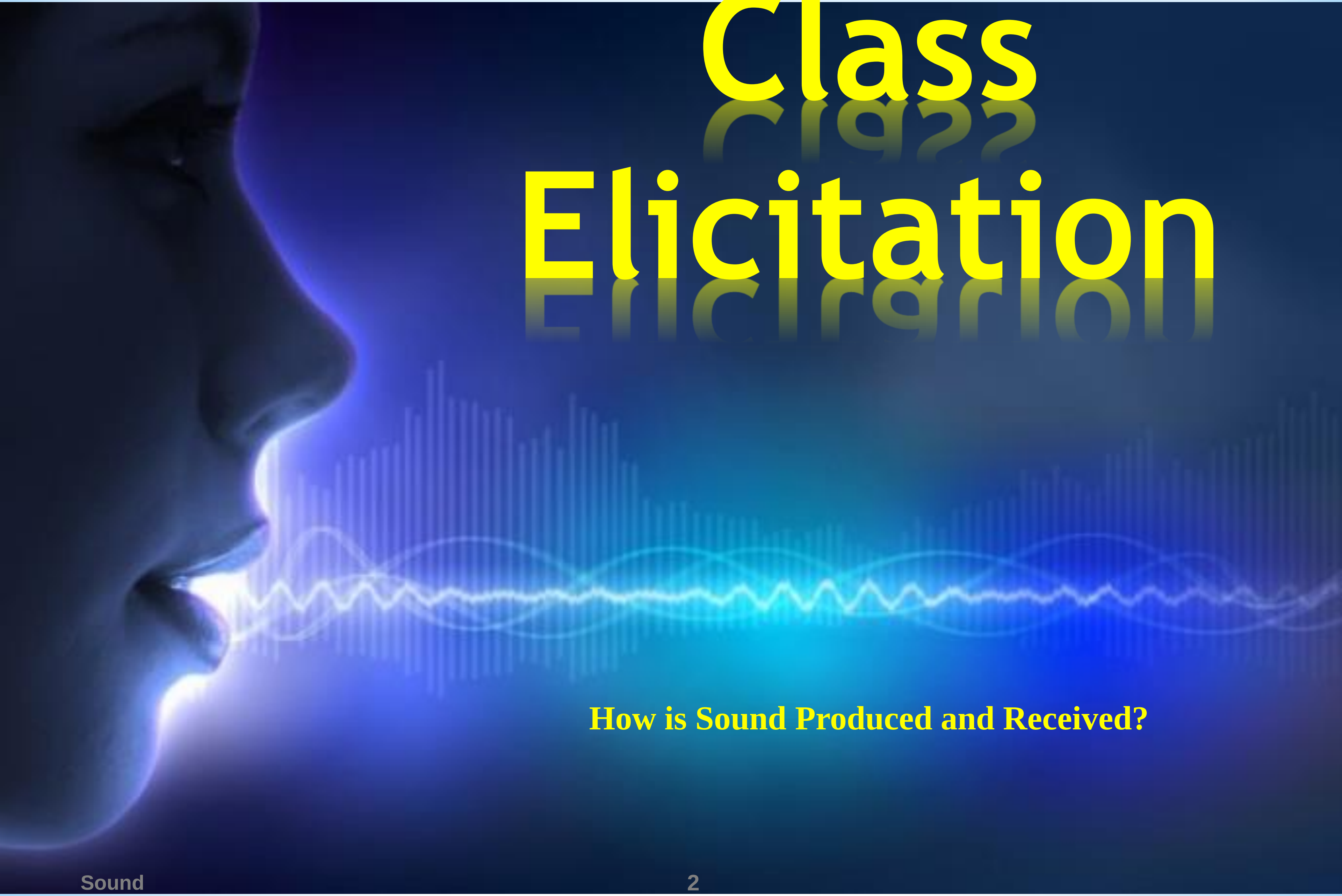
Mechanical Waves

Class Elicitation



How is Sound Produced and Received?

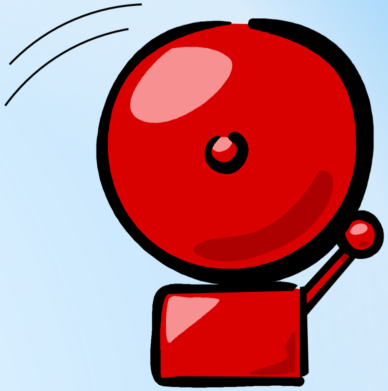
Try this:

* Put your thumb and index finger around your vocal chords and say “aah” pretty loud.

* Now say it soft.

* You can not only hear the sound, but you can feel the **vibration** inside your throat.

What is sound?



Sound is

* A form of energy made by vibrations **that can be heard.**
* When an object vibrates (moves back and forth quickly … oscillation) it causes the air particles around it to move.
* These particles collide with particles close to them (air pressure) and this continues until they run out of energy.

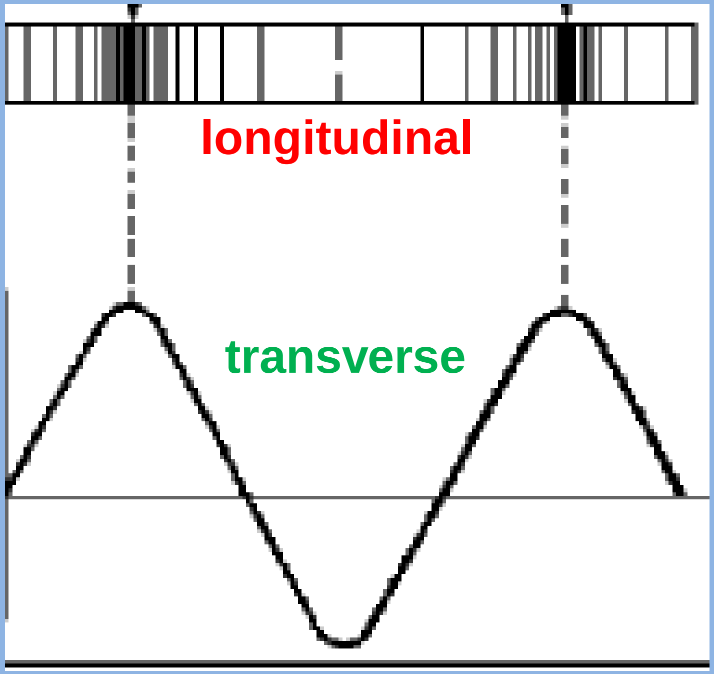
Sound is an example of Mechanical Waves?

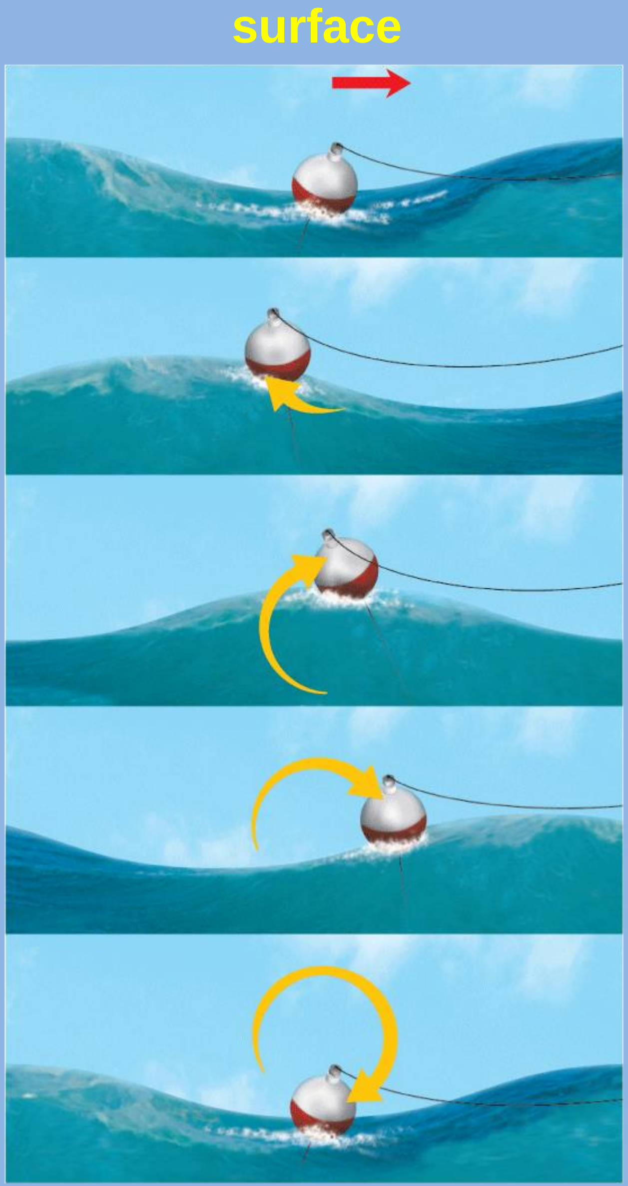
A **mechanical wave** is a disturbance in matter that carries energy from one place to another.

- The material through which a wave travels is called a **medium**.
- Mechanical waves require a medium to travel through. **Solids, liquids, and gases all can act as mediums**.
- A **vibration** is a repeating back-and-forth motion.

Types of Mechanical Waves

The three main types of mechanical waves, which are classified by the way they move through a medium.

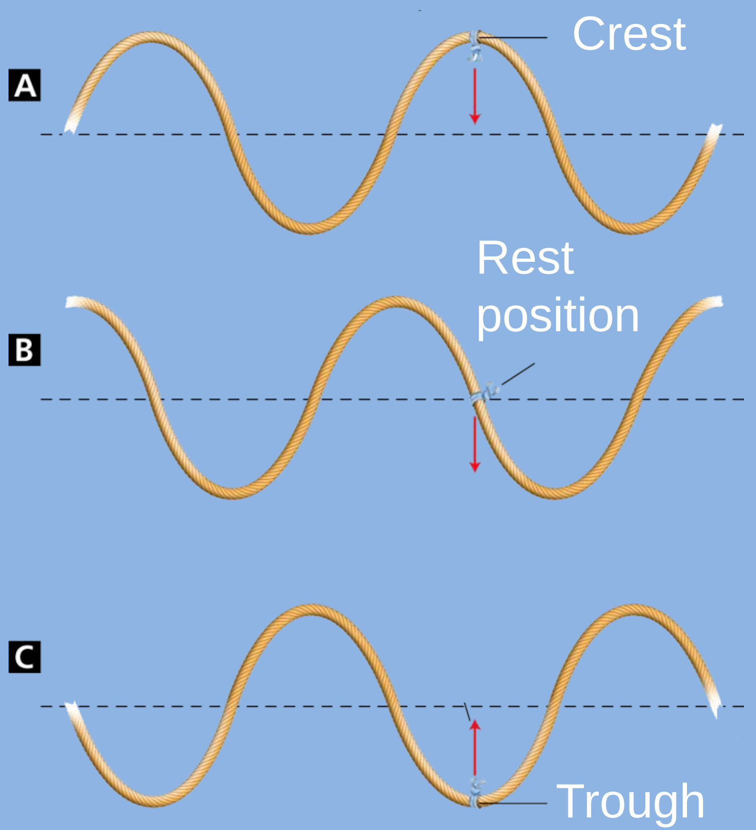




Transverse Waves

When you shake one end of a rope up and down, the vibration causes a wave.

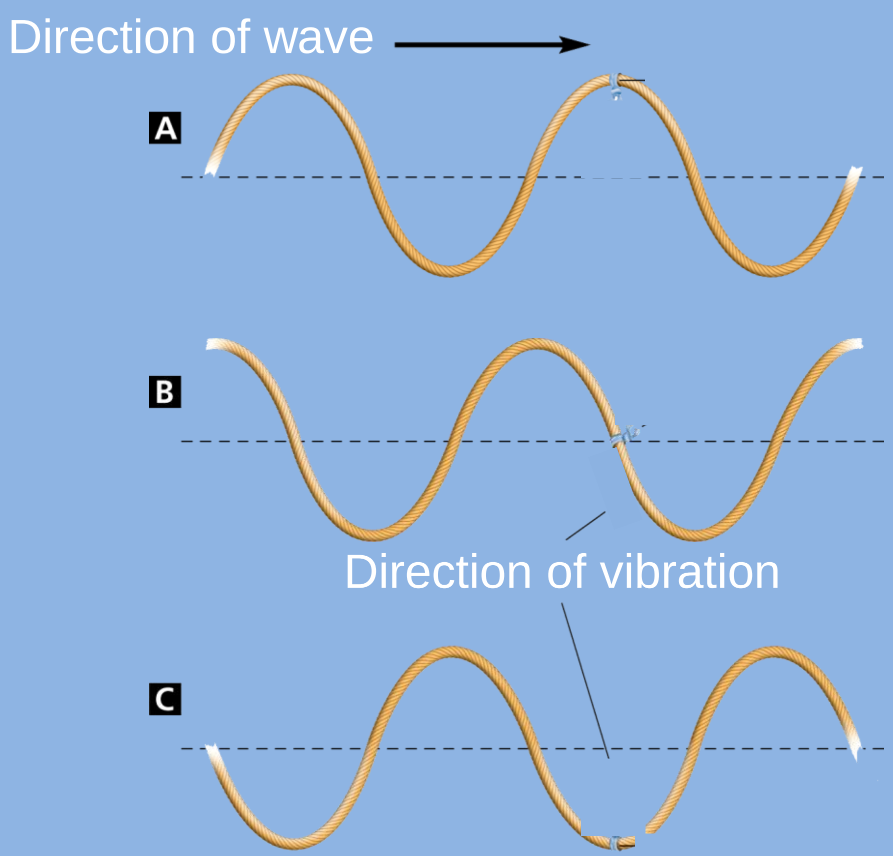
- The highest point of the wave is the **crest**.
- The lowest point of the wave is the **trough**.
- A single point on the rope vibrates up and down between a crest and trough.



