Unit 5
Energy Movement

Mrs. Valentine

Physical Science

Section 1
What are Waves?

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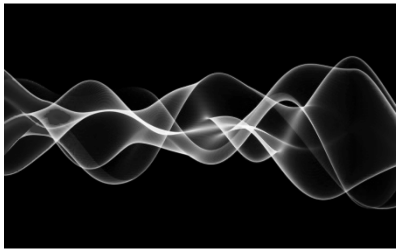
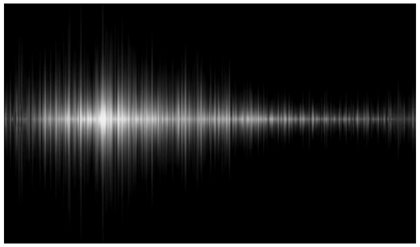
ocean: the fun of surfing, jumping waves, or just looking out over the ocean.

- However, the waves of the ocean are only one kind of wave that we experience.
- Other types include transverse waves, longitudinal waves, and surface waves.

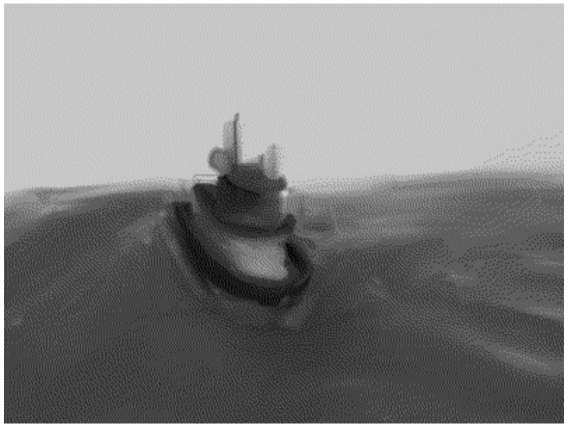
Waves and Energy

- <u>Wave</u> – a disturbance that transfers energy from place to place.





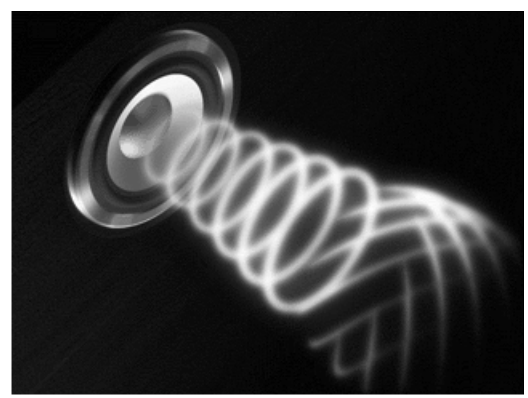
- Remember that in science, energy is defined as the ability to do work.
- The energy carried by a wave can be enough to even lift a large ship.



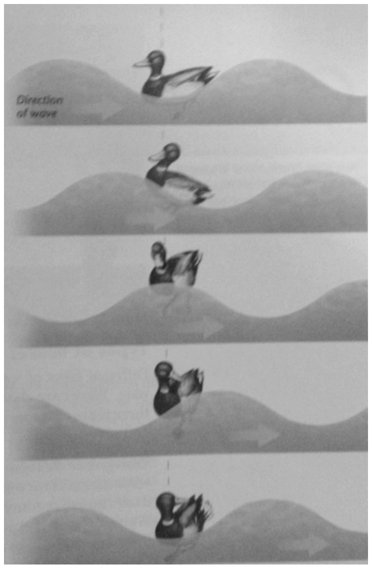
- The disturbance from a wave is only temporary. Once the wave passes, circumstances return to what they had been.

What Carries Waves?

- Many waves require something to travel through.
- Medium – the material through which a wave travels.
- Gases, solids, and liquids can all be mediums.
- Mechanical Waves – waves that require a medium through which to travel.
- Mechanical waves do not carry the medium with them as they move.

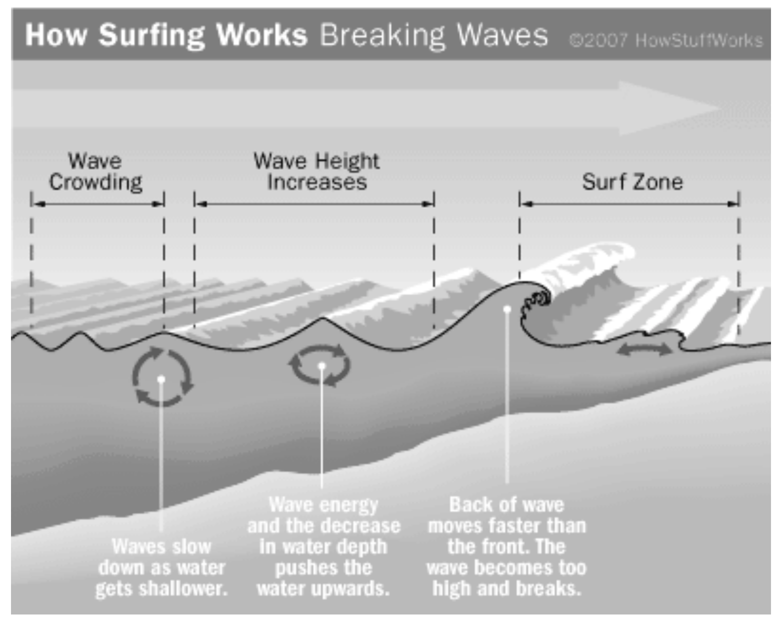


What Carries Waves?



- A duck sitting on wavy water does not move along with the waves.
- It moves up and down as the wave peaks and troughs.

- Breaking waves at a beach behave a bit differently.
- In this case, some of the water does move with the wave because the area is so shallow.



What Carries Waves?

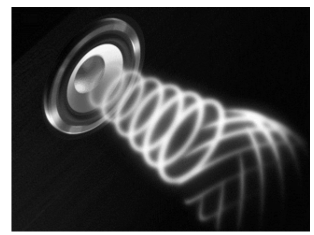
- Not all waves need mediums to carry them.
- Light and other forms of electromagnetic radiation do not require a medium.
- How can we prove this with our knowledge of outer space?

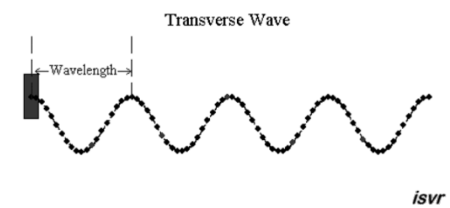
What Causes Waves?

