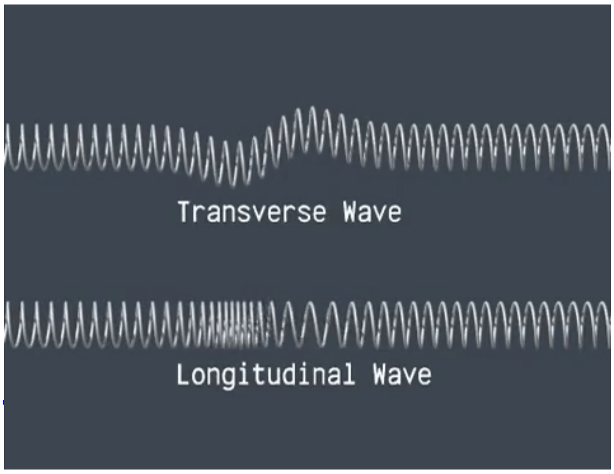
Symbol for wavelength → lambda

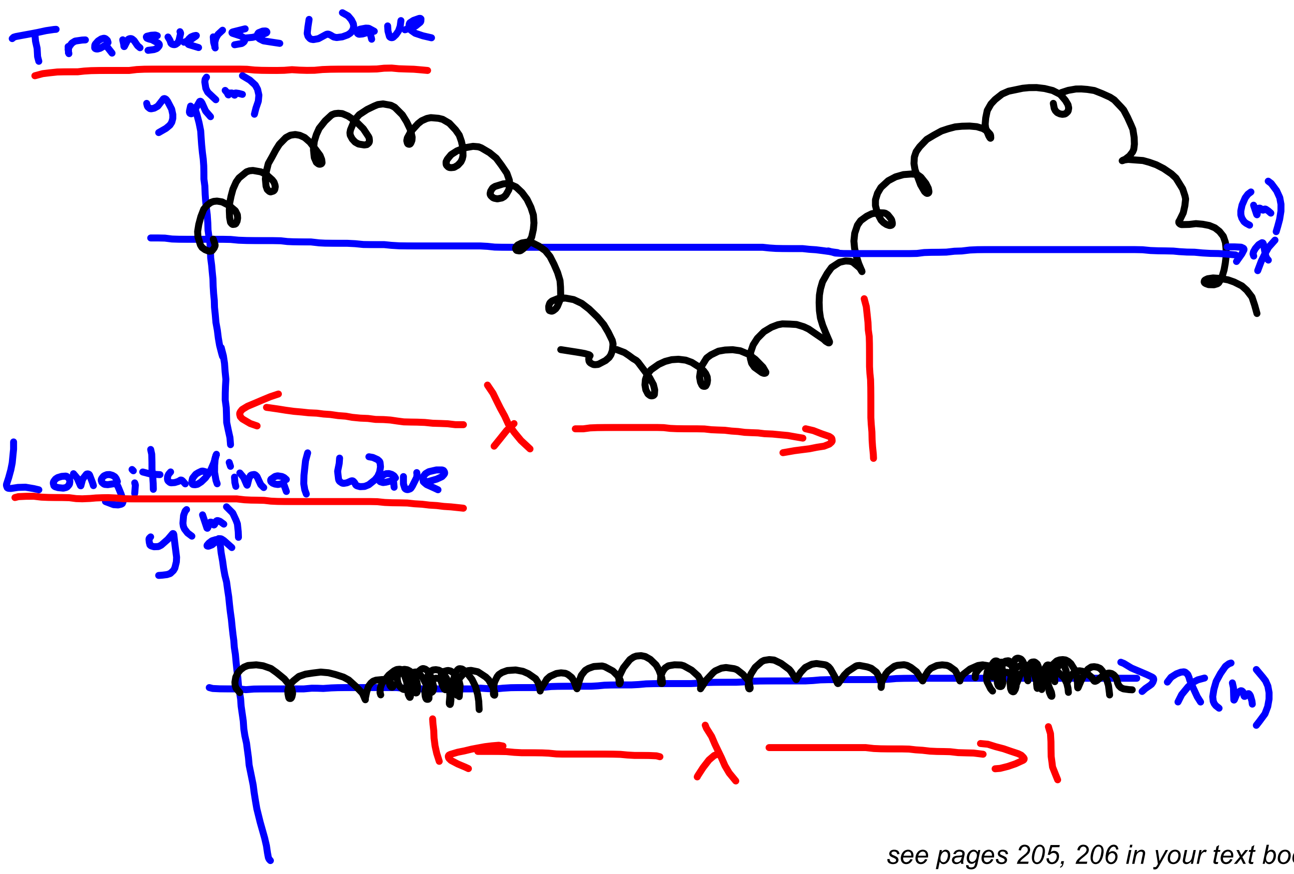
λ - units (m)

Transverse vs Longitudinal Wave

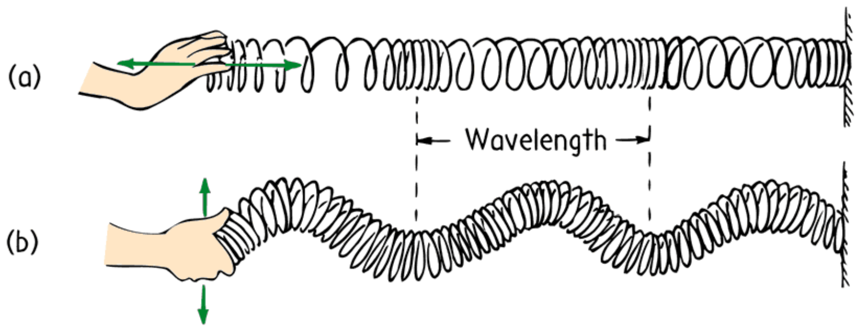
A transverse waves is a wave with oscillations perpendicular to the direction of the wave.