Transverse Waves

A **transverse wave** causes the medium to vibrate at right angles to the direction in which the wave travels.

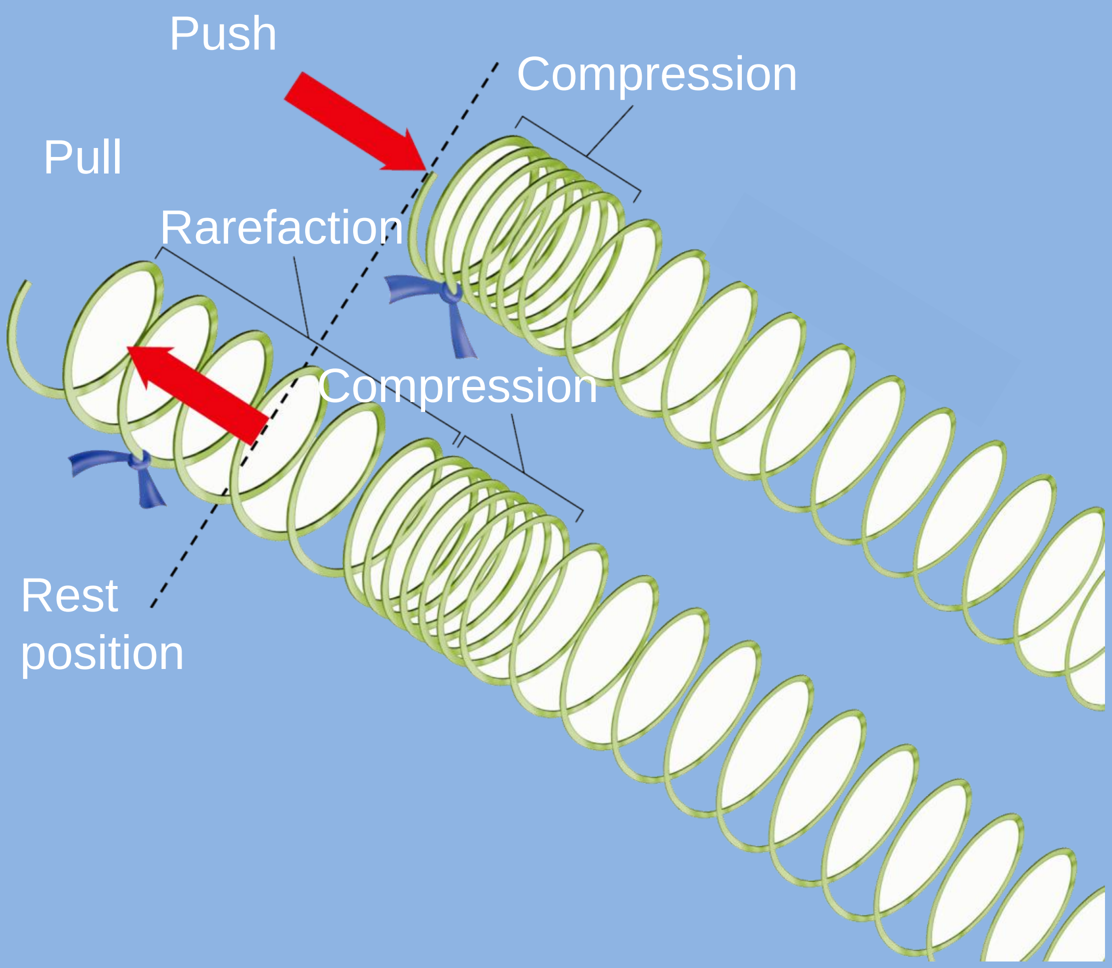
The wave carries energy from left to right, in a direction perpendicular to the up-and-down motion of the rope.



Longitudinal Waves

In a spring toy, the wave carries energy along the spring.

- An area where the particles in a medium are spaced close together is called a **compression**.
- An area where the particles in a medium are spread out is called a **rarefaction**.

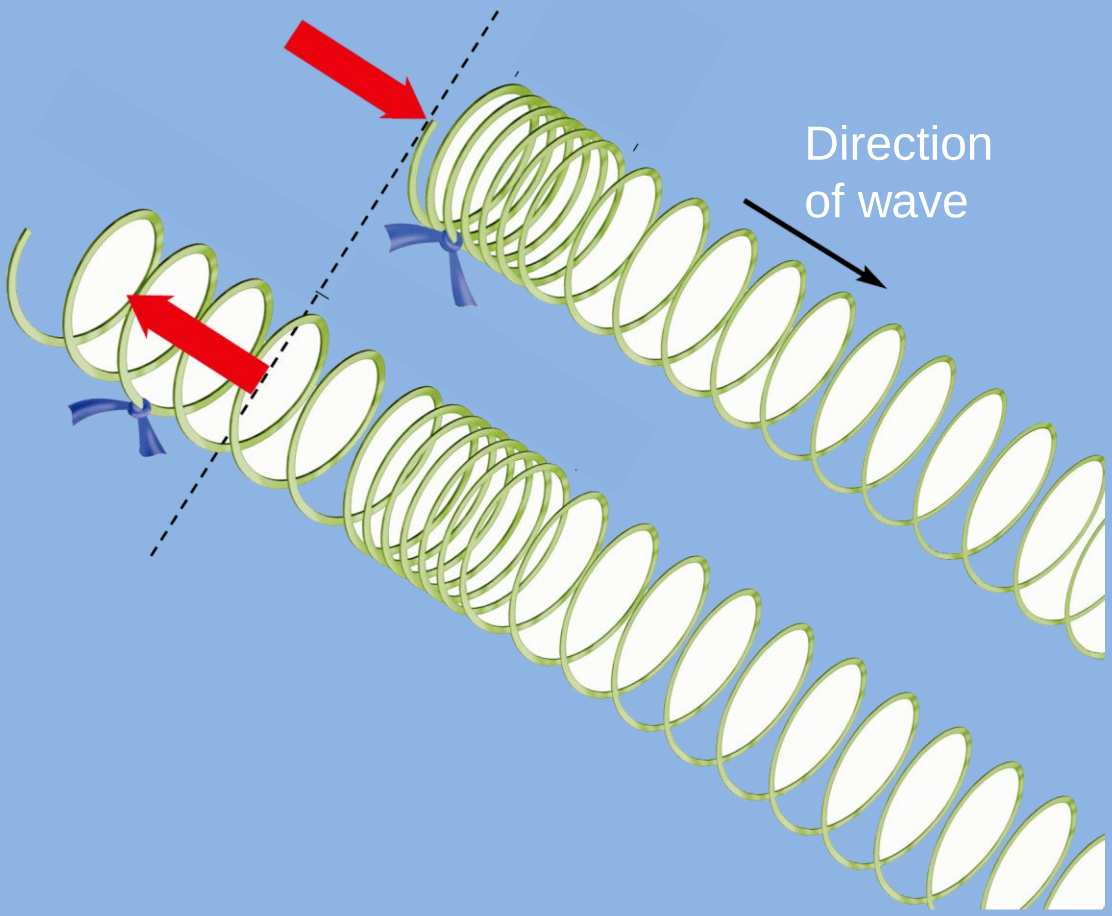


Longitudinal Waves

In a spring toy, the wave carries energy along the spring.

As compressions and rarefactions travel along the spring, each coil vibrates back and forth around its rest position.

A **longitudinal wave** is a wave in which the vibration of the medium is parallel to the direction the wave travels.



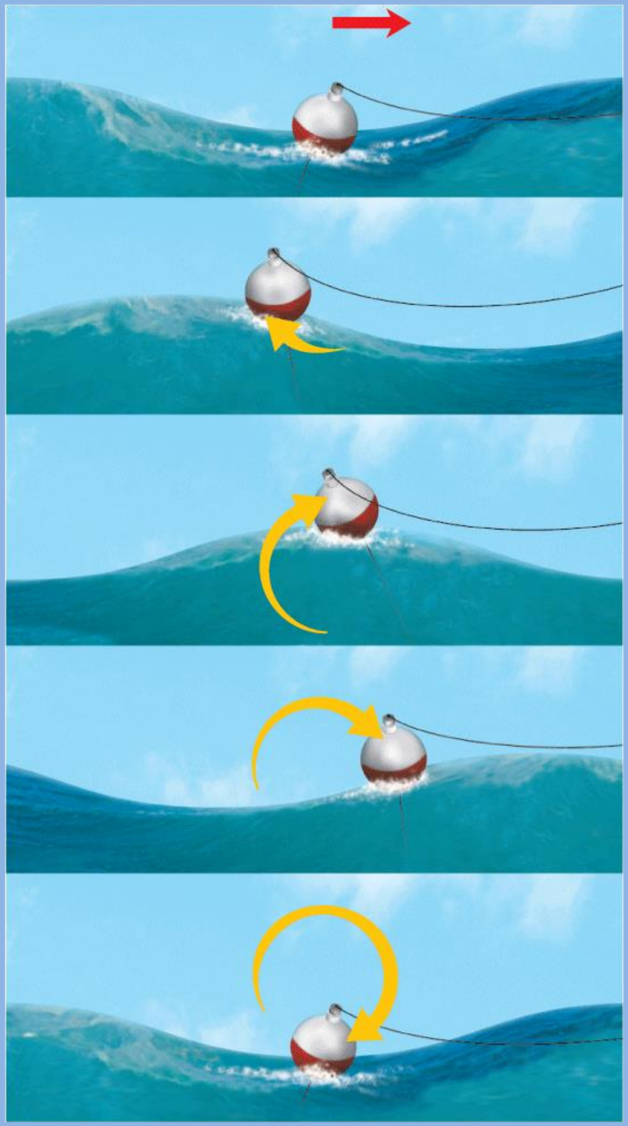
Surface Waves

Types of Mechanical Waves

Ocean waves are the most familiar kind of surface waves.

A **surface wave** is a wave that travels along a surface separating two media.

As the ocean wave moves to the right, the bobber moves in a circle, returning to its original position.



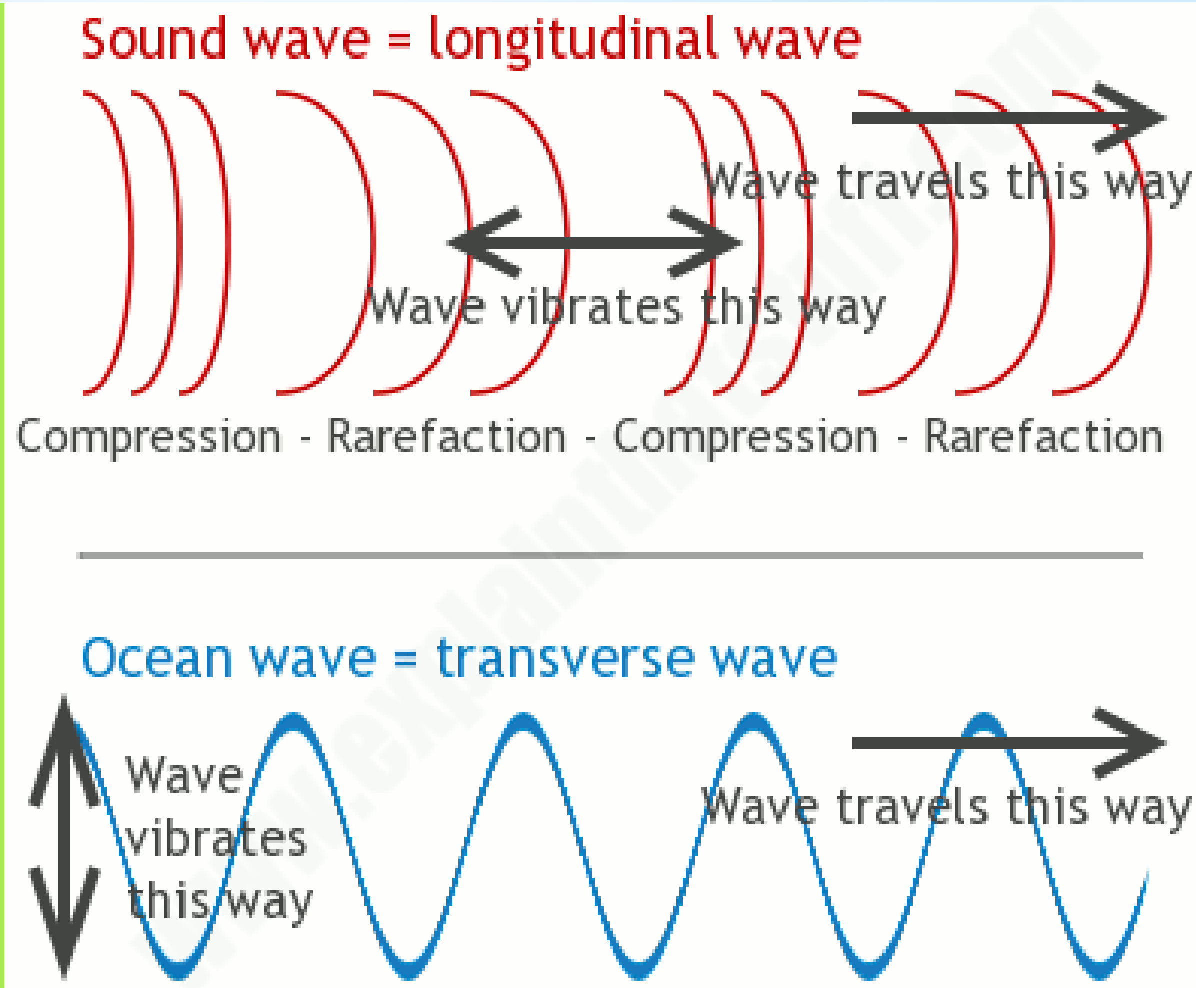
How do waves travel?

