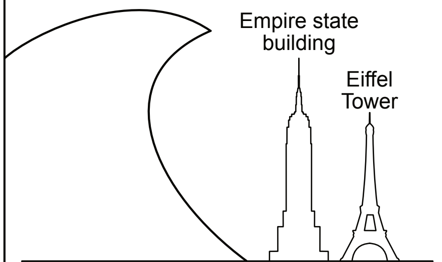
Making Waves

FACT OR FICTION? *Write your verdict below each statement:*

The largest recorded ocean wave had a height more than 1,000 ft above sea level.

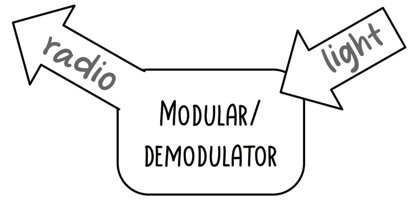


Fact - It was caused by the 1958 Lituya Bay earthquake. This megatsunami washed out trees 524 m (1,719 ft) above the entrance of the bay!

It's possible to do brain surgery using only sound.

Fact - But it can't be done with a violin. It's called High-Intensity Focused Ultrasound (HIFU).

Most modern homes contain a machine that converts light into radio waves.

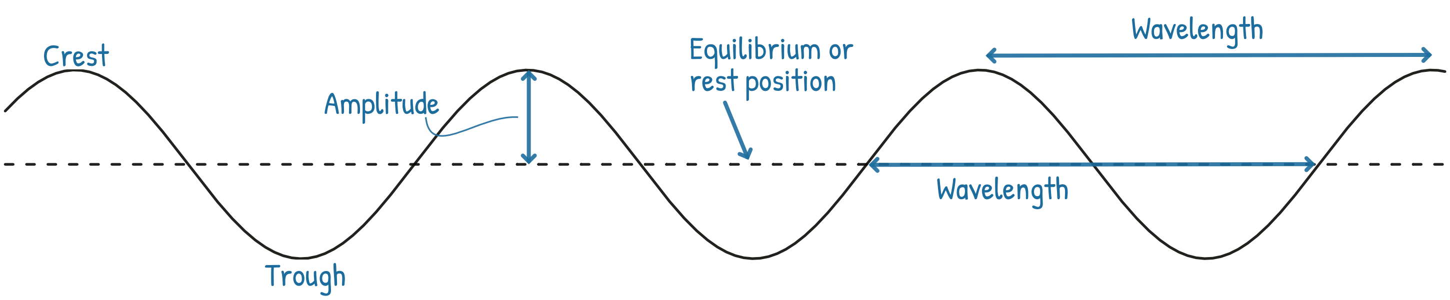


Fact - It's called a modem! Most high speed internet comes from converting information in light (via a fiberoptic cable) into radio waves (wifi).

FILL IN THE BLANKS:

energy *disturbance* *medium* *transmitted*

A wave is a disturbance that transfers energy from one place to another without transferring matter. Some waves, such as sound, require a medium. This means they can only travel or be transmitted through physical materials such as air, water, or rock.



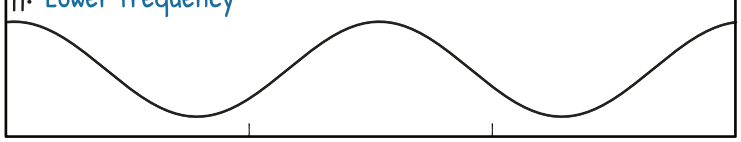
AMPLITUDE: From rest to crest! How HIGH a wave is.

WAVELENGTH: From crest to crest or trough to trough. A measure of how WIDE a wave is.

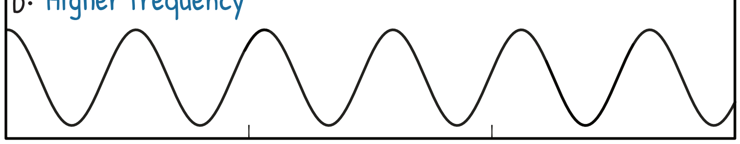
FREQUENCY: The number of crests/troughs (or oscillations) that happen in a certain amount of time. How FAST the wave is.

THE IMAGES BELOW SHOW HOW MANY OSCILLATIONS OCCUR IN 3 SECONDS. AVE HAS A HIGHER FREQUENCY?