A longitudinal wave is a wave with oscillations in the direction of motion.





see pages 205, 206 in your text book



2. Properties of Waves.

Speed of a Wave

A wave will move one wavelength (λ) in one period of time (T).

Universal Wave Equation

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

f - Hz (s^{-1})

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

$$V = f\lambda$$

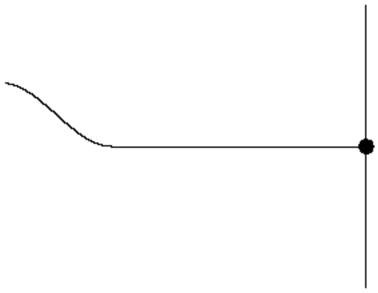
Factors affecting the speed of wave

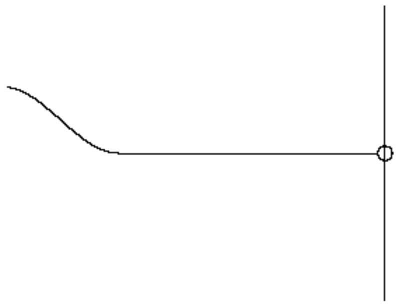
The speed of a waves is ***NOT*** affected by:

- The frequency of vibration
- The 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).

Reflections



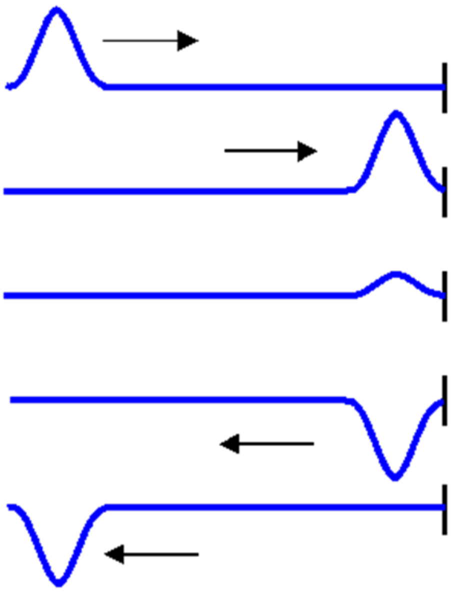


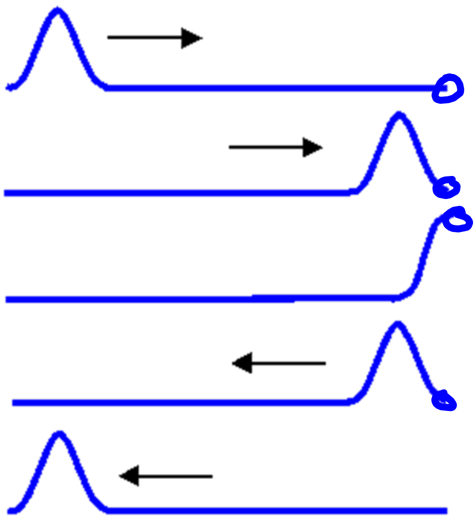
From a fixed end

- reflected pulse is inverted

From a free (or loose end)

- reflected pulse is not inverted





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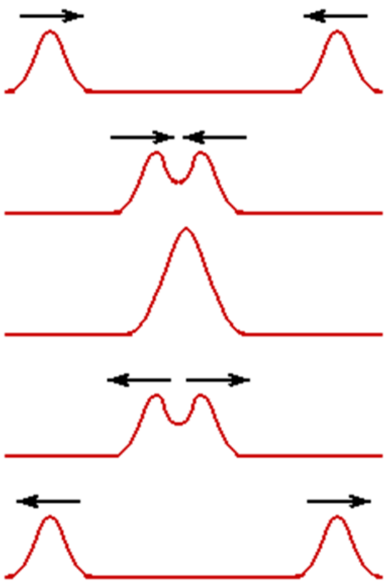
Interference

Wave interference is the phenomenon that occurs when two waves meet while traveling along the same medium.

As waves past through each other, their amplitudes add together.

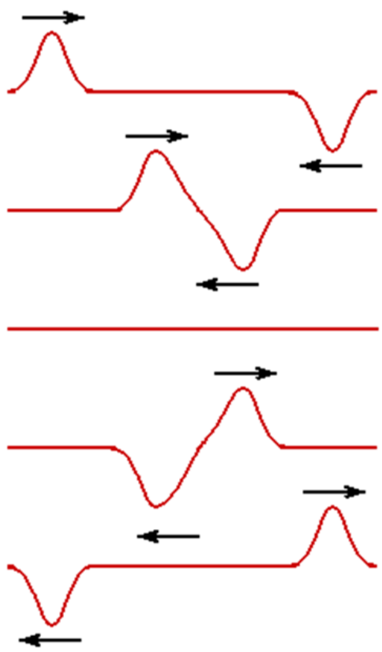
Constructive Interference

Occurs when two positive wave pulses (or two negative) add together to create a larger amplitude pulse.