LESSON QUESTION

Sound passes through a medium as **longitudinal waves**.

The direction of propagation of a sound wave is **parallel** to its direction of oscillation (**back & forth**).

The direction of propagation of a transverse wave is **perpendicular** to its direction of oscillation (**up & down**).



QUICK CHECK

A mechanical wave carries energy from one place to another through the

a. physical transfer of matter.
b. interaction of electromagnetic fields.
c. phase changes of a medium.
d. vibration of a medium.

In what type of wave is the vibration of the medium parallel to the direction in which the wave travels?

a. transverse wave
b. longitudinal wave
c. surface wave
d. ocean wave

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In what type of wave is the vibration of the medium parallel to the direction in which the wave travels?

a. transverse wave
b. **longitudinal wave**
c. surface wave
d. ocean wave

An example of a transverse wave is a(n)

a. sound wave traveling through air.
b. ocean wave far from the shore.
c. ocean wave as it approaches the shore.
d. light wave traveling through space.

As a ____ wave travels across water, molecules of water move in a circular pattern.

longitudinal wave … surface wave … transverse wave

A ____ wave vibrates the medium parallel to the direction the wave travels.

longitudinal wave … surface wave … transverse wave

QUICK CHECK

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longitudinal wave … **surface wave** … transverse wave

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longitudinal wave … surface wave … transverse wave

Simulation Part 1

How is Sound Processed and Received? (1:23)

http://somup.com/cbeDrkRAG

1) "Frequency" will increase from ~250 Hz, to ~500 Hz, to ~750 Hz, and then ~1000 Hz. Describe the sound. What happens as frequency changes from low to high?

2) Frequency is set to ~500 Hz. The "Amplitude" will increase. Describe the sound. What happens as amplitude changes from low to high?

3) How are the sounds produced in #1 & #2 different?

LESSON QUESTION

Properties of Waves.

http://somup.com/cbeD3zRBj (1:24)

Amplitude is set to 0.75 cm and Frequency to 0.75 Hz.

1) When that bead reaches its highest point, record the frequency: _____ . Wavelength _______.

2) Frequency is changed to 1.5 Hz. Repeat procedure 1. Measure the wavelength _______.

3) Frequency is changed to 3.0 Hz. Repeat procedure 1. Measure the wavelength _______.

4) What is the relationship between wavelength and frequency?

Properties of Waves.

LESSON QUESTION

http://somup.com/cbeD3zRBj (1:24)

Amplitude is set to 0.75 cm and Frequency to 0.75 Hz.

1) When that bead reaches its highest point, record the frequency : 0.75 Hz. Wavelength 7.5 cm.

2) Frequency is changed to 1.5 Hz. Repeat procedure 1. Measure the wavelength 4.0 cm.

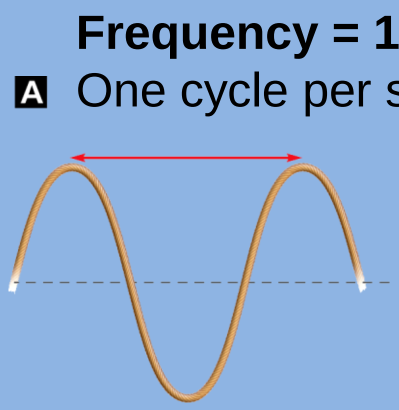
3) Frequency is changed to 3.0 Hz. Repeat procedure 1. Measure the wavelength 2.1 cm.

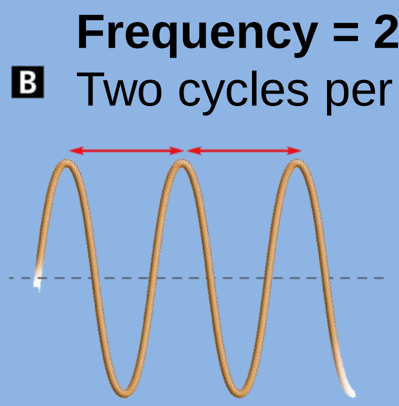
4) What is the relationship between wavelength and frequency? Inverse (as f increases, λ decreases)

Frequency and Period

Any motion that repeats at regular time intervals is called **periodic motion**.

- The time required for one cycle is called the **period**.
- Frequency is the number of complete cycles in a given time.
- Frequency is measured in cycles per second, or **hertz** (Hz).

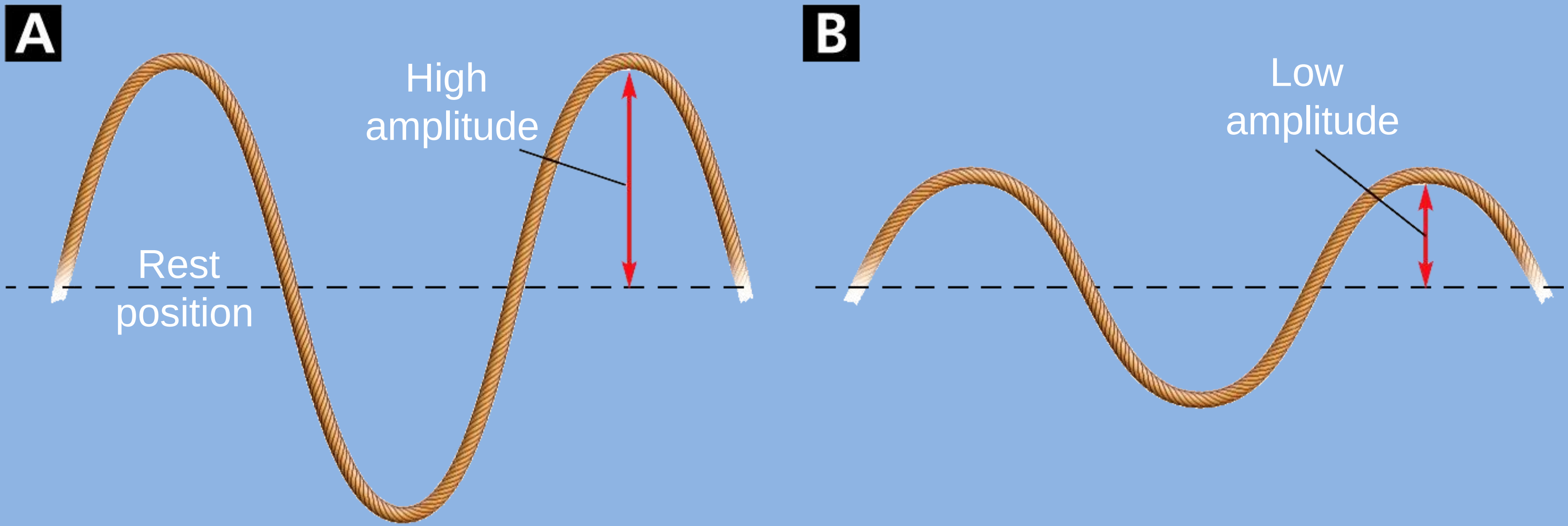




Amplitude

The amplitude of a transverse wave is the distance from the rest position to a crest or a trough.

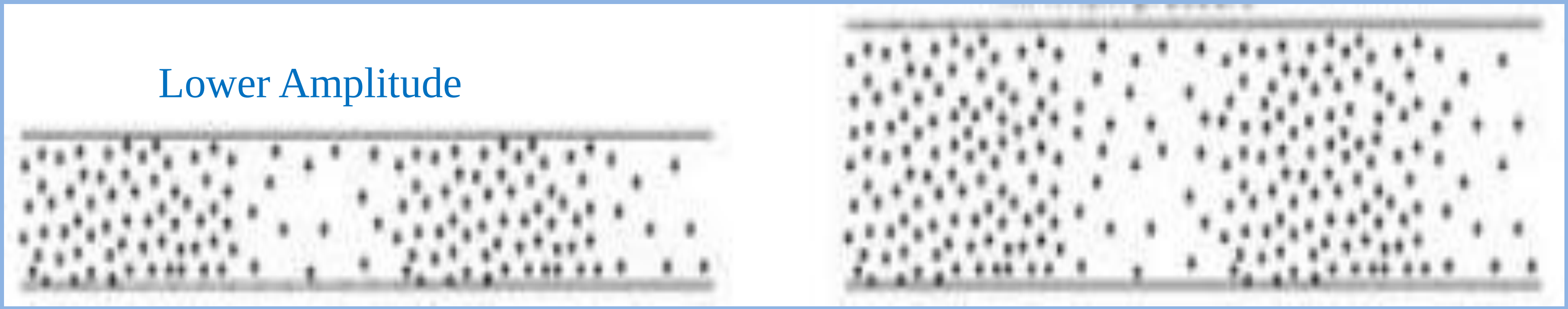
It takes more energy to produce a wave with higher crests and deeper troughs.



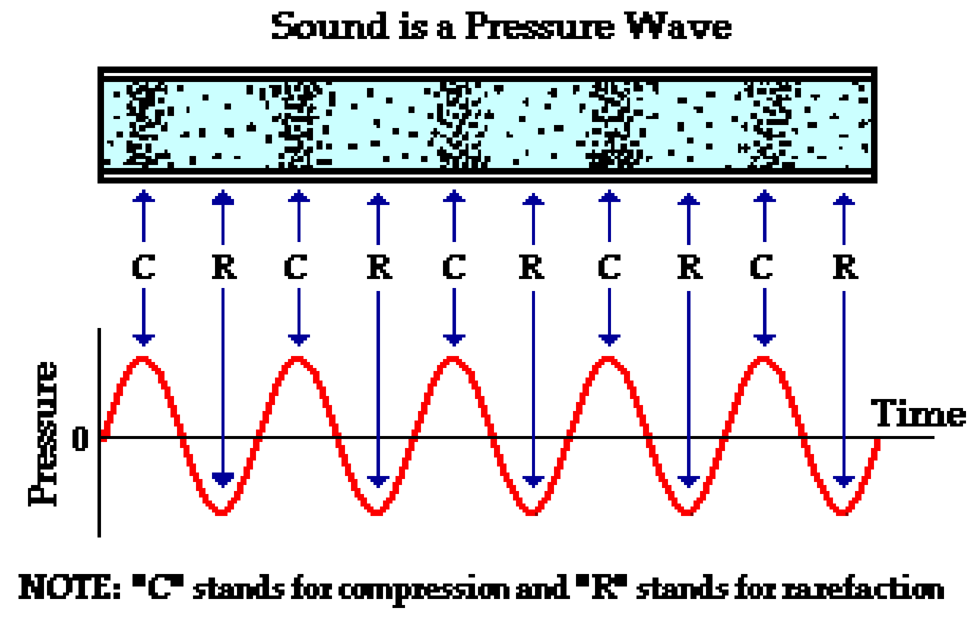
Amplitude

The amplitude of a longitudinal wave is the maximum displacement of a point from its rest position.

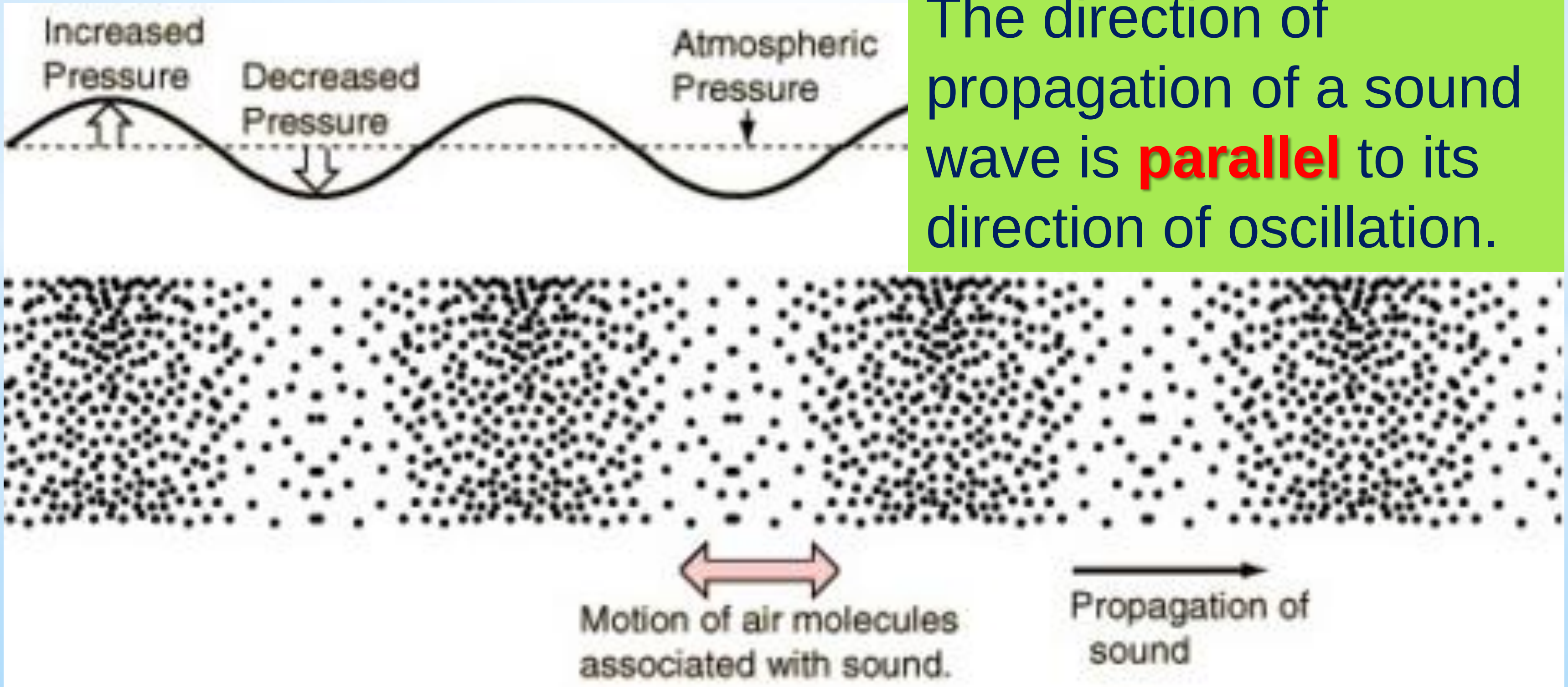
The more energy the wave has, the more the medium will be compressed or displaced.