- **vibrate.**

- **Definition:** Vibration – a repeated back-and-forth or up-and-down motion.

- **Vibrations are the sources of waves.**





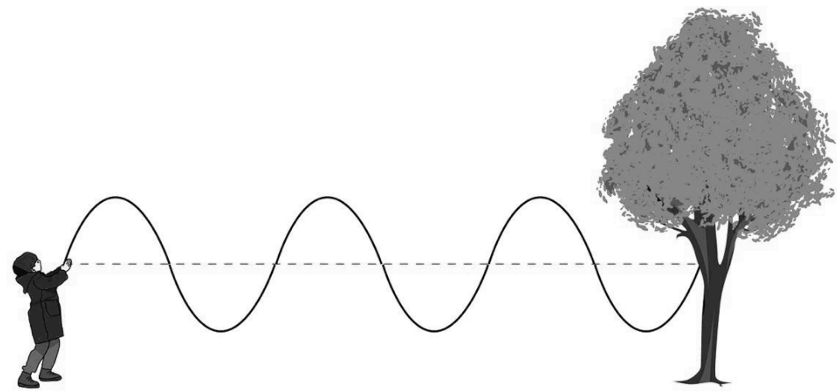
- A moving object can transfer energy to a medium to create a wave.

- For example, the propellers of a motorboat transfer energy to the water, producing a wave.

Types of Waves

- **Waves are classified according to how they move. The three types of waves are transverse waves, longitudinal waves, and surface waves.**

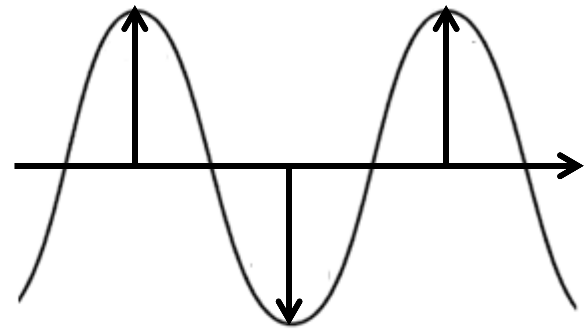
- Making a wave on a rope, the wave moves from one end to the other.



- **Definition:** <u>Transverse Waves</u> – waves that move the medium at right angles to the direction in which the waves are traveling.

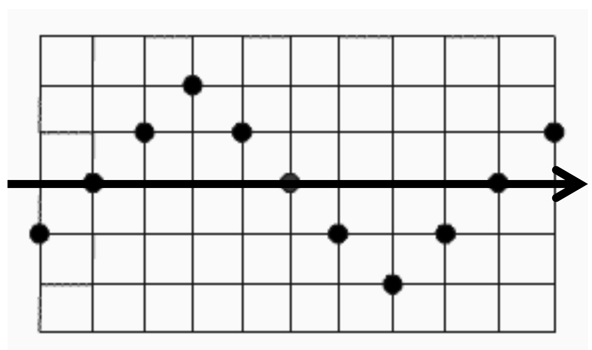
- The wave in the rope is a transverse wave, just like the waves under the duck in Figure 1.

Transverse Waves



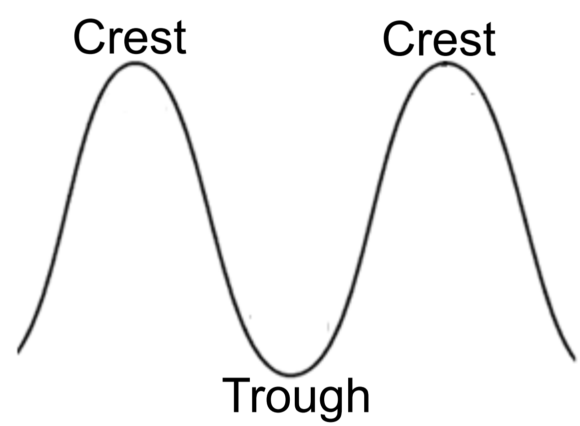
- Transverse means "across."

- As a transverse wave moves in one direction, the particles of the medium move across the direction of the wave.



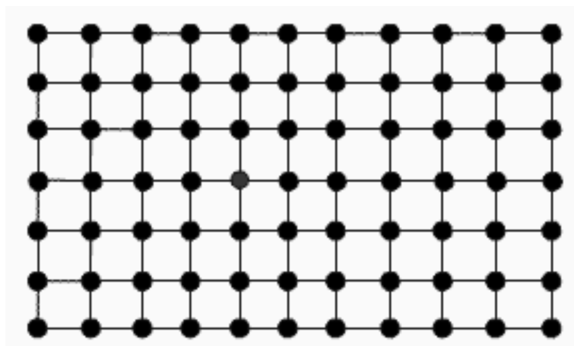
- **Definition:** <u>Crest</u> – the highest parts of the wave.

- **Definition:** <u>Trough</u> – the lowest parts of the wave.



Longitudinal Waves

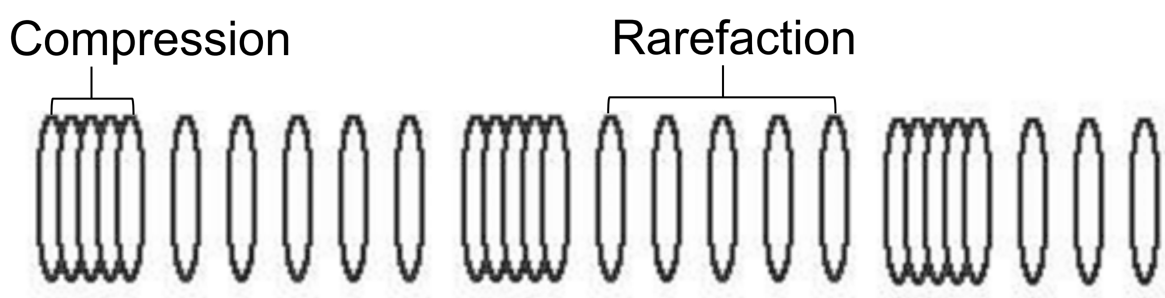
- **Definition:** Longitudinal Wave – a wave that moves the particles of the medium parallel to the direction that the waves are traveling.



- The coils of the spring in the slinky move back and forth in the same direction as the wave travels.
- In some parts, the coil is stretched out, and in other parts, the coils are close together.