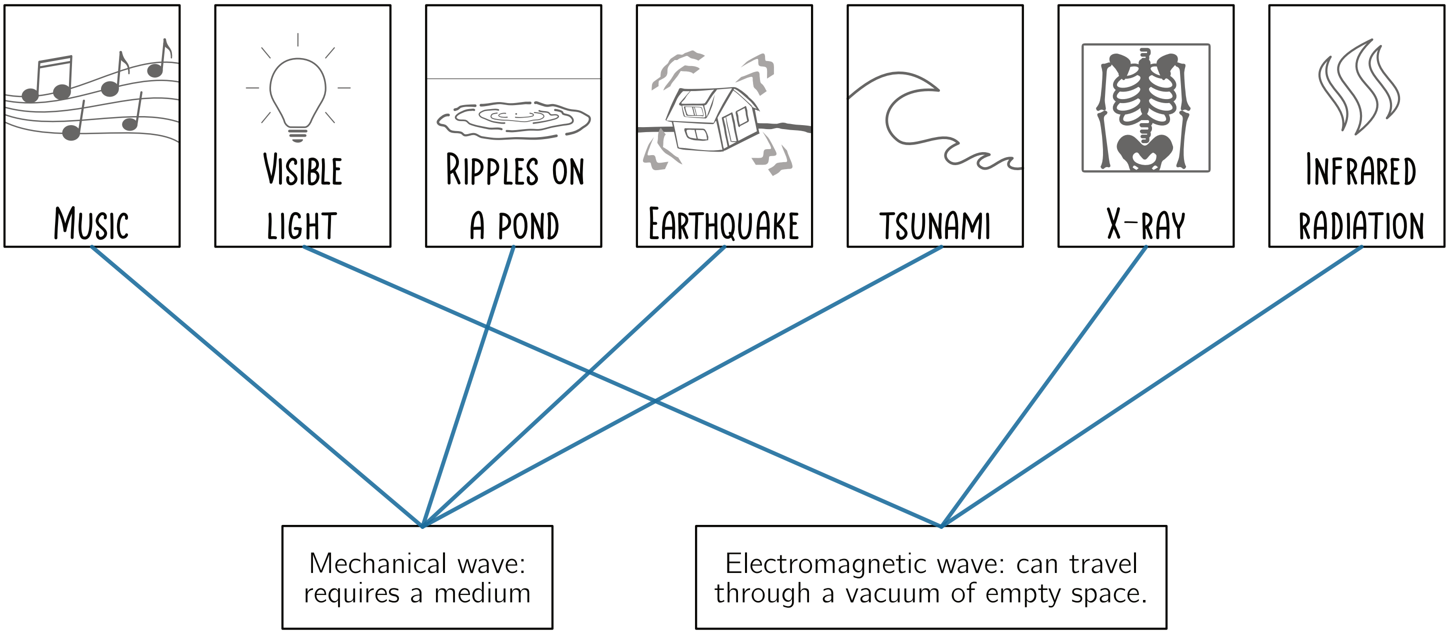
A: Lower frequency



B: Higher frequency

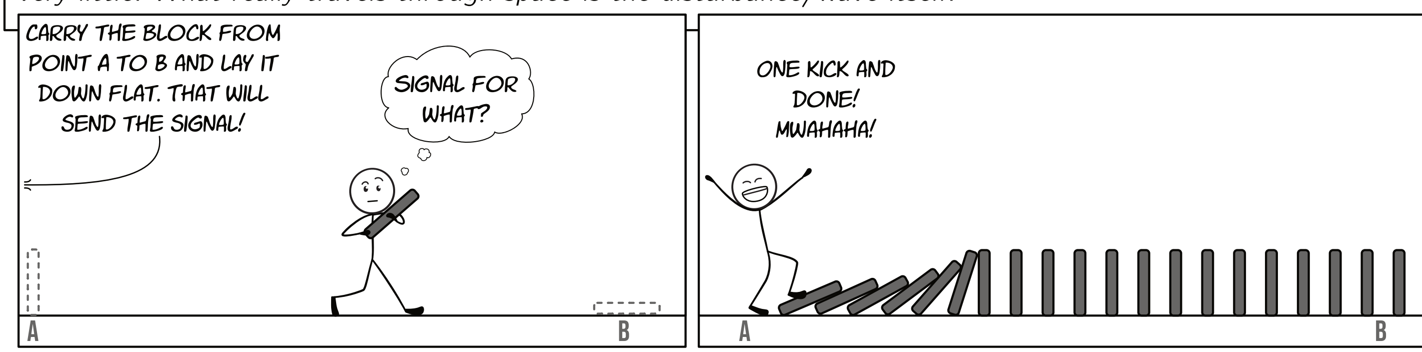


Draw lines to categorize each of these as either a mechanical or electromagnetic wave:

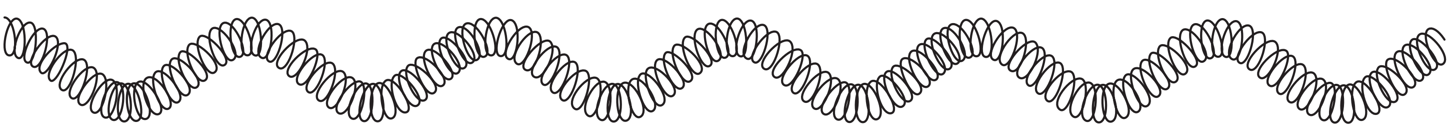


THINK ABOUT IT:

There are 2 primary ways to send energy or information from one place to another: by transporting physical matter or by creating a disturbance or wave that travels through space. With a wave, any matter involved moves very little. What really travels through space is the disturbance/wave itself.

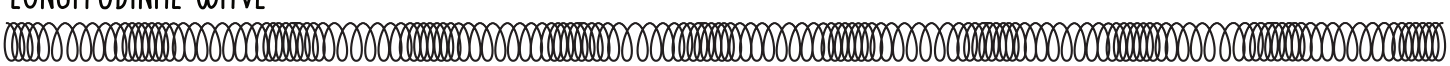


TRANSVERSE WAVE:



The motion is at a right angle to the direction of the wave speed. Ex. String vibrations, electromagnetic waves, earthquake (secondary or s-waves)

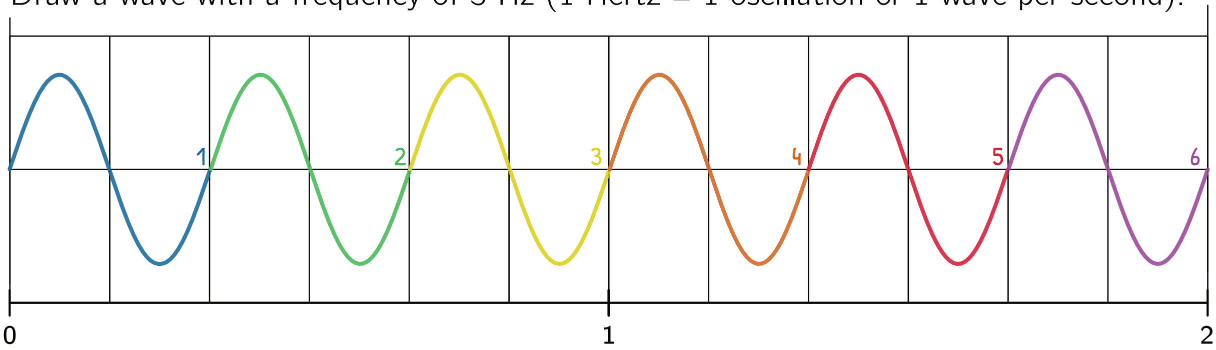
LONGITUDINAL WAVE:



The motion is in the same direction that the wave travels. Ex. Sound, sonar, pressure waves, earthquake (primary or p-waves)

Practice Problems – Making Waves

1. Draw a wave with a frequency of 3 Hz (1 Hertz = 1 oscillation or 1 wave per second).



2. Explain the difference between a mechanical wave and an electromagnetic wave and give an example of each.

   A mechanical wave must travel through a physical matter (a medium). It travels fastest through solids and slower through gases. Examples: sound, ocean wave, earthquake

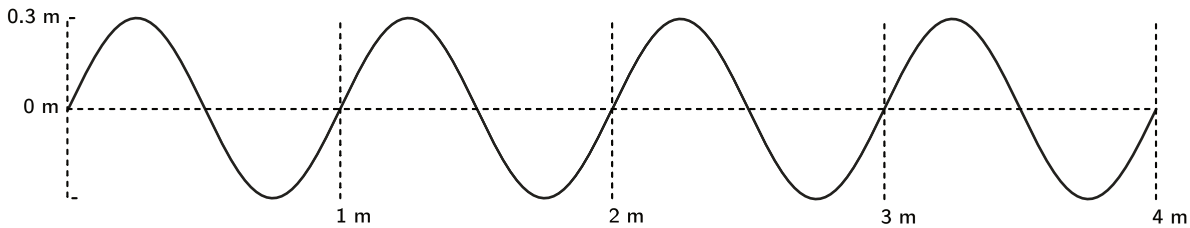
   An electromagnetic wave travels at the speed of light and can travel through a vacuum of empty space. Examples: radio waves, microwaves, infrared, visible light, UV light, x-rays, gamma rays