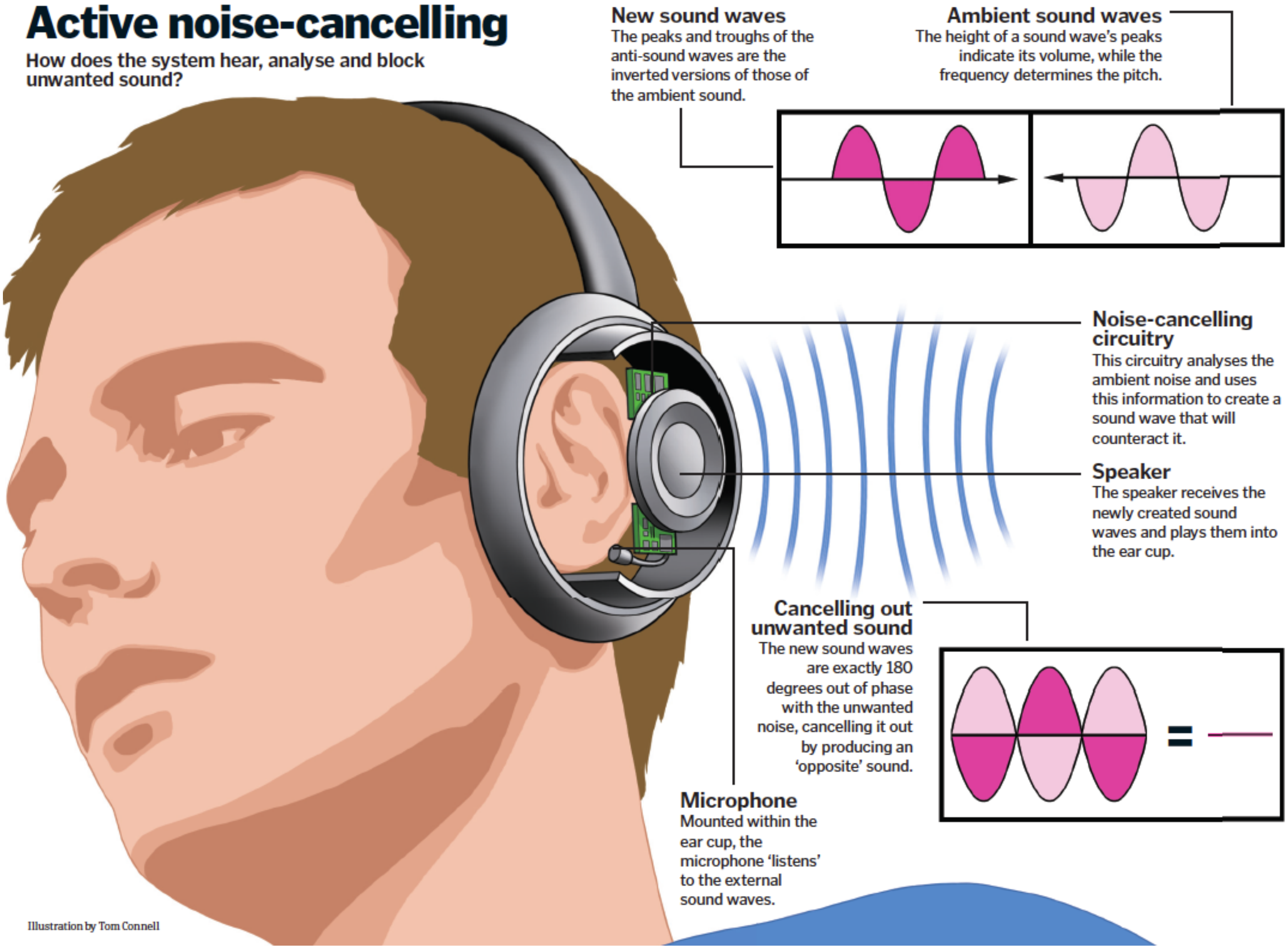
Destructive Interference

Occurs when two opposite pulses (one positive and one negative) add together to give a smaller amplitude pulse.