Longitudinal Waves

- **Definition:** <u>Compressions</u> – the parts of the wave where the coil is close together.



- **Definition:** <u>Rarefactions</u> – the parts of the wave where the coil is spread out.

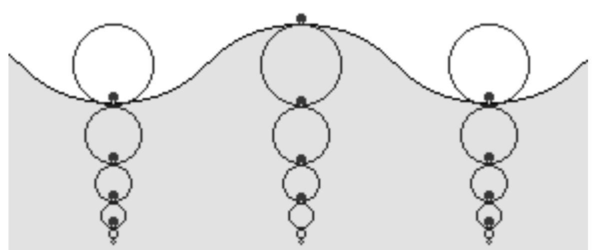
- As compressions and rarefactions move throughout the spring, energy is transferred from one end of the spring to the other, creating the wave.

Combinations of Waves

- **Definition:** Surface Waves – combinations of transverse and longitudinal waves.

- These waves occur between two mediums, such as water and air.

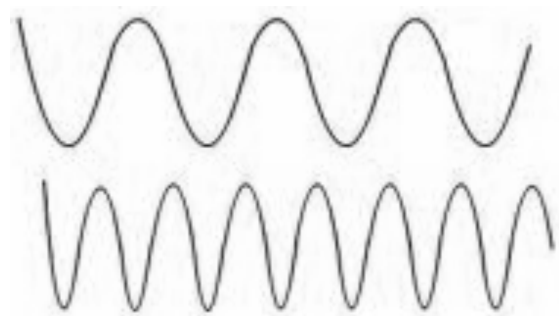
- However, instead of compression, like with the spring, the particles move in circles.



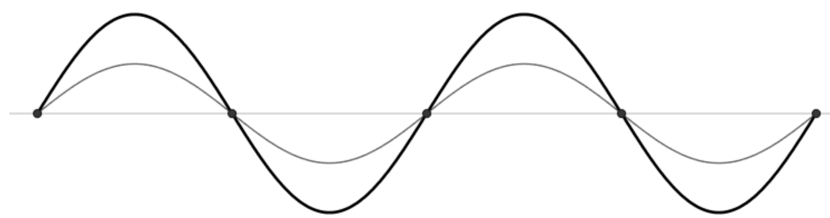
- It is the up-and-down motion combined with the back-and-forth motion that make these particles move in a circle.

Section 2
Properties of Waves

- Waves can carry a little energy or a lot.



- They can be short or long.
- They can be rare or frequent.

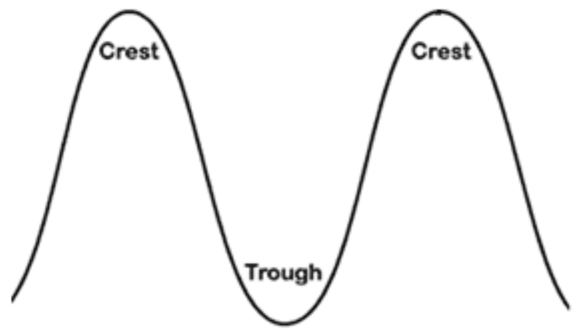


- They can be fast or slow.
- **The basic properties of waves are amplitude, wavelength, frequency, and speed.**

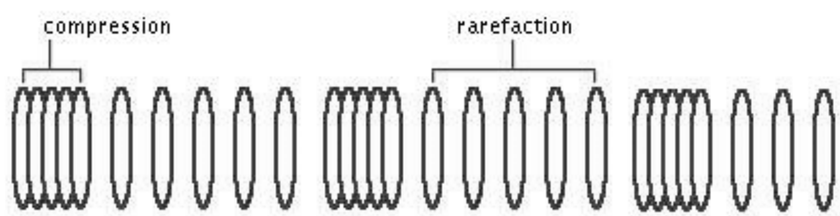
Wave Diagrams

- To understand the properties of a wave, it helps to draw the wave.

- Transverse:



- Longitudinal:

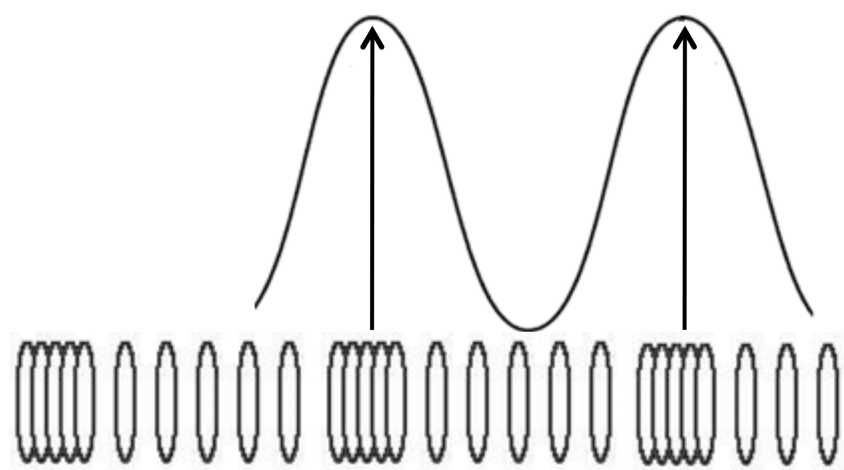


Wave Diagrams

- For longitudinal waves, think of the compressions in the spring as being similar to the crests of a transverse wave.

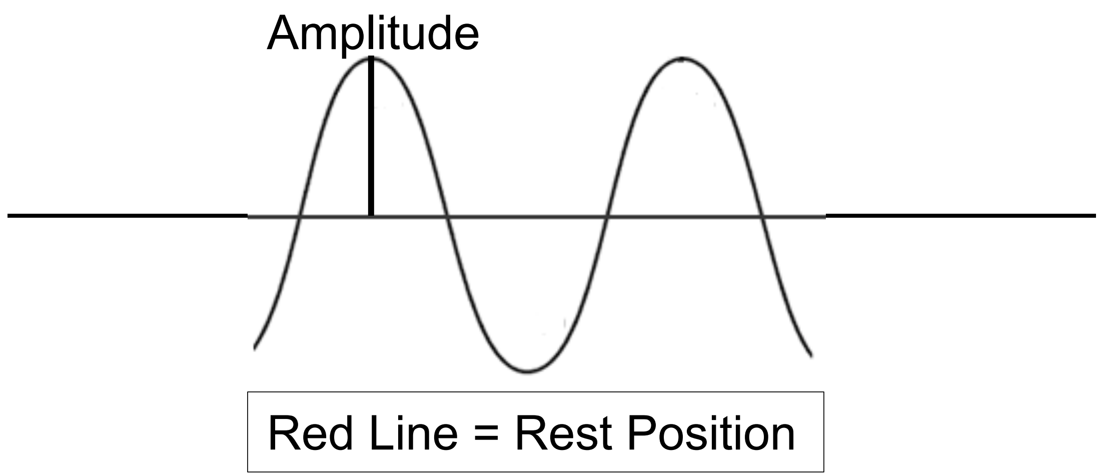
- The compressions of a longitudinal wave line up with the crest on a transverse wave and how the rarefactions line up with the troughs.