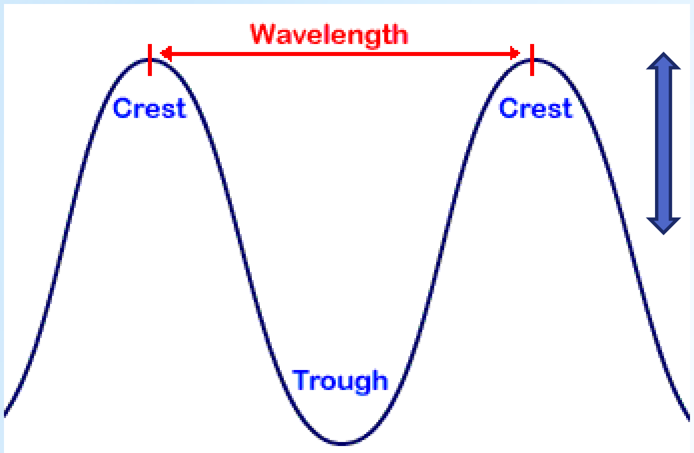
Anatomy of a Wave



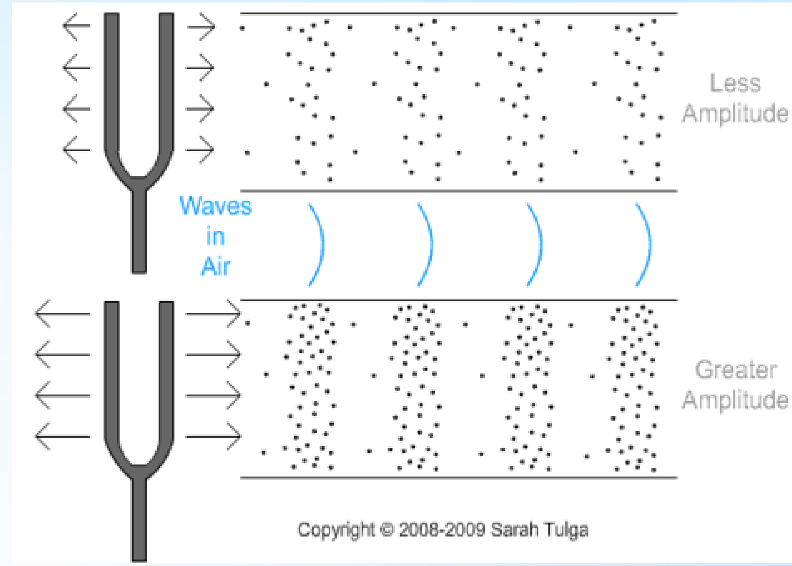
The direction of propagation of a sound wave is **parallel** to its direction of oscillation.

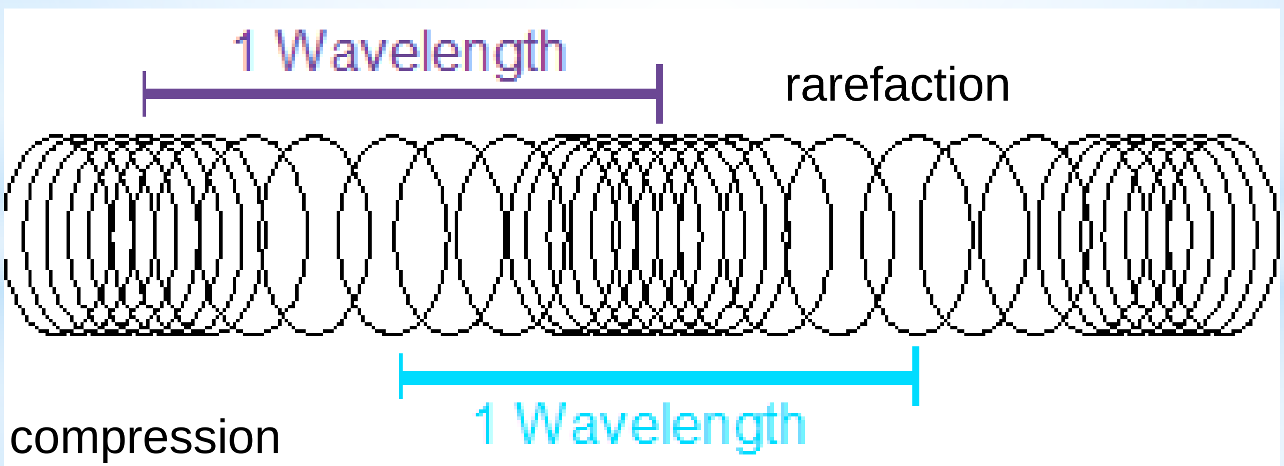


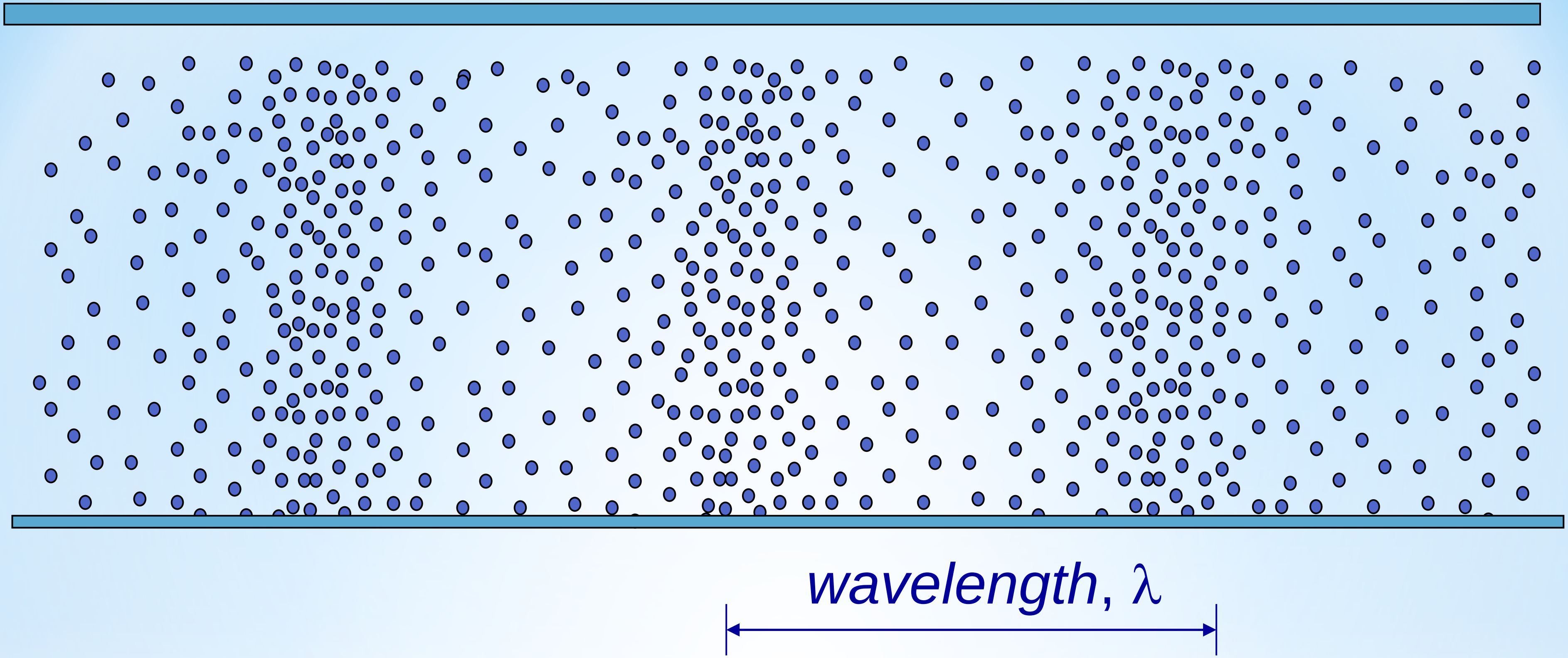
All waves have wavelength.



Amplitude

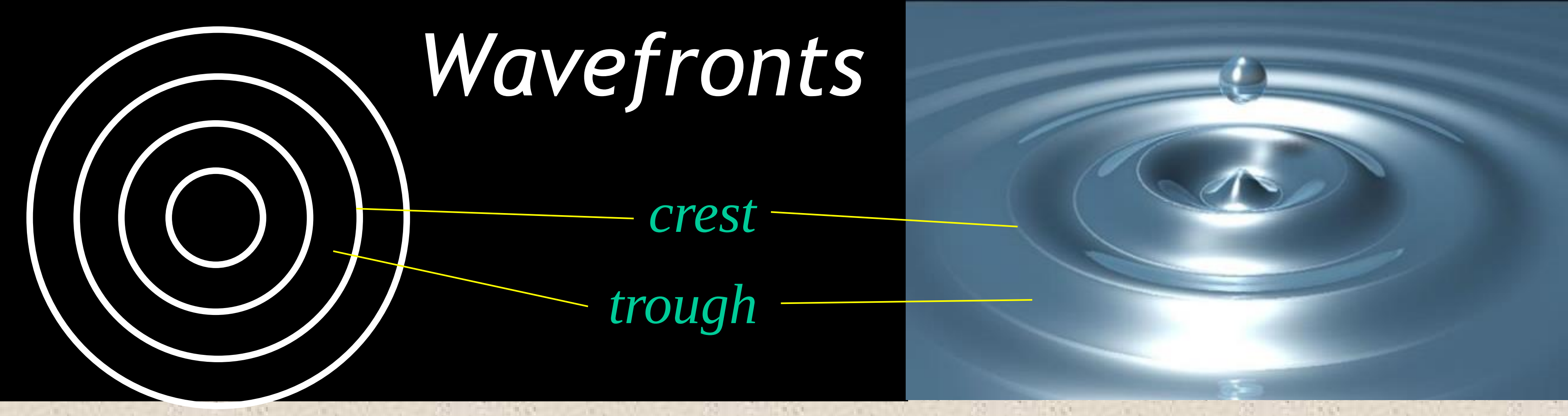




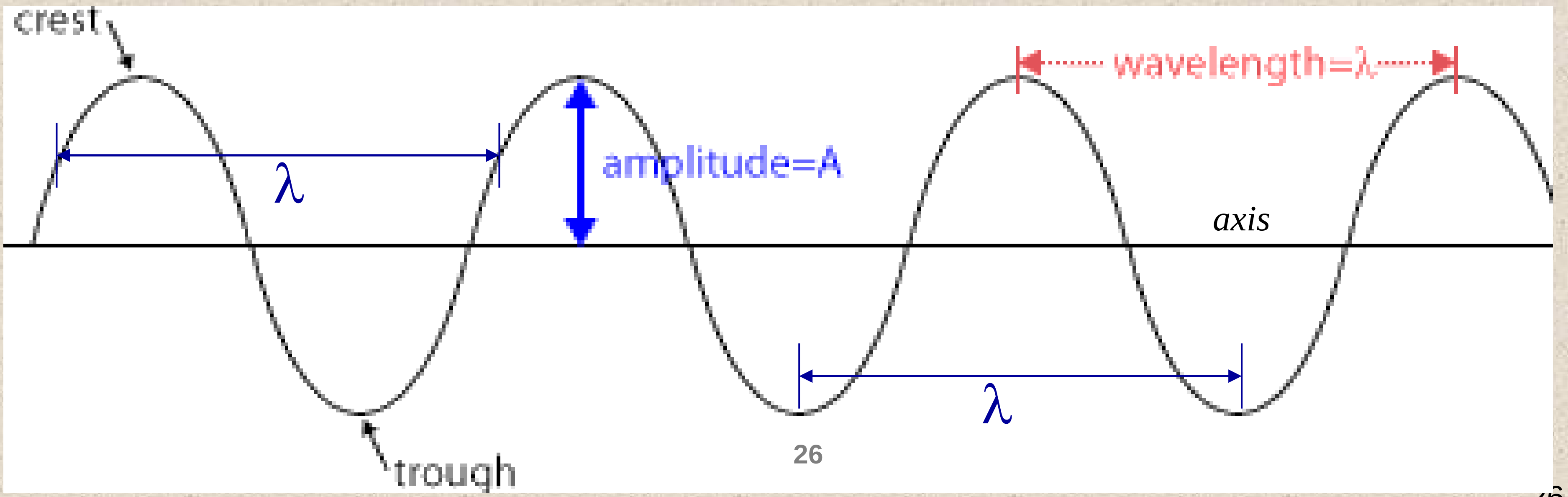


For a **longitudinal** wave, wavelength is the distance between adjacent compressions or rarefactions.