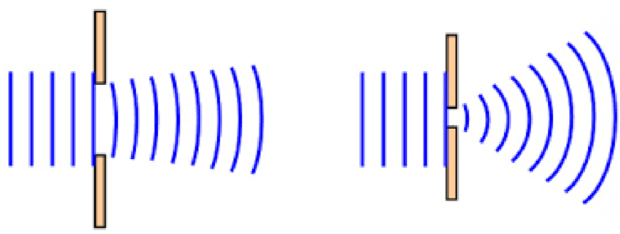
Active noise-cancelling

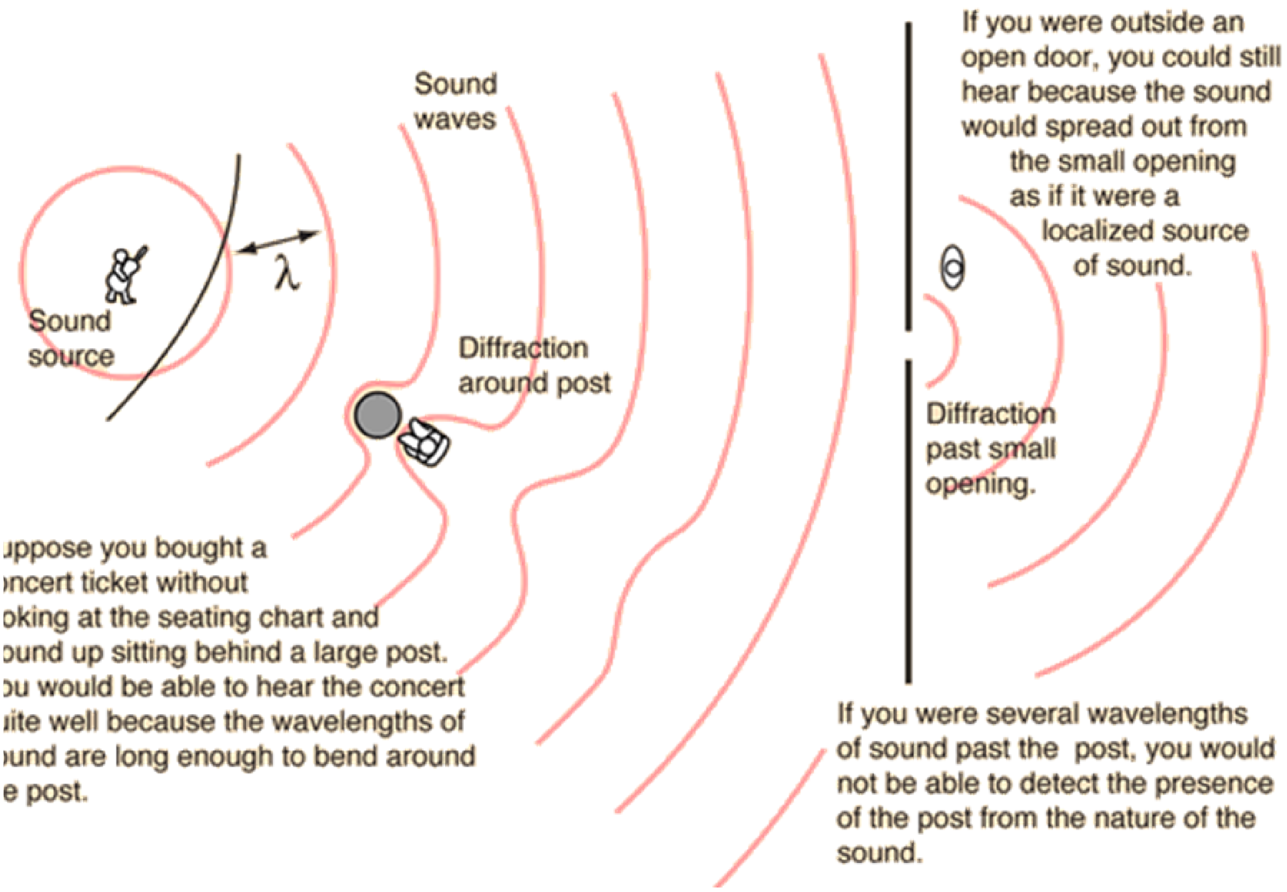
How does the system hear, analyse and block unwanted sound?



Diffraction

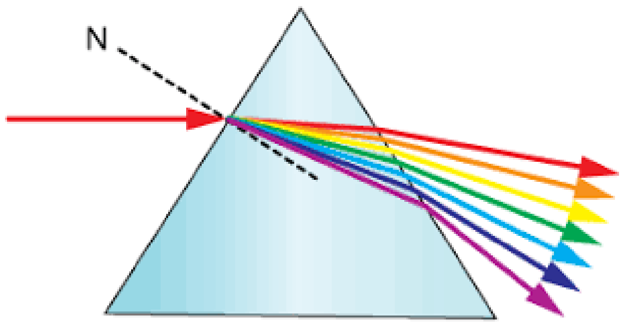
Diffraction is a phenomena that occurs when a wave encounters an obstacle or a slit. It is defined as the bending of waves around the corners of an obstacle or through an aperture into the region of geometrical shadow of the obstacle/aperture.