- These parts correspond to one another.



Amplitude

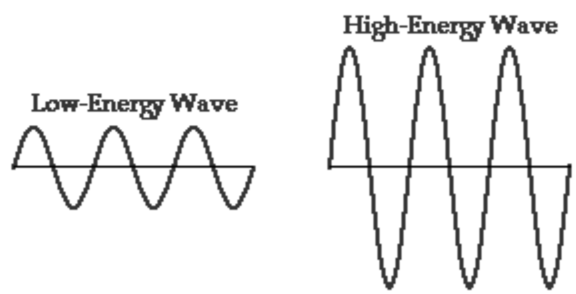
- **Definition:** Amplitude – the maximum distance of the particles of the medium carrying the wave more away from their rest positions.



- The amplitude is a measure of how much a particle in a medium moves when disturbed by the wave.

Amplitude

- Remember that the source of waves is vibration.
- The more the particles vibrate, the larger the amplitude.
- To increase the amplitude, the amount of energy put in to the wave must increase.



The amplitude of a wave is related to the energy which it transports.

- **Therefore, the amplitude of a wave is a direct measure of the wave's energy.**

Amplitude of Longitudinal Waves

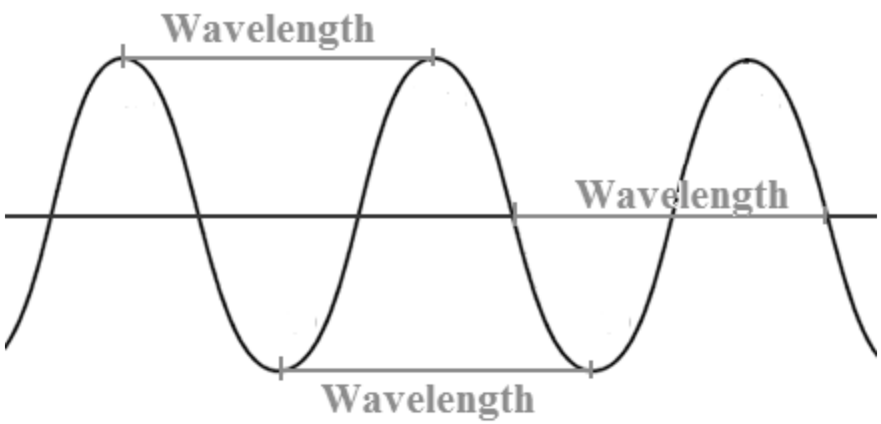
- The amplitude of a longitudinal wave is a measure of how compressed or rarefied the medium becomes.

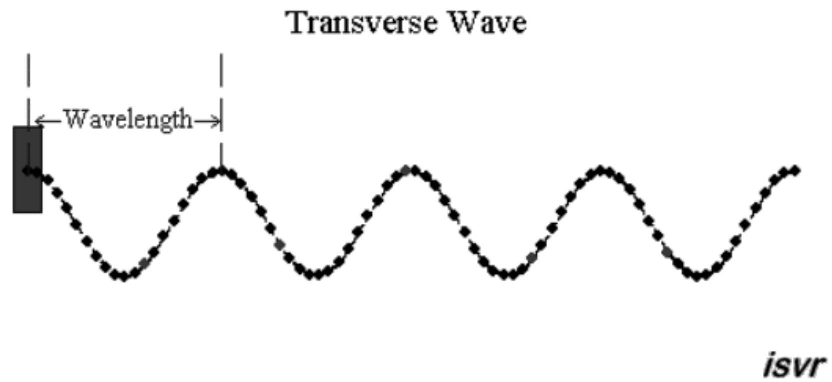
- High energy vibrations cause the coil to compress more.

- The tighter the compressions and the looser the rarefactions, the higher the amplitude of a longitudinal wave.

Wavelength

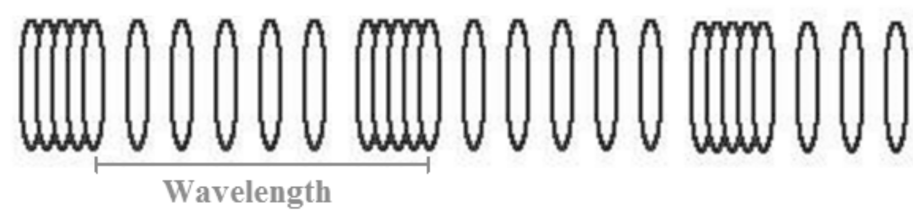
- **Definition:** <u>Wavelength</u> (λ)– the distance between two corresponding parts of a wave.





- The wavelength can go from crest to crest, trough to trough, or between adjacent points of intersect with the rest line that have the same slope, as seen above.

- Longitudinal wavelength can be found by measuring the distance from one compression to the next.



Frequency

- **Definition:** <u>Frequency</u> ( ) – the number of complete waves that pass a point in a certain amount of time.

- If you make waves on a rope so that one wave passes by every second, the frequency is 1 wave per second, 1 cycle/s, or 1Hz.

- **Definition:** <u>Hertz (Hz)</u> – A measure of frequency. 1Hz equals 1 cycle/s.

$$= \frac{\text{cycles}}{t}$$

Frequency Practice Problems

$$v = \frac{\text{cycles}}{t}$$

- **Five cycles** of a wave pass a point in **0.40 seconds**. What is the frequency of the wave in Hertz?

  Cycles = 5

  t = 0.40s

  $$v = \frac{5 \text{ cycles}}{0.40\text{s}}$$

  v = 12.5Hz

- A wave has a frequency of 39485Hz. How many cycles will pass a point in 3 seconds?