Wavefronts



For a **transverse** wave, wavelength is measured between adjacent crests or between adjacent troughs.



Measuring the Speed of Waves

Wave Velocity

The speed with which a wave crest passes by a particular point in space.

It is measured in meters/second.

Speed of Waves

$$\text{Speed} = \text{Wavelength} \times \text{Frequency}$$

$$V = f \times \lambda$$

Speed of Sound

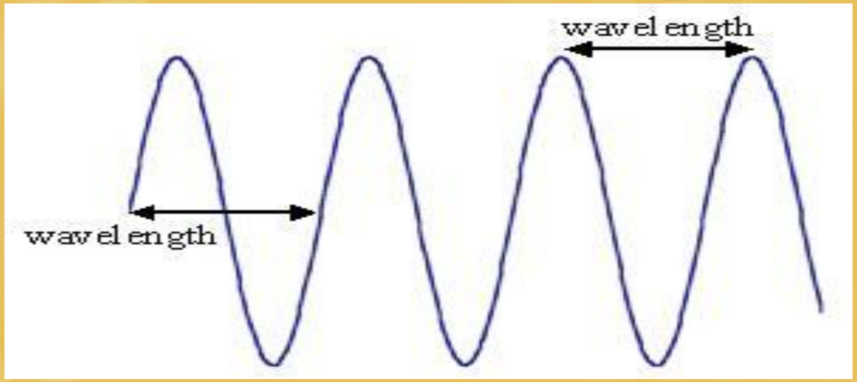
• Medium	velocity m/sec
air (20 C)	343
air (0 C)	331
water (25 C)	1493
sea water	1533
diamond	12000
iron	5130
copper	3560
glass	5640

Sound travels 4 times faster through water than through air.

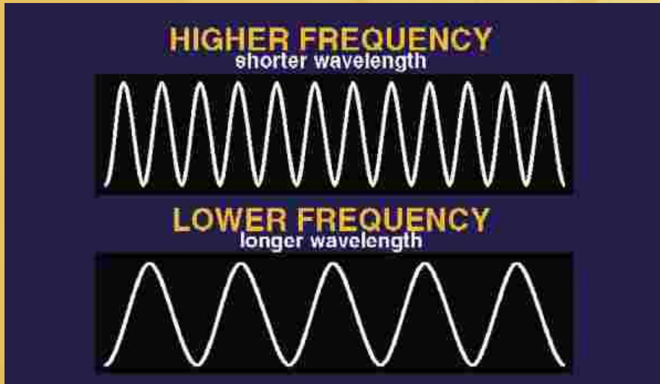
Sound travels 16 times faster through glass than through air.

Wavelength & Frequency

- **Wavelength** is the distance between one part of a wave and the same part of the next wave



- **Frequency** is the number of waves moving past a point in one second.

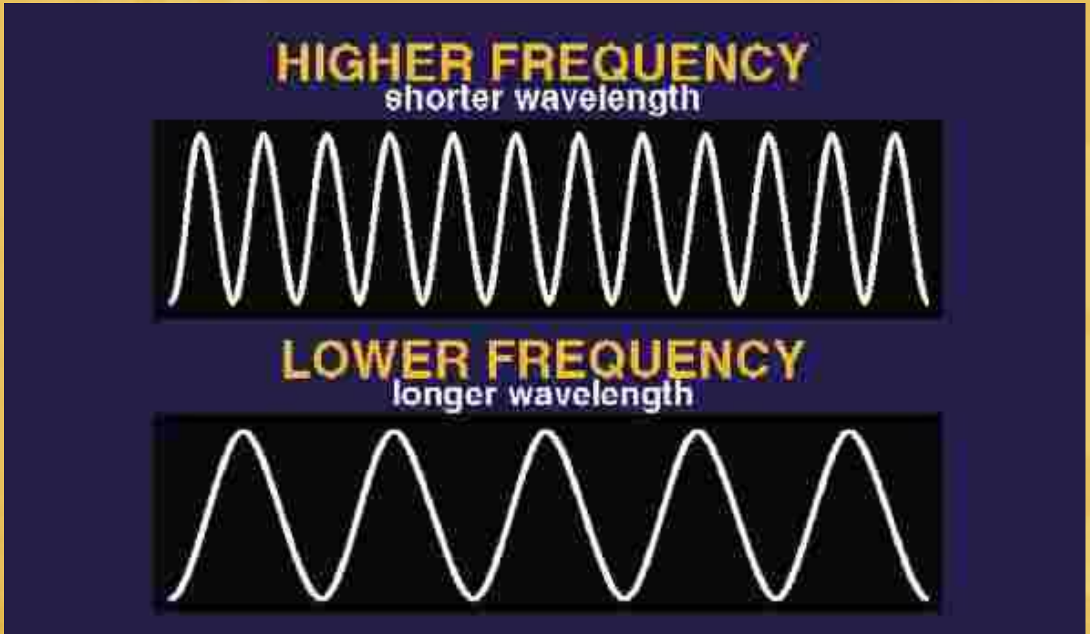


Wavelength & Frequency

$$v = f \lambda$$

What is the relationship between frequency and wavelength?

THINK ABOUT IT



Sound

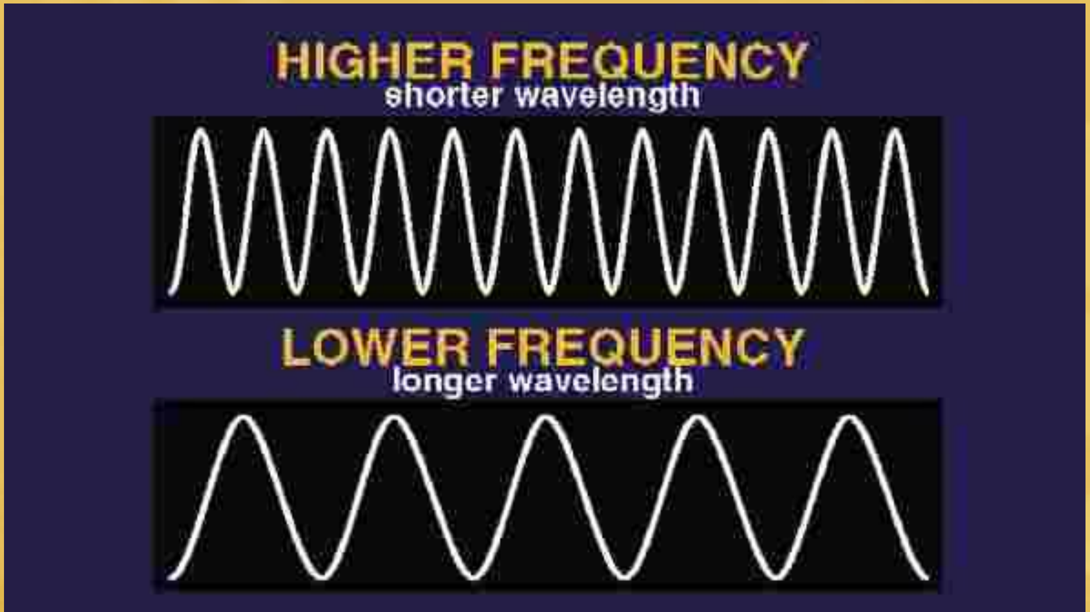
Wavelength & Frequency

$$v = f\,\lambda$$

Speed of sound = frequency x wavelength

If the speed of sound is constant, then, frequency and wavelength are INVERSELY proportional: $f \propto 1/\lambda$

- as frequency (f) increases, wavelength (λ) decreases
- as frequency (f) decreases, wavelength (λ) increases



Sound

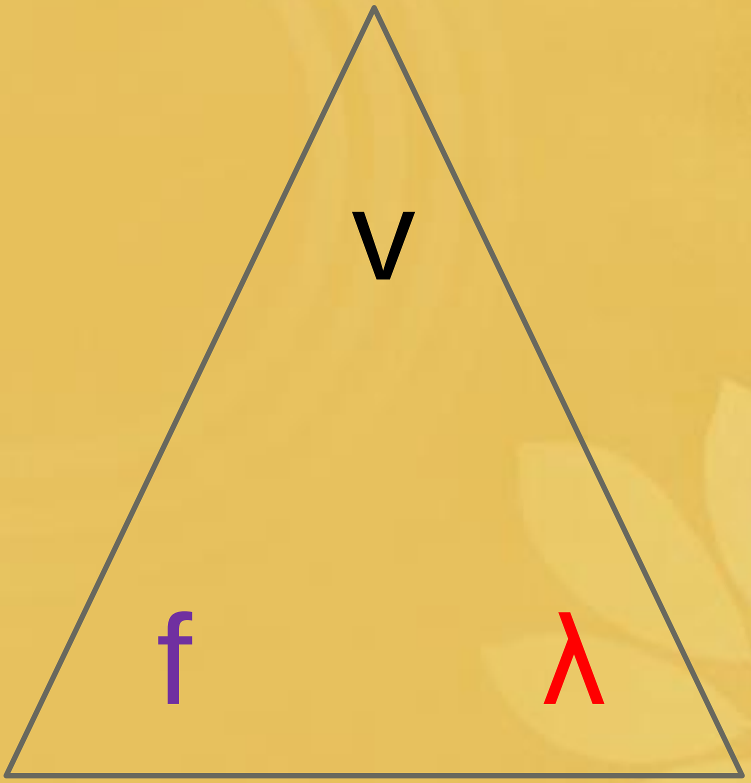
Wavelength & Frequency

$v = ?$

Speed of sound = ? x ?

$f = ?$

$\lambda = ?$



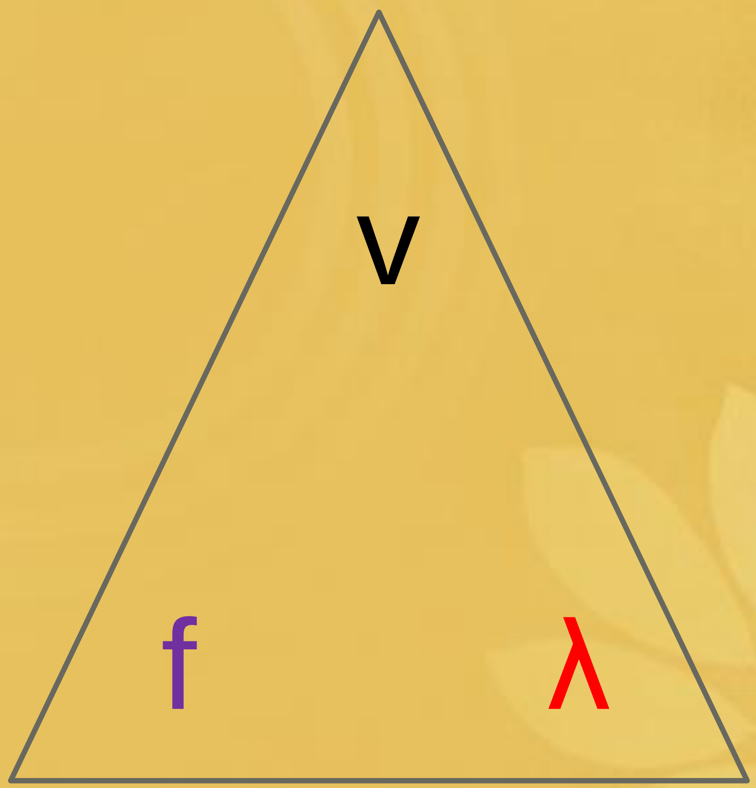
Wavelength & Frequency

$$v = f\,\lambda$$

Speed of sound = frequency x wavelength

$$f = v\,/\,\lambda$$

$$\lambda = v\,/\,f$$



Wavelength & Frequency

TRY IT

If the wavelength (λ) of a tuning fork is 1.29 meters and we assume the speed of sound is 330 meters per second, what frequency (f) will it produce? SHOW WORK

A

G

E

S

Wavelength & Frequency

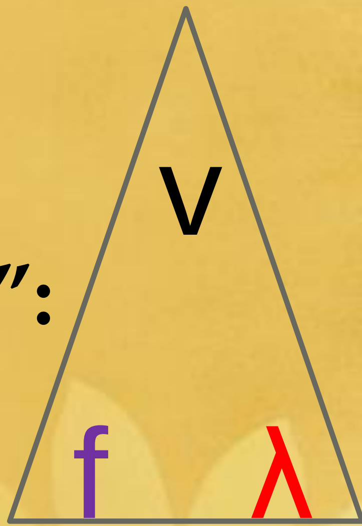
If the wavelength (λ) of a tuning fork is 1.29 meters and we assume the speed of sound is 330 meters per second, what frequency (f) will it produce? SHOW WORK

A frequency

G **$v = 330$ m/s; $\lambda = 1.29$ m**

E $v = f\lambda$ … **rearrange to solve for "f":**

$$f = v / \lambda$$



S $f = 330 \text{ m/s} / 1.29 \text{ m}$ **$f = 256$ Hz**

Wavelength & Frequency

TRY IT

What is the wavelength (λ) of the musical note, G, which has a frequency of 767 Hz?