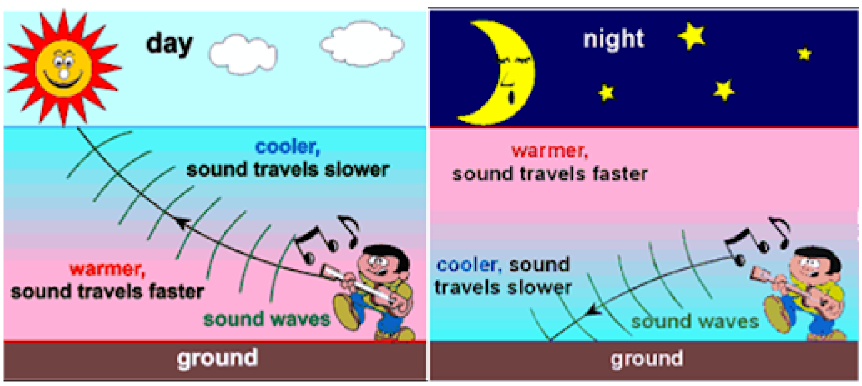




Refraction

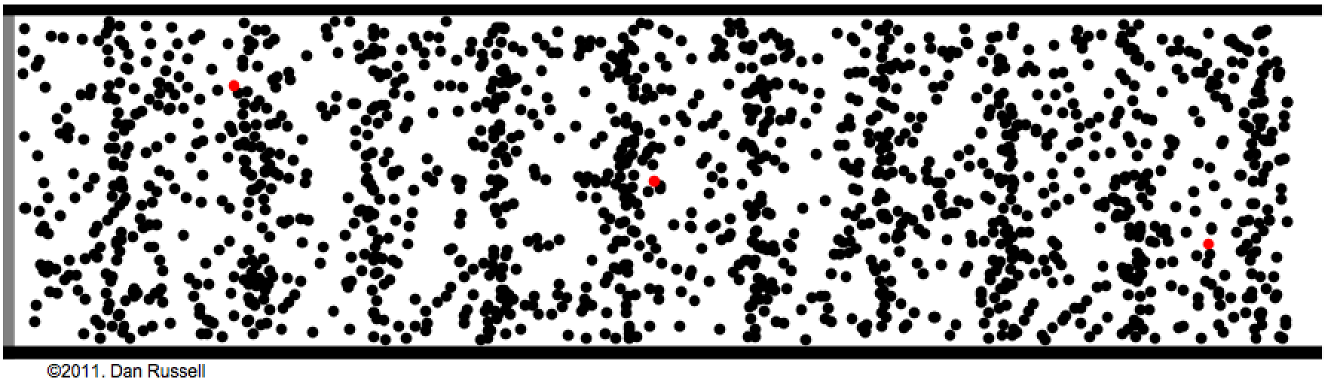
Refraction is the change in direction of a wave passing from one medium to another or from a gradual change in the medium.
Refraction can happen in electro-magnetic waves (light), sound waves, water waves and others.

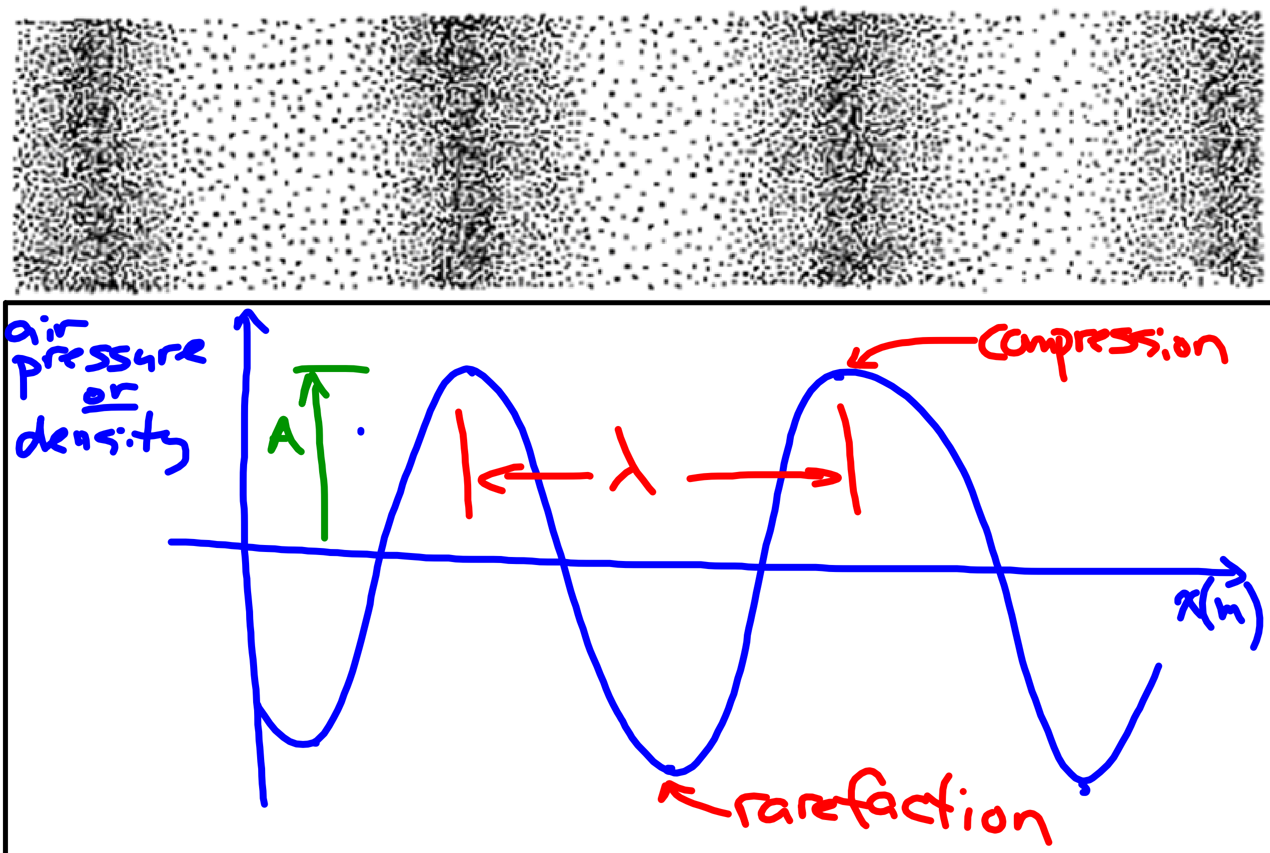




3. What is Sound

Sound is a longitudinal wave of air pressure variations, caused by a rapidly vibrating source (i.e. a tuning fork or your vocal cords)





amplitude A → is a measure of air pressure.