  118455cycles

- A wave has a frequency of 18Hz. How long will it take 32 cycles to pass a point?

  t = 1.78s

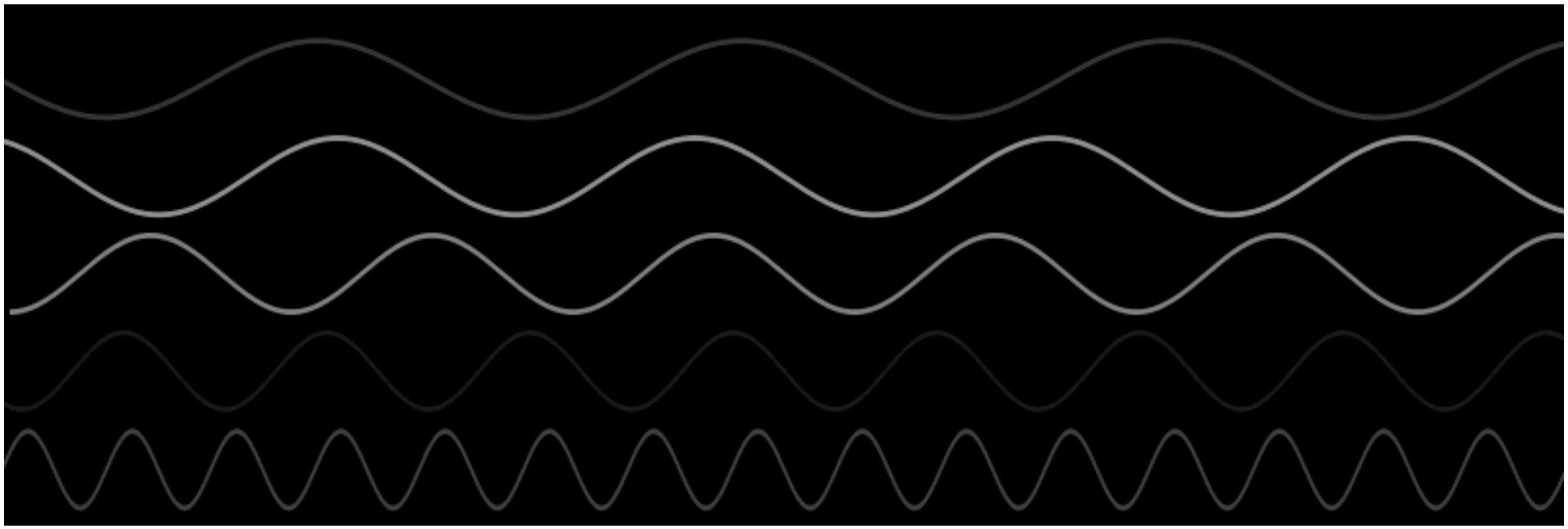
- It takes a wave 23seconds for 52 cycles to pass a point. What is the frequency of the wave?

  v = 2.26Hz

Frequency Demonstration

- **Materials:** Pencil, clock with second hand.
- What is the frequency at which I am tapping this pencil on the desk?
- How would you increase the frequency?
  - Tap the pencil faster (more times each second)
- How would you decrease the frequency?
  - Tap the pencil slower (fewer times each second)
- Frequency is the number of vibrations or waves per second.

Frequency and Wavelength



- Which of these waves has the highest frequency?

  The violet wave

- The lowest frequency?

  The red wave

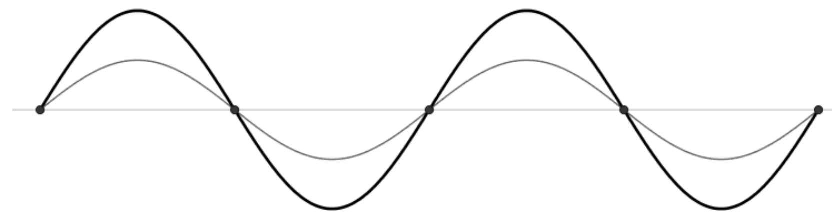
- The longest wavelength? The shortest?

  Longest: the red wave Shortest: the violet wave

Speed

- Light and sound travel at different speeds, even though both are waves.

- Different waves travel at different speeds.



- **The speed, wavelength, and frequency of a wave are related to each other by a mathematical formula.**

c =

- If you know any two of these quantities, the third can be figured out.

Speed

- Light travels at 3.00x10 m/s (i.e. this is the speed of light in a vacuum).
- Waves travel at different speeds in different mediums.
- Imagine, for example, that you are running on a track.
- Now imagine that this track is flooded up to your waist.
- If you are exerting the same amount of energy to run, are you going the same speed?

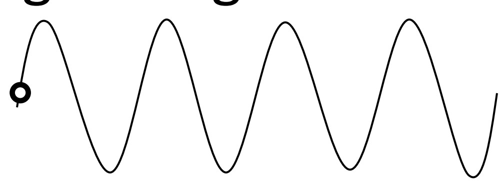
Speed

- In a given medium, under the same conditions, the speed of a wave is constant.

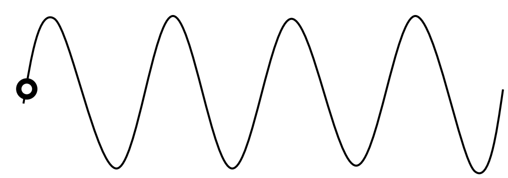
- For example, sound will always travel at the same speed at standard temperature and pressure (0 C and 1atm).

- However, if one sound wave is traveling through air at 0 C and another is traveling through air at 25 C, their speeds will not be the same.

0°C



25°C



- This is because the conditions they are traveling under are different.

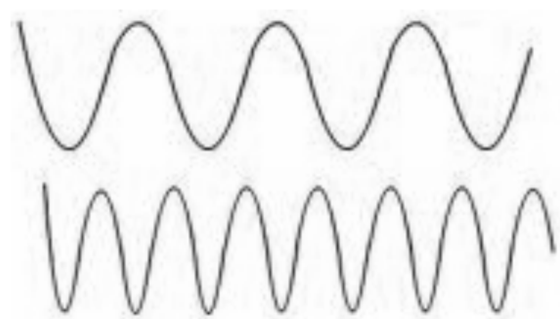
Speed

- Using our equation, if speed is the same for two waves, and the frequency increases, what must happen to the wavelength?

c =

- Since you must get the same number when you multiply the wavelength and the frequency, the wavelength must decrease to compensate.

- Therefore, if wavelength increases, frequency must decrease when a wave is traveling at the same speed.