A

G

E

S

Wavelength & Frequency

TRY IT

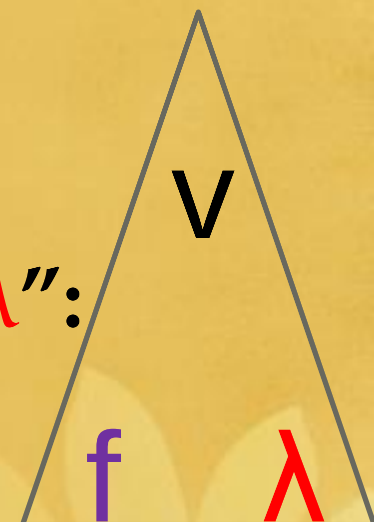
What is the wavelength (λ) of the musical note, G, which has a frequency of 767 Hz?

A wavelength (λ)

G **v = 330 m/s; f = 767 Hz**

E $v = f \lambda$ … **rearrange to solve for "λ":**

$$\lambda = v / f$$



S $\lambda = 330 \text{ m/s} / 767 \text{ Hz}$ $\lambda = 0.43 \text{ m}$

Behavior of Waves

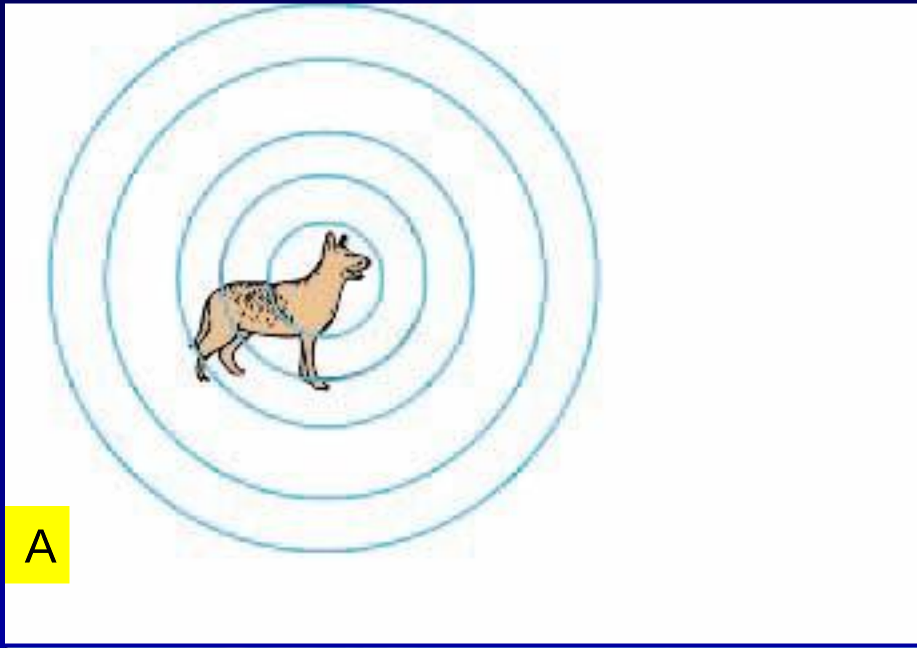
“Doppler Effect”

“Refraction of Sound”

“Reflection of Sound”

Spherical sound waves are produced from a <u>STATIONARY</u> source, spreading out evenly in all directions.

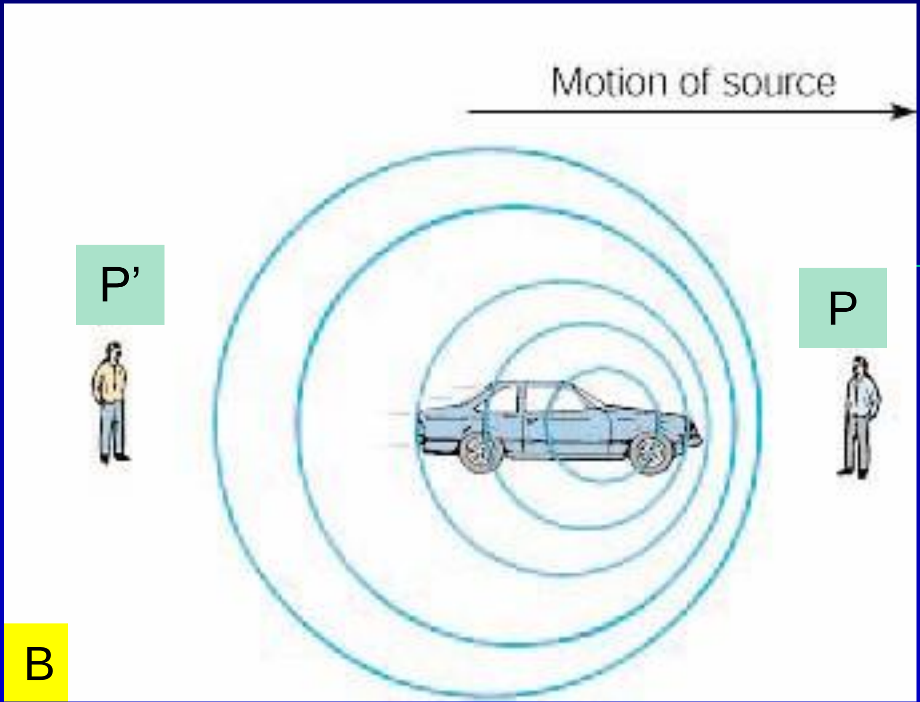
E.g. throw a stone into a calm pond.



Doppler Effect

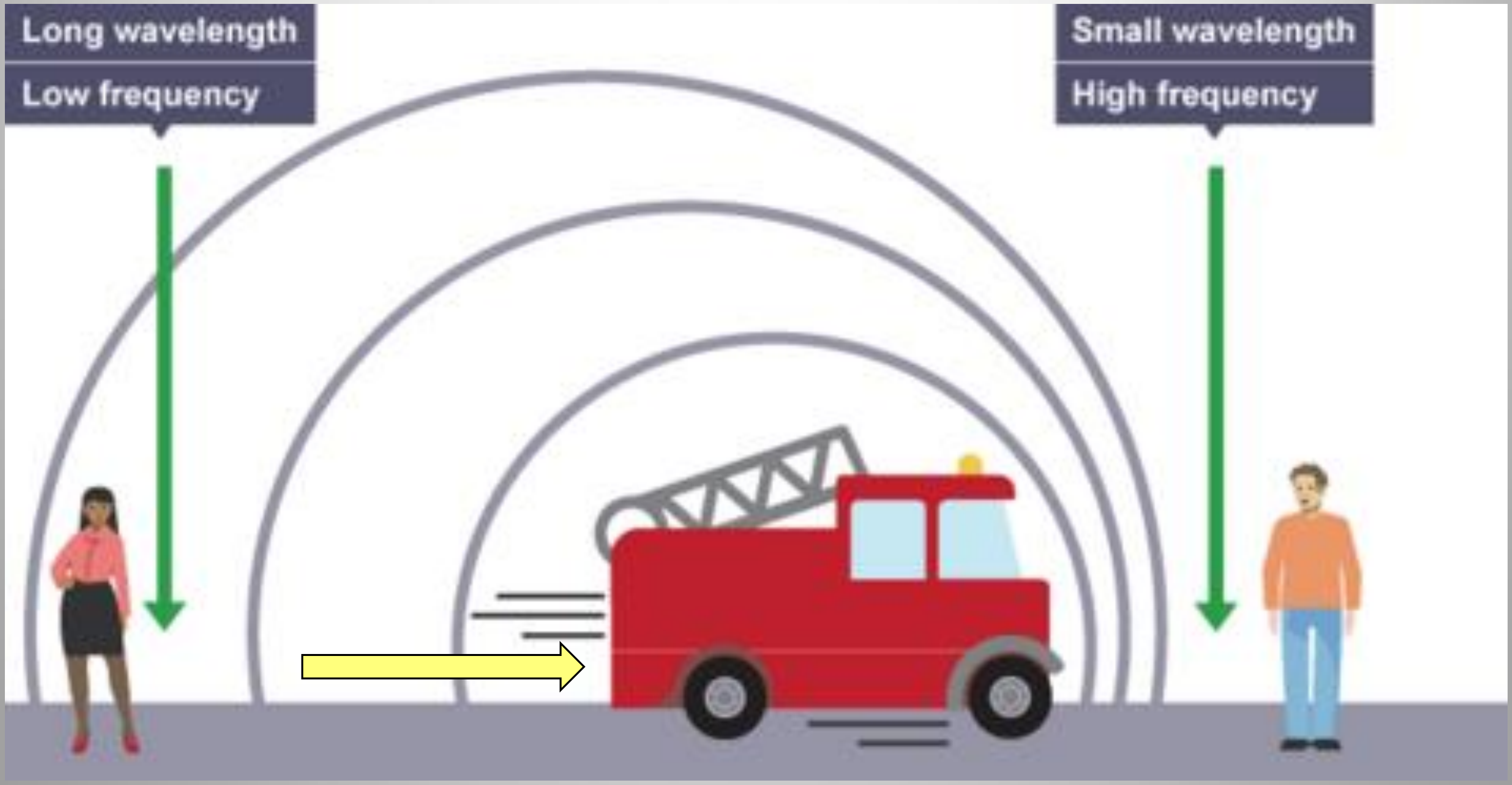
If the source is <u>MOVING</u>, an observer at position P will experience more wave crests per second than an observer at position P'.

The observer at P interprets this as a higher pitch.

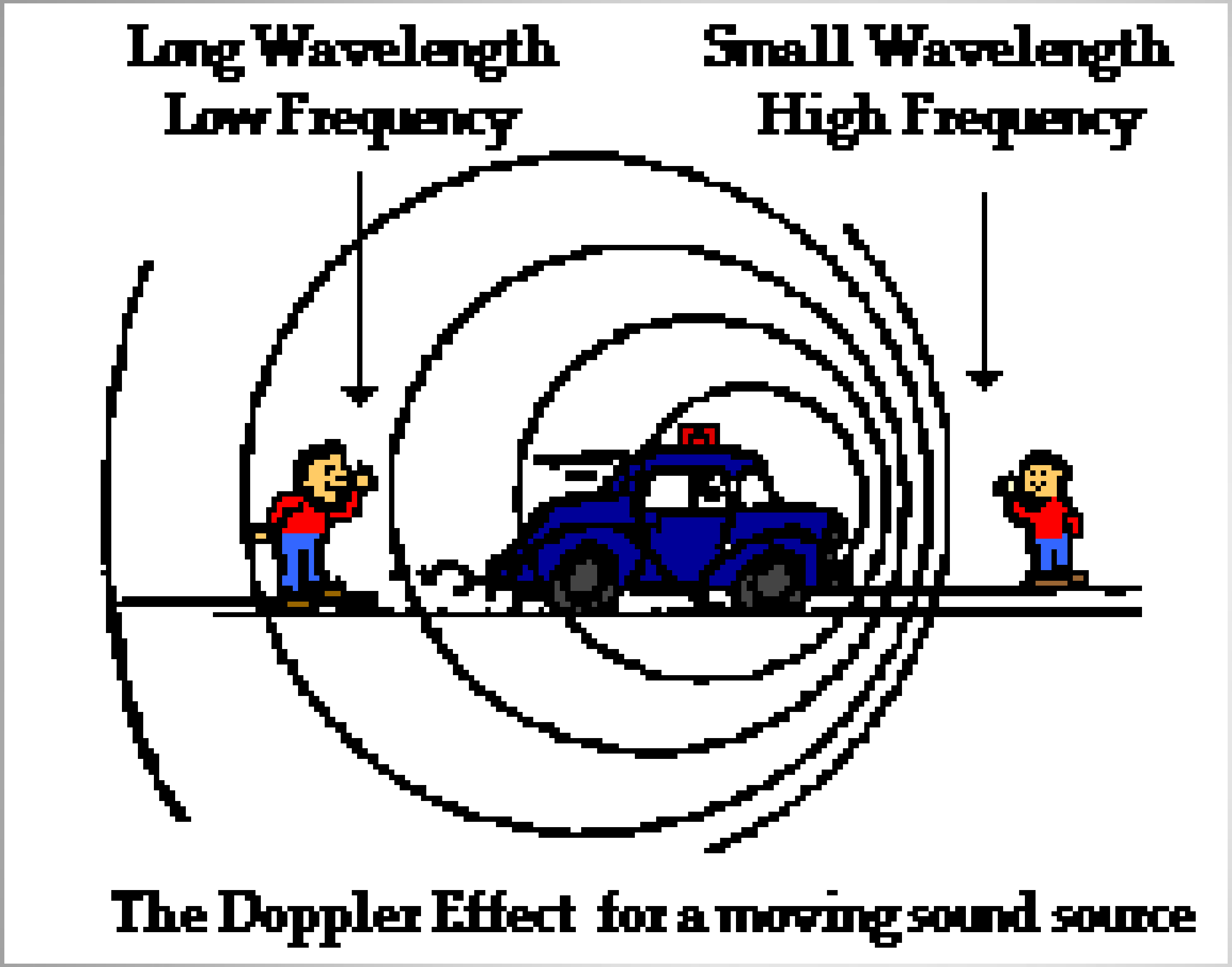


Doppler Effect

The apparent change in the frequency of a sound caused by the motion of either the listener or the source of the sound.