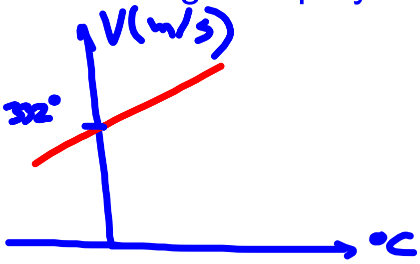
Speed of sound

The speed of sound at sea level and $0^\circ C$ is **332 m/s**.
~1200km/hr

Factors affecting the speed of sound:

→ temperature as T ↑, v ↑
→ air pressure as P ↑, v ↑
→ properties of medium transmitting the wave
- humidity

As the temperature ↑ the air molecules are moving faster and sound waves can be transmitted faster. For each degree Celcius the velocity of sound goes up by 0.59m/s.



$$V = 332 + 0.59T$$

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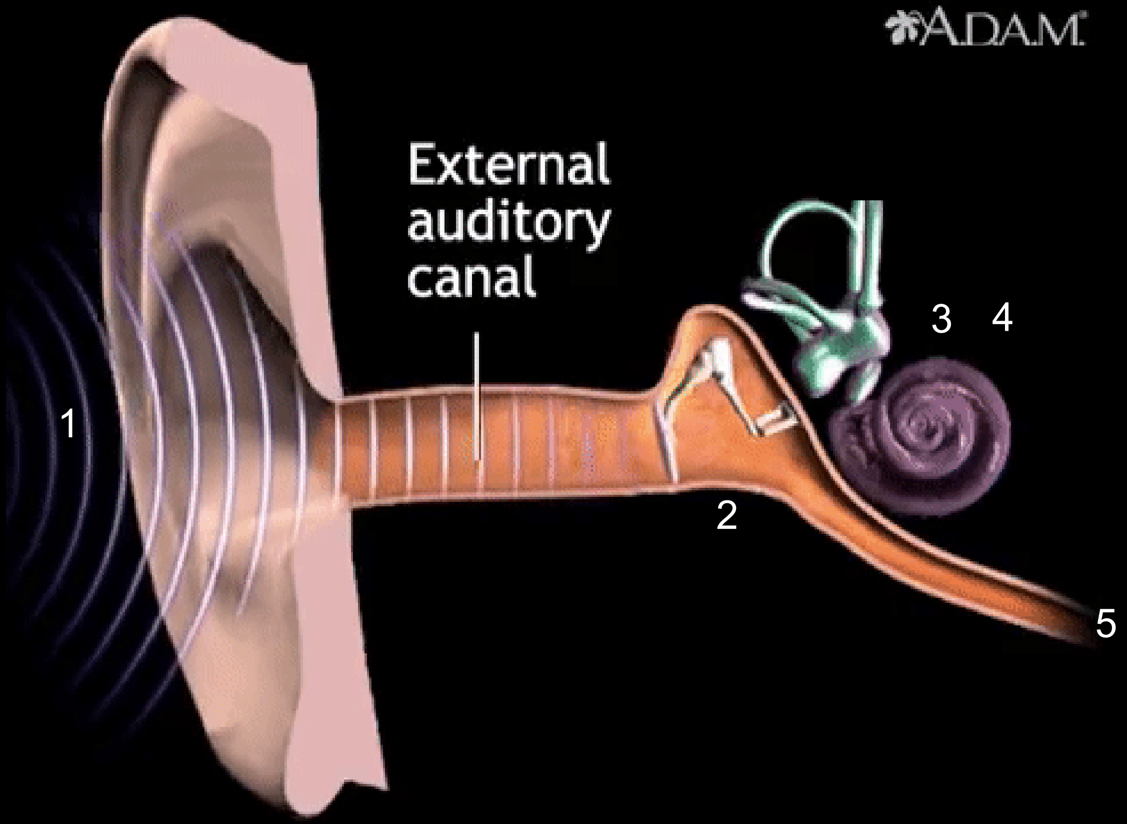
Speed of sound in other materials

increasing velocity ↓

• Air	332 m/s
• Helium	970 m/s
• Water	1493 m/s
• Glass	5050 m/s
• Aluminum	5104 m/s

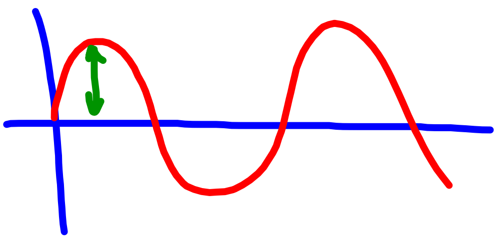
Sound typically travels faster in denser material due to the closeness of the molecules (however - the sound is absorbed quicker into the material so it often does not travel as far).

4. Human Hearing



1. Sound is transmitted as sound waves from the environment. The sound waves are gathered by the outer ear and sent down the ear canal to the eardrum.
2. The sound waves cause the eardrum to vibrate, which sets the three tiny bones in the middle ear into motion.
3. The motion of the bones causes the fluid in the inner ear or cochlea to move.
4. The movement of the inner ear fluid causes the hair cells in the cochlea to bend. The hair cells change the movement into electrical pluses.
5. These electrical impulses are transmitted to the hearing (auditory) nerve and up to the brain, where they are interpreted as sound.

Sound Intensity



Intensity is related to the amplitude of the wave.