Speed of Light Practice Problems

c =

- A radio wave has a frequency of **93.3MHz**. If it is travelling at the **speed of light**, what is the wavelength of the wave?

$\nu = 93.3MHz$

$c = 3.00*10^8 m/s$

$$\nu = 93.3MHz*(10^6\ Hz/1\ MHz) = 93.3*10^6\ Hz$$

$$3.00*10^8 m/s = \lambda\ (93.3*10^6\ Hz)$$

$$\lambda = \frac{3.00*10^8 m/s}{93.3*10^6\ Hz}$$

$$\boxed{\lambda = 3.22m}$$

- An x-ray has a wavelength of 10nm. If it is travelling at the speed of light, what is the frequency?

$$\boxed{\nu = 3.00*10^{16}\ Hz}$$

- An yellow light has a wavelength of 0.589μm. If it is travelling at the speed of light, what is the frequency?

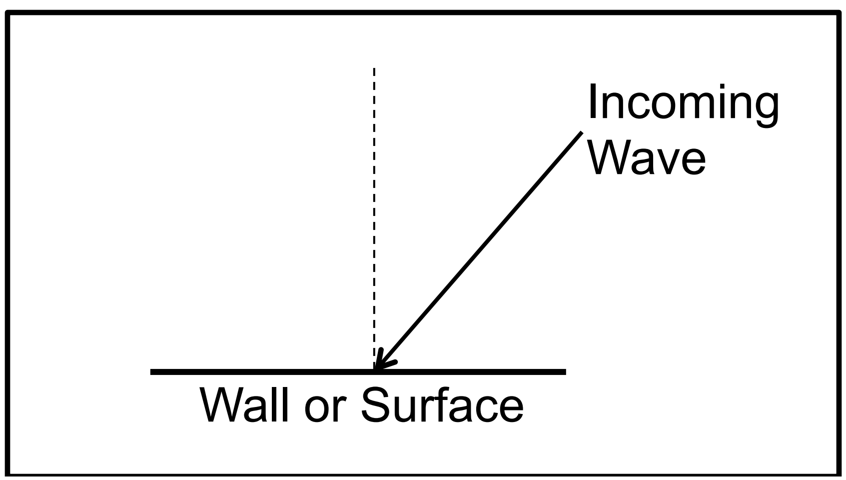
$$\boxed{\nu = 5.09*10^{14}\ Hz}$$

Section 3
Interactions of Waves

- **Definition:** Reflection – **When an object or wave hits a surface through which it cannot pass, it bounces back.**

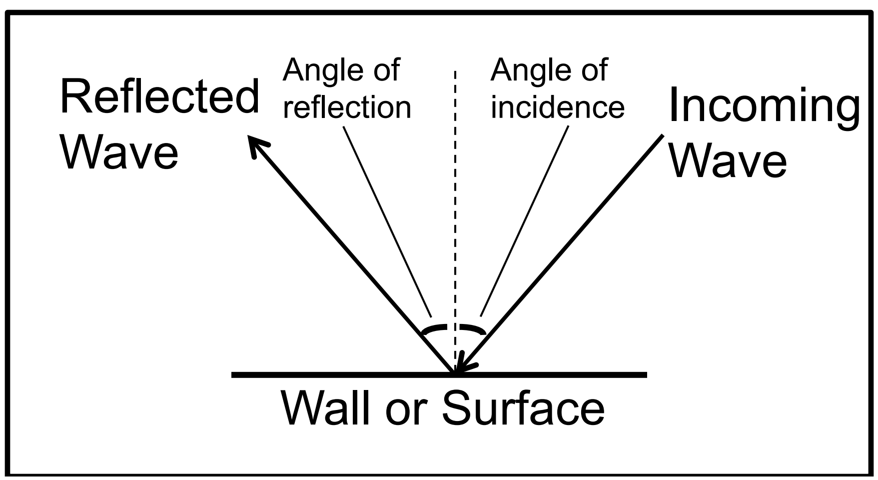
- To show reflection of a wave, draw a line in the direction of the motion of the wave.

- Now imagine a line perpendicular to the wall or surface.



Reflection

- **Definition:** Angle of Incidence (   ) – the angle between the incoming wave and the imaginary perpendicular line.
- **Definition:** Angle of Reflection (   ) – the angle between the reflected wave and the imaginary line.
- The angle of reflection is equal to the angle of incidence according to the law of reflection.



Reflection

- All waves obey the law of reflection.

- When we hit a wall with a ball, the law of reflection is obeyed.

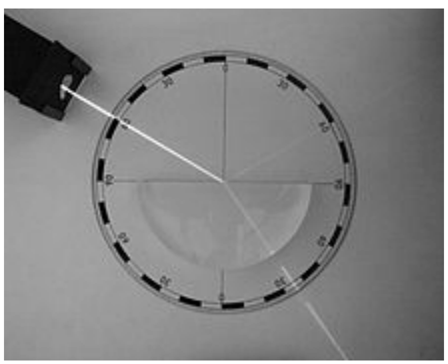
- The same is true with light in a mirror.

- An echo is an example of reflected sound.

Refraction

- When waves enter a new medium, they sometimes change direction.

- If a wave enters a medium at an angle, one side changes speed before another.



- **When a wave moves from one medium into another medium at an angle, it changes speed as it enters the second medium, which causes it to bend.**

- **Definition:** <u>Refraction</u> – the bending of waves due to a change in speed.

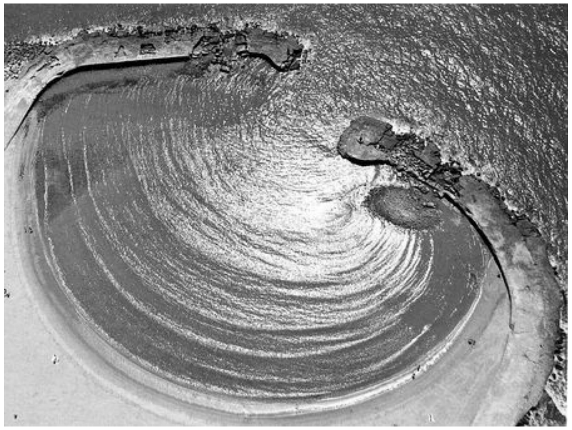
Demonstration: Refraction

- One example of refraction occurs when light enters water.
- At the front of the room is a pencil in a beaker of water.
- View the beaker from the position of the water being at eye level.
- Draw what you observe on the paper.