3. A wave represented in the diagram below travels 4 meters in 2 seconds. Answer the following questions about the wave:

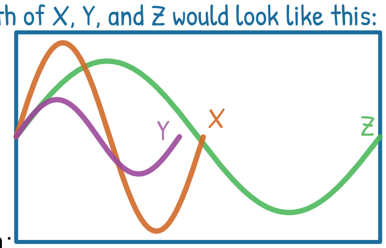
   A. What is the wavelength in meters? 1 meter

   B. What is the amplitude? 0.3 m

   C. What is the speed of the wave in meters per second? 4 m in 2 sec = 2 m/s



One wavelength of X, Y, and Z would look like this:



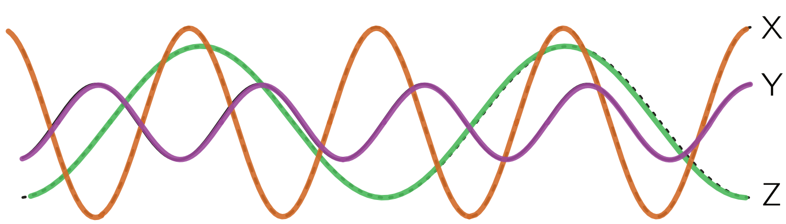
4. Three waves labeled X, Y, and Z are shown below.

   A. Rank curves X, Y, and Z below from smallest to largest amplitude:

   amplitude of Y < amplitude of Z < amplitude of X

   B. Rank curves X, Y, and Z below from smallest to largest wavelength:

   wavelength of Y < wavelength of X < wavelength of Z



5. Are earthquake waves mechanical or electromagnetic? Explain.

   Earthquake waves are mechanical. They are a movement of physical matter.

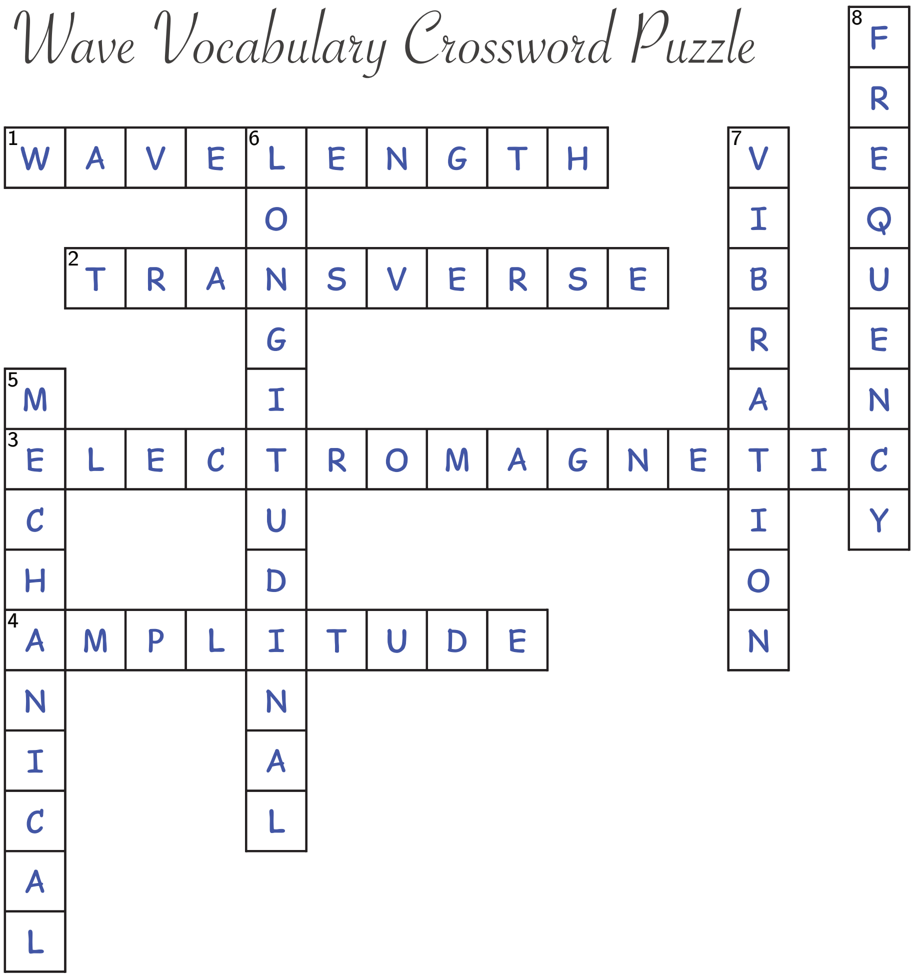
6. What wave has motion that moves in the same direction the wave travels?