Measure of the overall energy of the sound per unit area.

measured in W/m^2

W = Watt
= J/s

Human Range is from about
$10^{-12} W/m^2$ to $1 W/m^2$

A huge range (0.000000000001 to $1 W/m^2$)

Normally measured in dB (decibels).

0dB to 120dB

Intensity Levels of Common Sources of Sound

Source	Intensity (dB)	Intensity (W/m^2)
threshold of hearing	0	10^{-12}
whisper	20	10^{-10}
loud IPOD's	80-90	10^{-4} - 10^{-3}
loud rock concerts	120	$10^0 = 1$
threshold of pain	130	10^1
instant perforation of ear drum	160	10^4

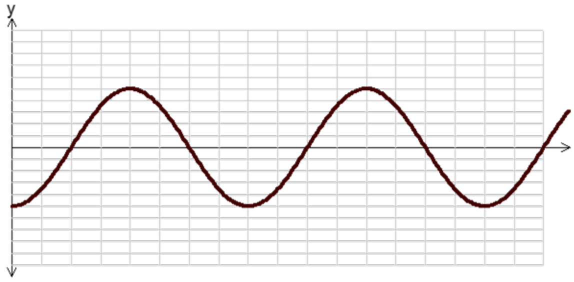
Practice

How many times louder is a 70dB sound compared to a 40 dB sound?

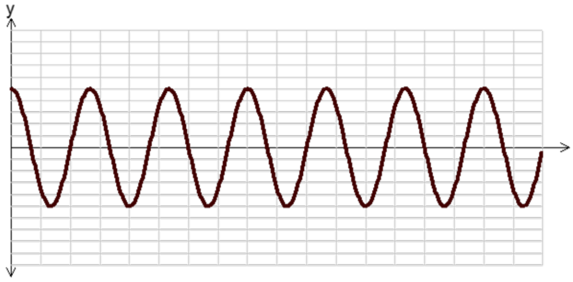
Answer - 70dB is 30dB higher than 40dB.

Each increase of 10dB is 10x's more intense. Therefore a 30dB increase is (10x10x10) 1,000 times more intense (in other words the energy of a 70 dB sound is 1,000 x's higher that a 40dB sound)

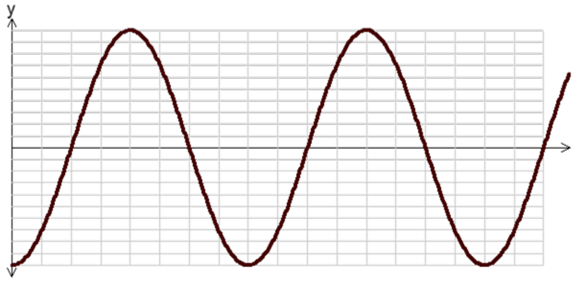
Pitch and Sound Quality



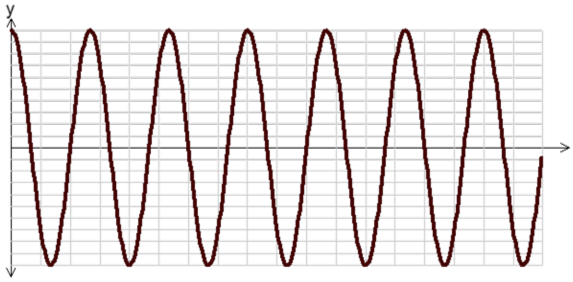
low pitch, quiet



high pitch, quiet



low pitch, loud



high pitch, loud

- High pitch relates to short wavelengths and high frequency
- Sound Quality is a measure of the cleanliness of the signal

What is white noise?

Just like white light, (white light is composed of all frequencies (wavelengths) of visible light), white noise is composed of all frequencies of audible sound.

Normal Human Response

20Hz - 20kHz

Ability to hear high frequencies drops off as we age ☹

Summary

1. What is a wave
    - types of waves
        - pulse vs periodic / transverse vs longitudinal

2. Properties of waves
    - wavelength, period, frequency, amplitude
    - speed, reflection, interference, diffraction, refraction

$$V = f\lambda$$

3. Sound Waves
    - transverse pressure wave
    - speed of sound versus temperature (T in degrees C).

$$V = 332 + 0.59T$$

4. Human Hearing - intensity & pitch

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5. Sample Problems

1. Predicting wave shape when waves reflect and interfere.
2. Using period and wavelength to calculate velocity.
3. Using speed of sound to measure how far away things are.

1. Two wave pulses as shown below are incident on a fixed end and an open end. The first wave pulse will reflect back to the left and will interfere with the incoming wave pulse. Draw the resultant interference of the two wave pulses when they are perfectly aligned.

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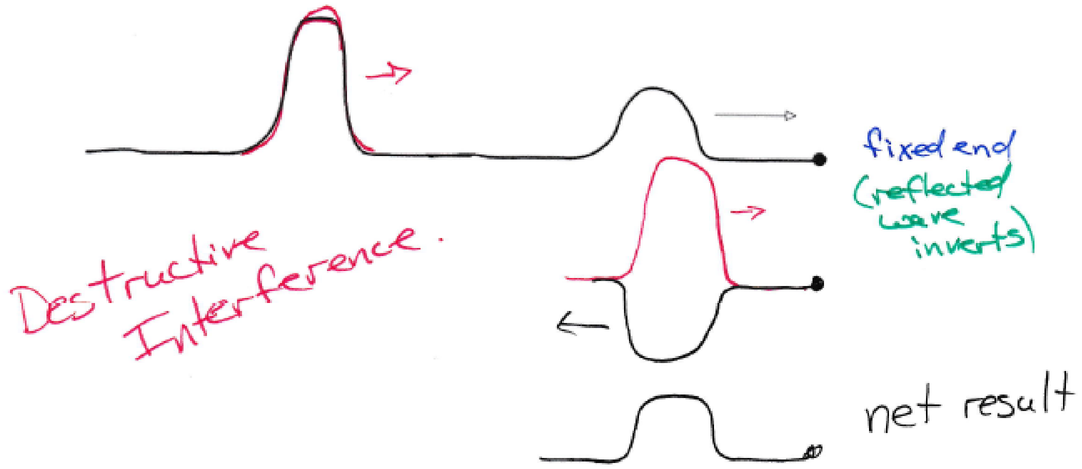