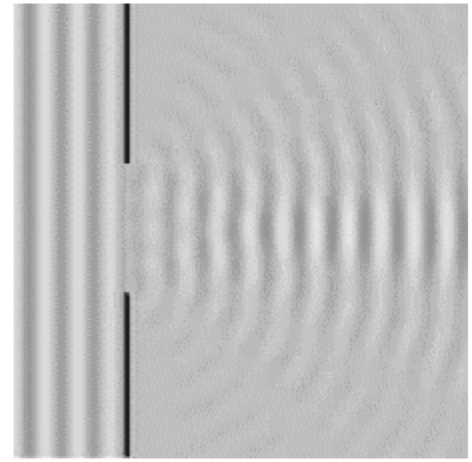
Refraction

- Waves do not always bend when they enter a new medium.
- Bending only occurs when one side of the wave enters the new medium before the other.
- The bending occurs because one side of the wave is now travelling at a different speed than the other side.
- If the wave enters all at once, no bending occurs.

Diffraction



- Sometimes, waves bend around obstacles.



- Before the wave enters the bay, the lines appear straight.
- However, the waves must bend to enter the bay through the much smaller entrance.
- After they have entered the bay, the waves appear to be curved.

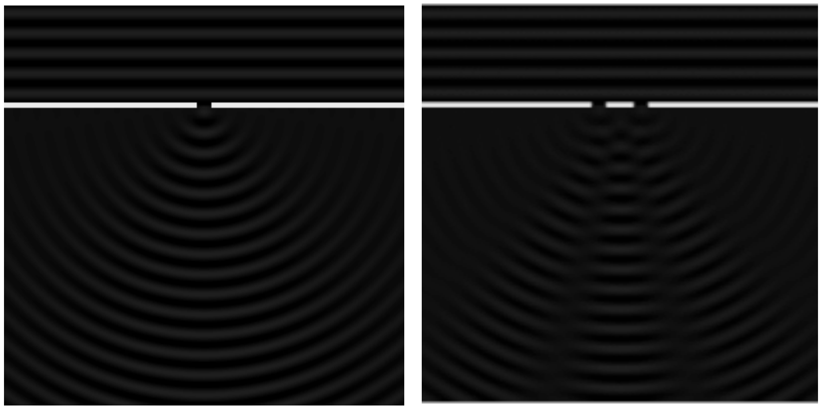
Diffraction

- **When a wave passes a barrier or moves through a hole in a barrier, it bends and spreads out.**

- **Definition:** Diffraction – the bending of waves around the edge of a barrier.

- The figure below shows single diffraction through the hole in a barrier and the diffraction around both edges of an obstacle.

- The right side of the figure also shows interference.



Interference

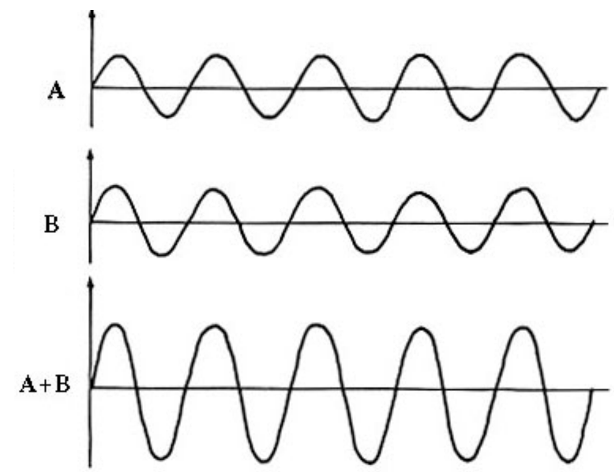
- **Definition:** Interference – the interaction of two or more waves when they meet.

- There are two kinds of interference: constructive and destructive.

- **Definition:** Constructive Interference – the interaction of two or more waves resulting in a wave with a larger amplitude.

- Therefore, you can think of constructive interference as adding energy to waves.

Interference



- In this figure, we have two identical waves: A and B.

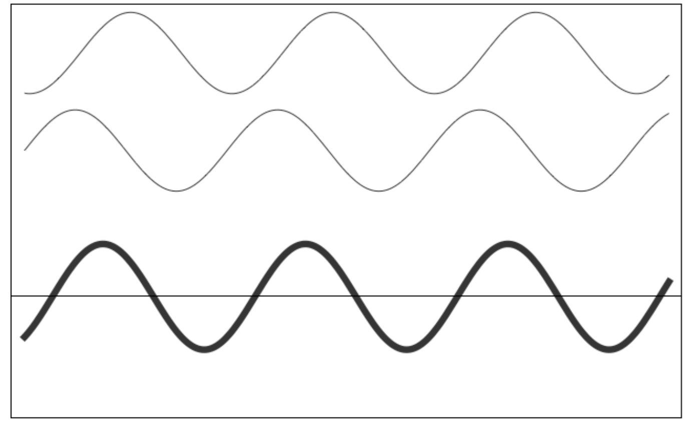
- We can see that the crests of A align with the crests of B.

- When we add these together, the result is the third wave shown here, having twice the amplitude of either A or B.

- The amplitude of a wave produced by constructive interference is equal to the sum of the amplitudes of the individual waves added together.

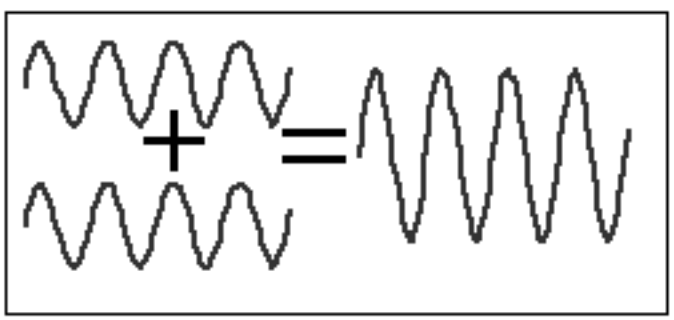
Interference

- Since we add the amplitudes, we also add the energies of the waves.

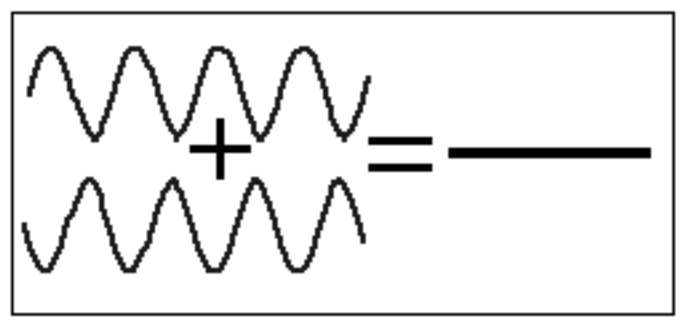


- What do you notice about the wavelength of these three waves?