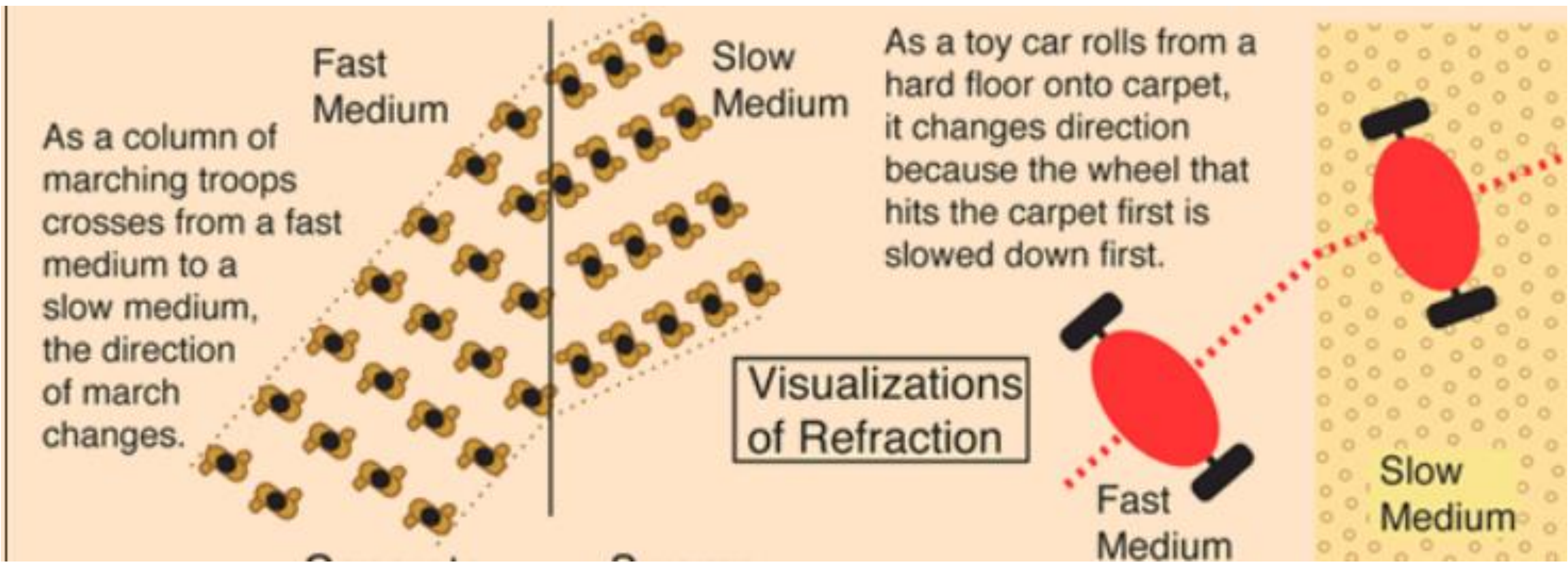
Doppler Effect



http://somup.com/cFXoILnjiI Car Horn (0:13)

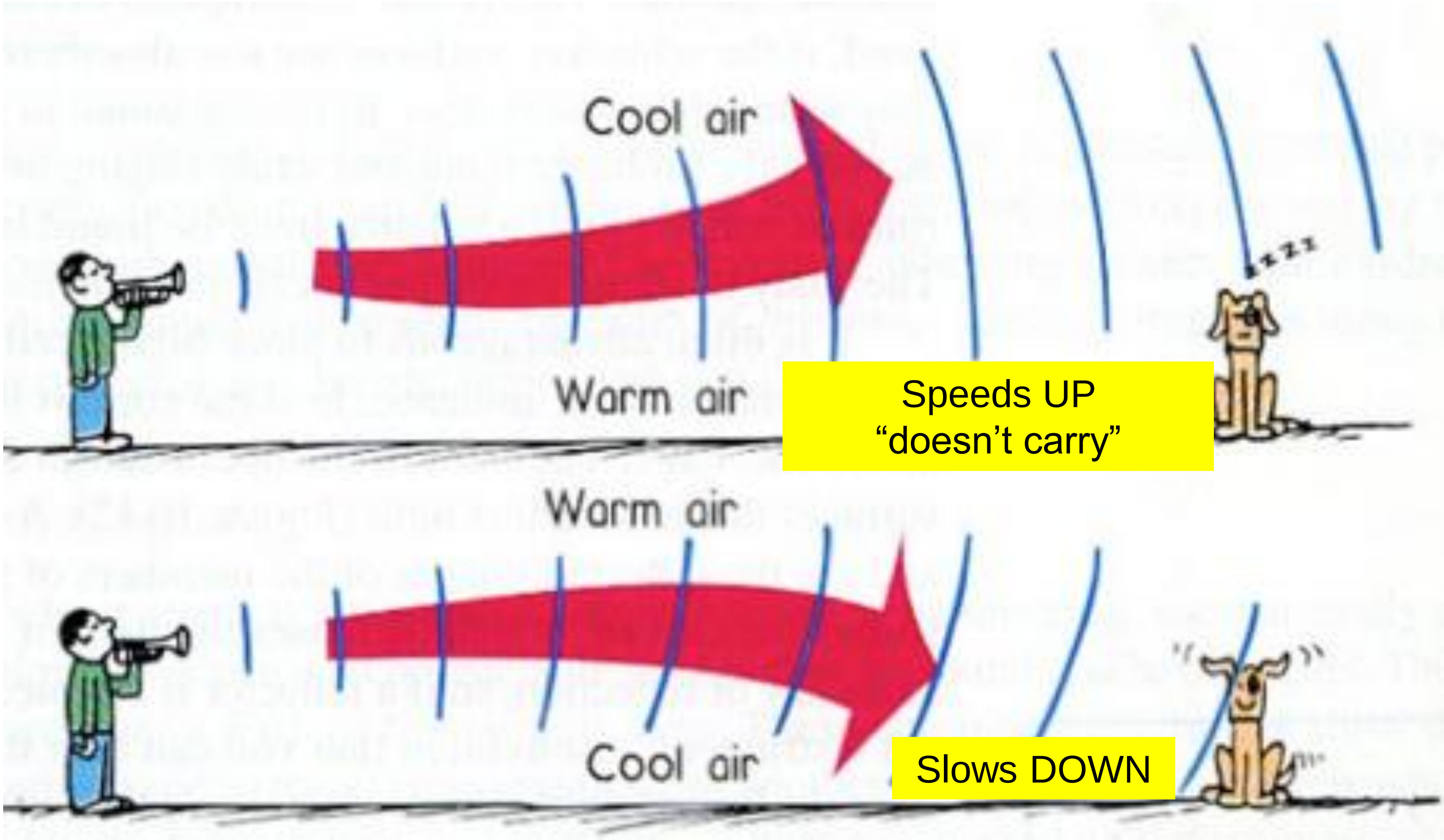
Refraction

Refraction is the bending of a wave as it enters a new medium at an angle *(e.g.* ***waves speed up or slow down****):*



Refraction

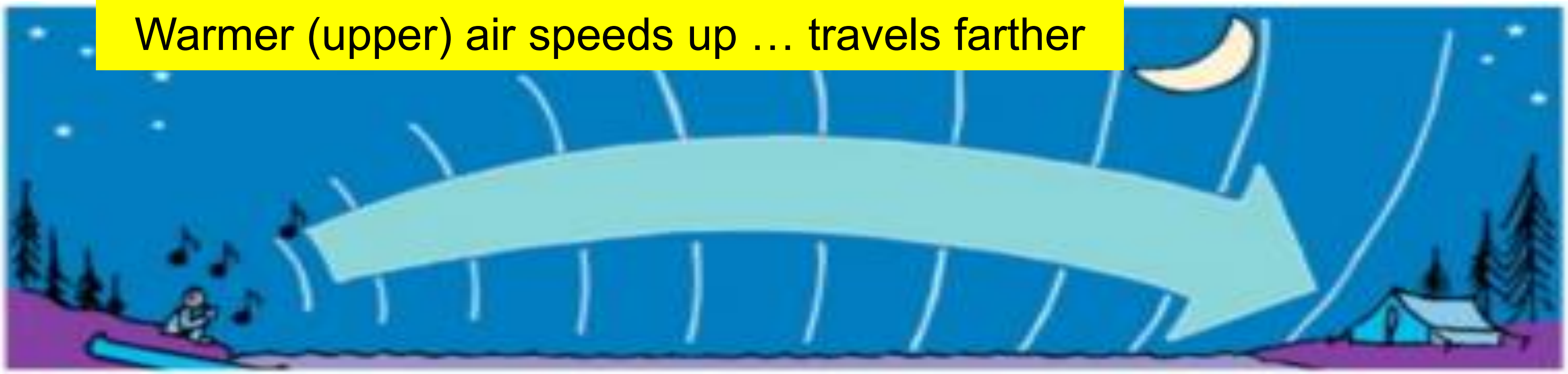
The temperature of air changes its density and "bends" sound waves (e.g. they speed up or slow down):

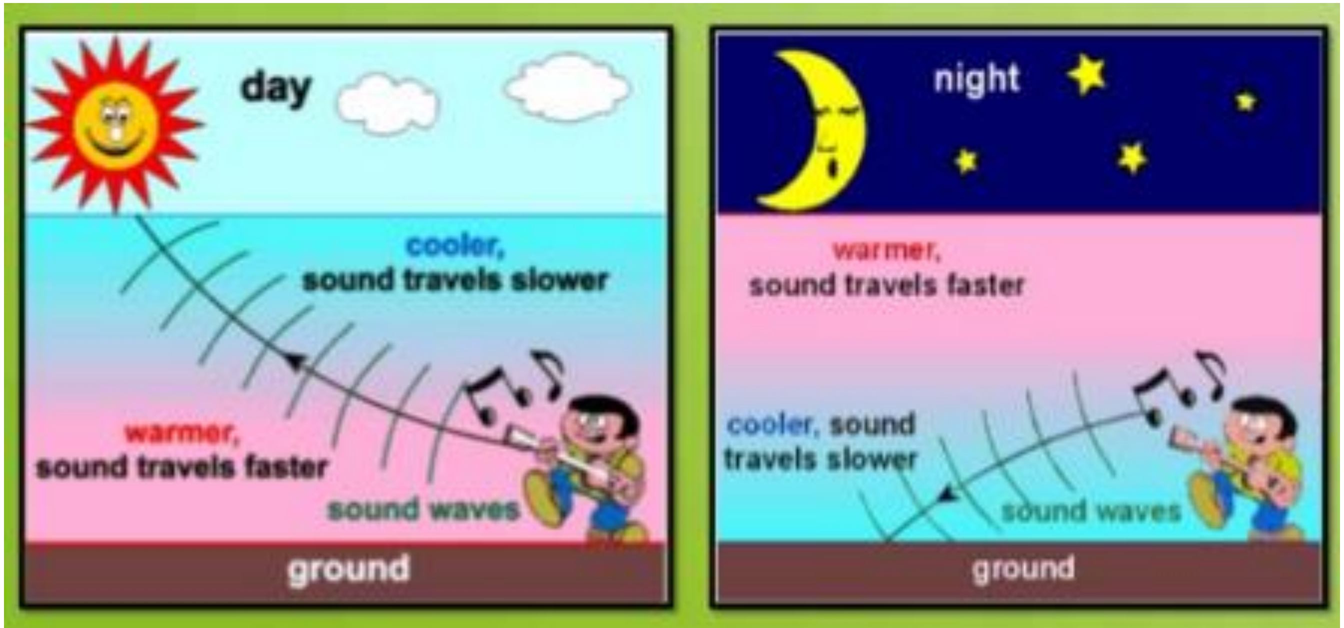


Refraction

At night, when the air is cooler over the surface of the lake, sound is refracted toward the ground and carries unusually well.