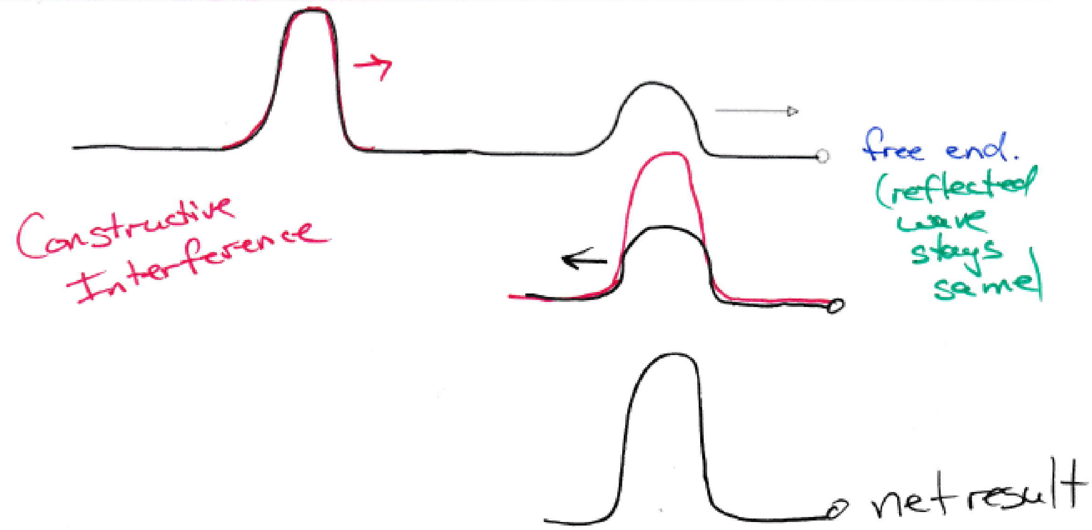

2. A large crest of water requires 12 seconds to travel from a fishing boat to the pier which is 48m away. While sitting on the boat, the fishermen notice that 5 crests pass the boat in 10 seconds. What is the wavelength of the waves?

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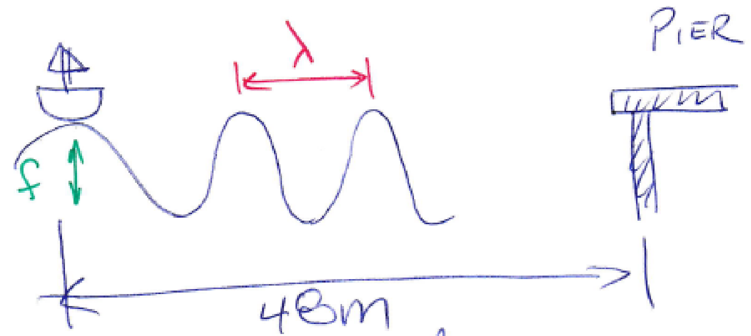

12 seconds.

$V = \frac{dist}{time} = \frac{48m}{12s} = 4.0 m/s$

$V = f\lambda$

$f = cycles/sec = \frac{5 \text{ cycles}}{10s} = 0.5 Hz \ (s^{-1})$

$\lambda = \frac{V}{f} = \frac{4.0 m/s}{0.5 Hz} = 8.0m$

3. On a cold day at the Grand Canyon, a hiker yells and can hear her echo 5.0 seconds after she yells. If the distance to the far canyon wall is 815m, what is the temperature?

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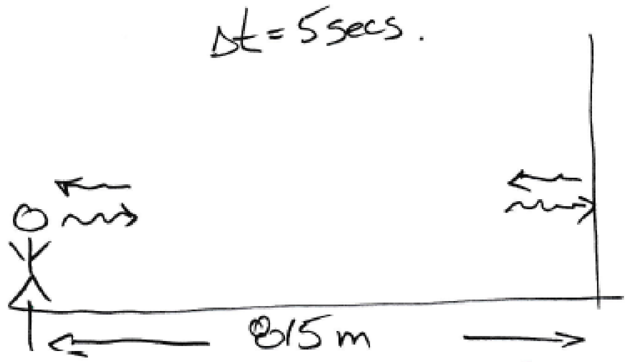

$$V = \frac{\text{dist}}{\text{time}} = \frac{2 \times 815\text{m}}{5\text{s}} = 326 \text{ m/s}$$

$$V = 332 + 0.59T$$

$$326 = 332 + 0.59T$$

$$-6 = 0.59T$$

$$T = -10^\circ C.$$

V = 326 m/s solve for T(°C)