- The wavelength of a wave produced by the constructive interference of two waves with the same wavelength will not change.



Constructive Interference



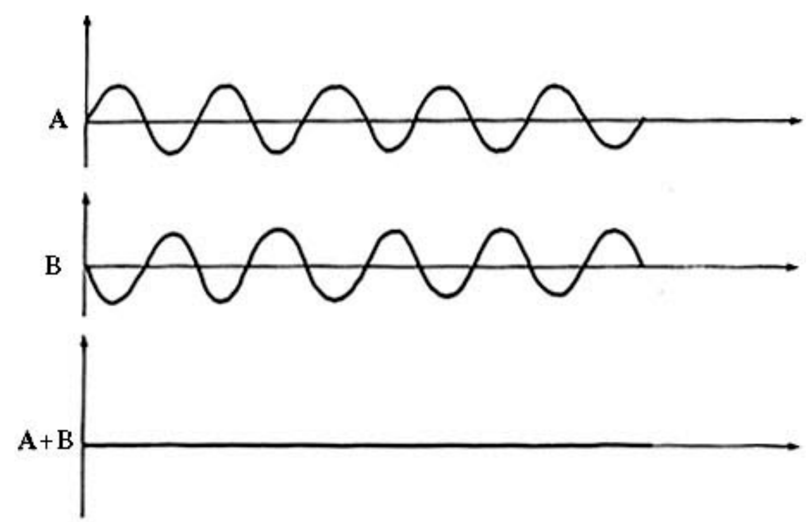
Destructive Interference

Interference

- **Definition:** <u>Destructive Interference</u> – the interaction of two or more waves resulting in a wave with smaller amplitude.

- Destructive waves occur when two waves combine where the crests are not aligned.

- In this case, the crest of one wave is aligned with the trough of another identical wave.



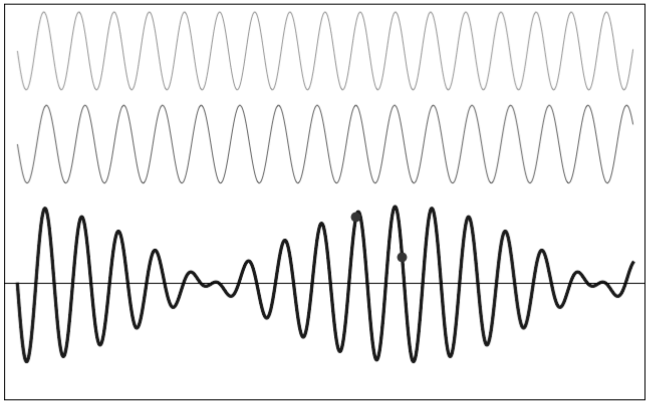
- This produces a flat line.

Interference

- If the two added waves do not have the same amplitude, then the amplitude of the smaller wave is subtracted from the amplitude of the bigger wave.

- Therefore, destructive interference results in a smaller amplitude.

- If two waves with identical amplitude are added, but are only slightly misaligned, they will experience constructive interference in some places and destructive interference in others.

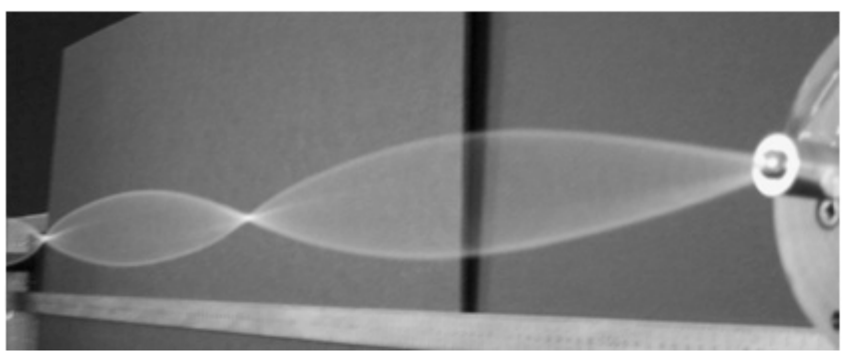


Standing Waves

- If an incoming wave and a reflected wave collide in just the right places, it can look like the wave is not moving.

- **Definition:** Standing Wave – a wave that appears to stand in one place, even though it is really two waves interfering as they pass through each other.

- Even though the wave appears to be standing, in fact, waves are travelling along the medium in both directions.

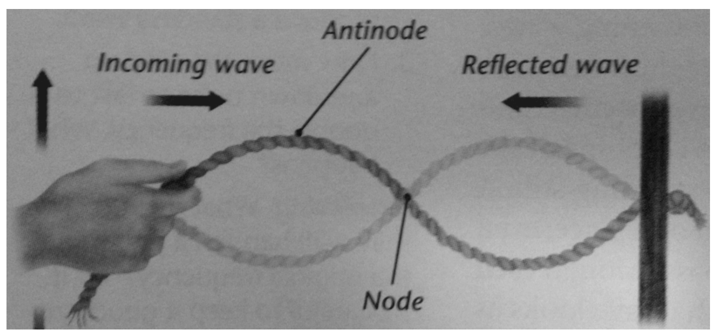


Nodes and Antinodes

- **Definition:** <u>Nodes</u> – points where two waves cross and produce an amplitude of zero.

- Nodes always occur at the same place on a medium.

- Let's look at the figure below to see what a node looks like.



- We can also see the part of the wave called the antinode.

- **Definition:** <u>Antinodes</u> – the crests and troughs of a standing wave.

Resonance

- When an object is vibrating at a certain frequency, it takes very little energy to maintain or increase the amplitude of the wave.
- Many particles have a natural frequency of vibration.
- **Definition:** Resonance – occurs when vibrations traveling through an object match the object's natural frequency.
- Waves with the same frequency add together increase the amplitude of the object's vibrations.

Resonance

- If an object has the same natural frequency as a wave, and is rigid, it may become shattered when the amplitude is increased.

- This is why it is possible for a singer to break a glass with their voice.

- This is also how an army marching across a bridge can collapse an otherwise solid bridge.