Warmer (upper) air speeds up … travels farther

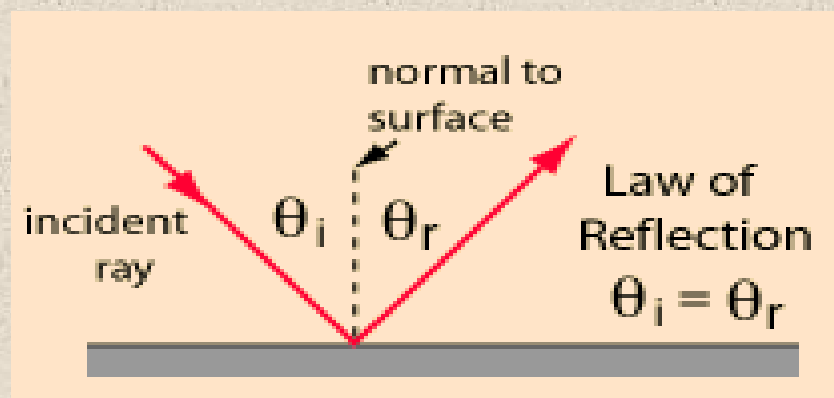


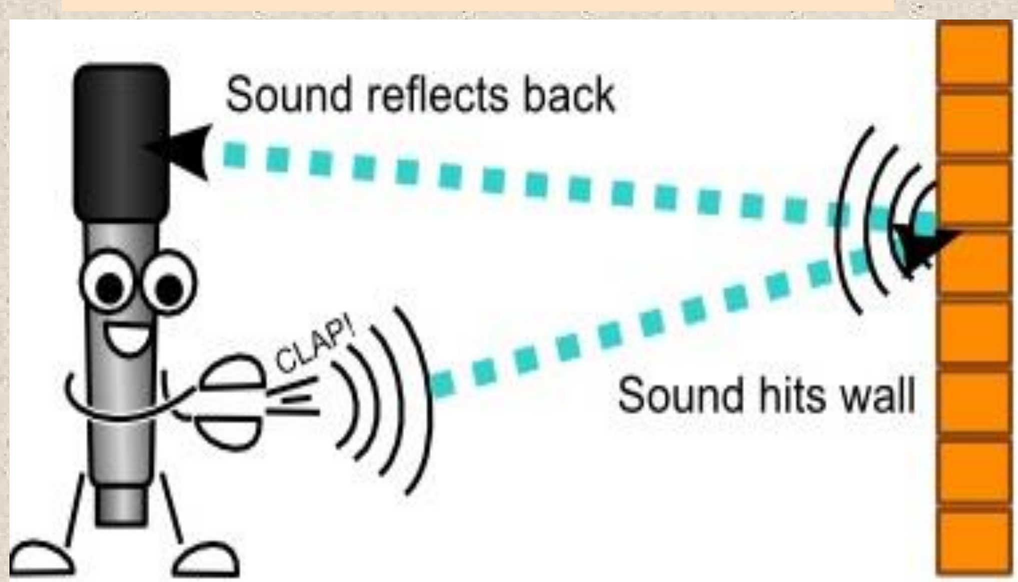


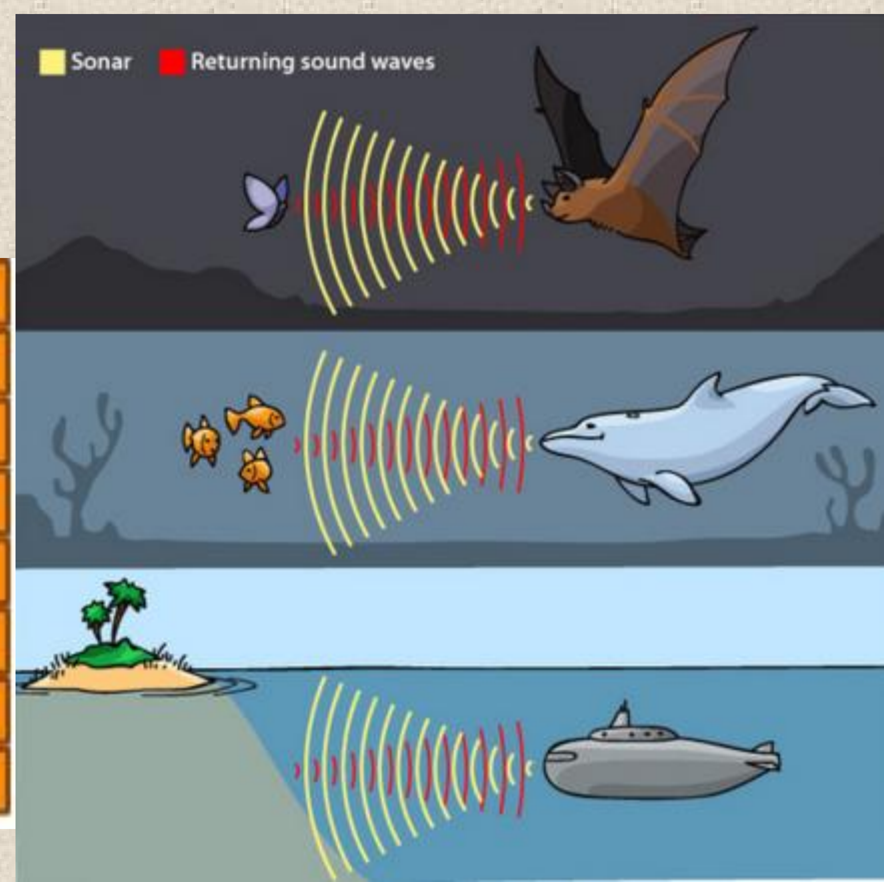
Sound tends to be louder at night

Reflection

When a sound wave "bounces back" from a surface at the same angle at which it hit the surface. *The angles are typically measured with respect to the "normal" to the surface.*







Reflection Echoes & Reverberation

ECHO *is defined by distinct repetitions of a sound occurring after 30 milliseconds*. This is when you can unquestionably hear a distinct echo of a sound coming back to you. Echoes are common in a big canyon or inside a gigantic room. In the world of music production, it's called 'delay'.

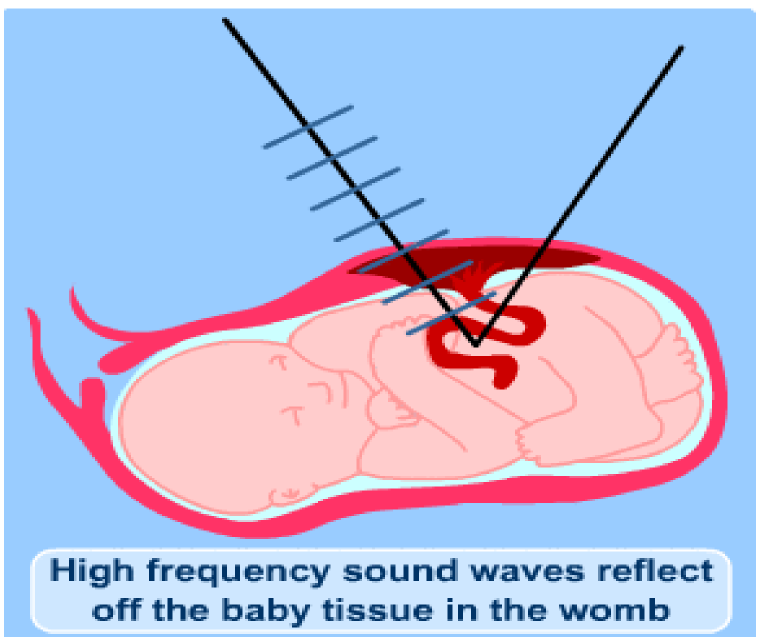
Reverberation *is characterized as random, blended repetitions of a sound occurring within thirty milliseconds after the sound is made*. This is all the sound that immediately bounces off any nearby surfaces before it gets back to your ears. So first you'll hear the original sound and then all the stuff bouncing off the walls, furniture, trees, people, giraffes and even acoustic tiling.

http://somup.com/cFXoIKnjil Echo & Reverberation (1:09)

Reflection

Ultrasound is very, very high frequency sound used to see inside people

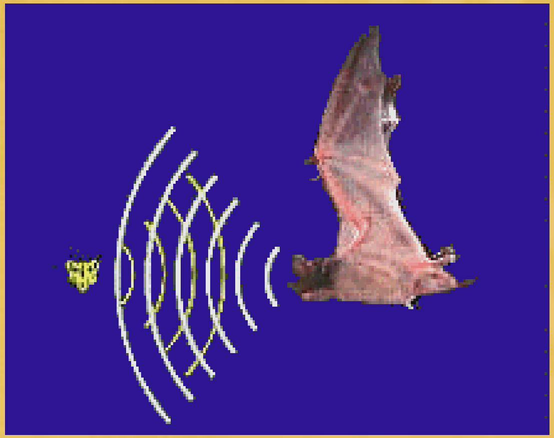
- babies before they are born
- monitor the heart
- blood flow

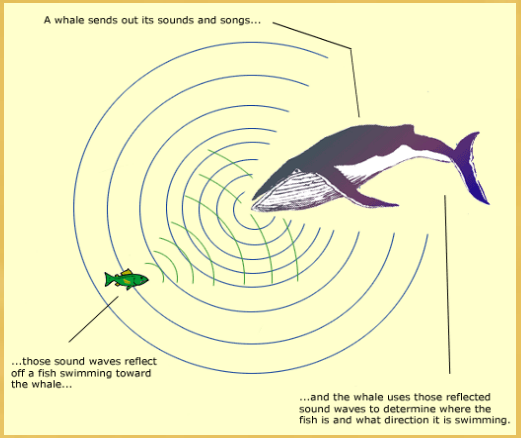


Sonar

Reflection

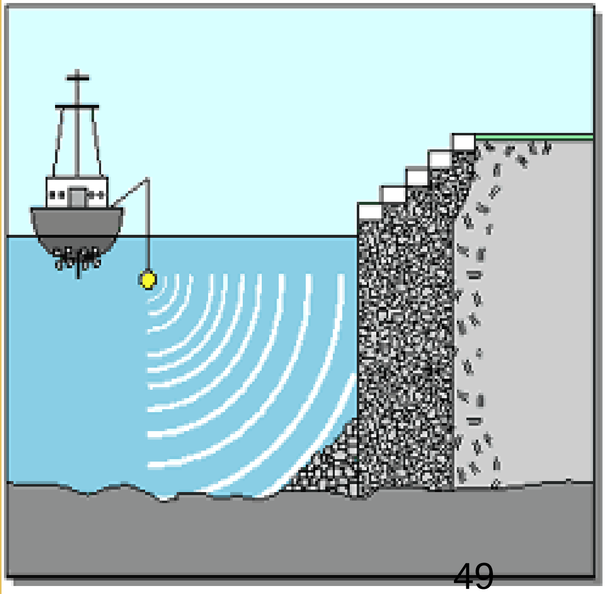
- An instrument that uses reflected sound waves to find underwater objects.
- For example,





Animals use sonar or echo location to find their prey; these sounds have such a high pitch or frequency that the human ear cannot hear them.

Humans use sonar to locate or map objects.



When does refraction of a wave occur?

a. The wave cannot enter the new medium.
b. The wave enters a new medium at any angle.
c. The wave enters a new medium at any angle except 90°.
d. Part of the wave enters a new medium and part is reflected.

The property of waves bounces off a surface that is cannot pass through is called

a. reflection.
b. refraction.
c. diffraction.
d. destructive interference.

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c. diffraction.
d. destructive interference.

What is the speed of a wave in a spring if it has a wavelength of 10 cm and a period of 0.2 s?

A

G

E

S

While wading in shallow waters, six waves crash into your legs in a 24-second span. What is the frequency of the waves?

A

G

E

S

Math Practice

What is the speed of a wave in a spring if it has a wavelength of 10 cm and a period of 0.2 s?

A speed

G **λ = 10 cm; period (T) = 0.2 s**

E **v = wavelength/period = λ / T**

S **v = λ / T = 10 cm / 0.2 s = 50 cm/s**

While wading in shallow waters, six waves crash into your legs in a 24-second span. What is the frequency of the waves?

A frequency

G **6 waves in 24 s**

E **f (Hz) = waves / second**

S **f (Hz) = waves / second = 6 waves/24 s = 0.25 Hz**

Assessment Questions

1. A mechanical wave carries energy from one place to another through the
   a. physical transfer of matter.
   b. interaction of electromagnetic fields.
   c. phase changes of a medium.
   d. vibration of a medium.

Assessment Questions

1. A mechanical wave carries energy from one place to another through the
   a. physical transfer of matter.
   b. interaction of electromagnetic fields.
   c. phase changes of a medium.
   d. vibration of a medium.

   ANS: D

Assessment Questions

2. In what type of wave is the vibration of the medium parallel to the direction in which the wave travels?
   a. transverse wave
   b. longitudinal wave
   c. surface wave
   d. rarefaction

Assessment Questions

2. In what type of wave is the vibration of the medium parallel to the direction in which the wave travels?

   a. transverse wave
   b. longitudinal wave
   c. surface wave
   d. Rarefaction
   e. Two choices apply

ANS: C & D both apply

Assessment Questions

3. An example of a transverse wave is a(n)
   a. sound wave traveling through air.
   b. ocean wave far from the shore.
   c. ocean wave as it approaches the shore.
   d. light wave traveling through space.

Assessment Questions

3. An example of a transverse wave is a(n)
   - **a. sound wave traveling through air.**
   - b. ocean wave far from the shore.
   - c. ocean wave as it approaches the shore.
   - d. light wave traveling through space.

   ANS: A

Wave Speed

Math Practice

1. A wave on a rope has a wavelength of 2.0 m and a frequency of 2.0 Hz. What is the speed of the wave?

Answer: $v = f\lambda$

The speed is 2.0 Hz x 2.0 m = 4.0 m/s

Wave Speed

Math Practice

2. A motorboat is tied to a dock with its motor running. The spinning propeller makes a surface wave travel at 0.4 m/s in the water and a wavelength of 0.1 m. What is the frequency of the waves?

Answer:

Wave Speed

Math Practice

2. A motorboat is tied to a dock with its motor running. The spinning propeller makes a surface wave travel at 0.4 m/s in the water and a wavelength of 0.1 m. What is the frequency of the waves?

Answer: $v = f \lambda$ … **rearrange to solve for "λ":**

$$f = v / \lambda$$

The frequency is 0.4 m/s / 0.1 m = 4 Hz

Wave Speed

Math Practice

4. What is the wavelength of an earthquake wave if it has a speed of 5 km/s and a frequency of 10 Hz?

Answer:

Wave Speed

Math Practice

4. What is the wavelength of an earthquake wave if it has a speed of 5 km/s and a frequency of 10 Hz?

Answer:

$v = f\lambda$ … **rearrange to solve for "λ":**

$$\lambda = v / f$$

The wavelength is (5 km/s)/10 Hz = 0.5 km.

Assessment Questions

1. The intensity of sound waves is measured in units of
   a. hertz (Hz).
   b. decibels (dB).
   c. joules (J).
   d. meters (m).

Assessment Questions

1. The intensity of sound waves is measured in units of
   a. hertz (Hz).
   b. decibels (dB).
   c. joules (J).
   d. meters (m).

   ANS: B