   Longitudinal wave

7. What type of wave has motion that moves perpendicular to the direction the wave travels?

   Transverse wave

Wave Vocabulary Crossword Puzzle



Horizontal Words

1. The distance between crests of the wave
2. A wave that moves perpendicular to the direction of the wave speed
3. The type of wave that can travel through a vacuum of empty space
4. The distance from rest to the top of the wave (the distance from crest to peak)

Vertical Words

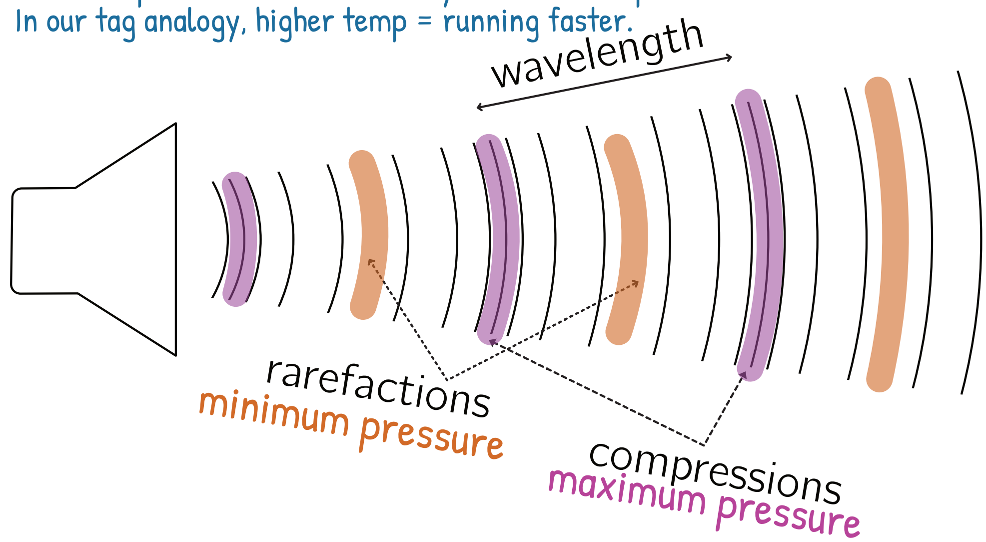
5. A type of energy-carrying wave that always travels through material matter
6. A wave that moves along the same direction as the wave speed.
7. An oscillation, a wiggle repeated over time
8. How often a wave repeats itself.

Good Vibrations

Fill in the blanks! Options for words include density, longitudinal, temperature, transverse

Sound is a longitudinal wave created by a vibrating source. These waves or compressions travel at varying speeds depending on the density or temperature of the medium.

When temperature increases in any medium, the speed of sound increases.
In our tag analogy, higher temp = running faster.



Humans have a specific range of sound frequencies they can hear, typically between 20 hertz and 20,000 hertz. This range varies and tends to decrease with age. Frequencies below 20 Hz are called **infrasound** or **infra-sonic** and are too low for human ears to detect. Frequencies too high for human hearing are called **ultrasound**.

20 Hz | Human vocal range: 85-1,100 Hz | 20,000 Hz

Infra-sonic | Human hearing range (20-20,000 Hz) | Ultrasound

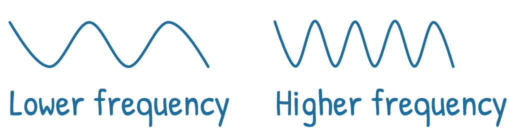
Which 3 animals have these hearing ranges? Bat, cat, dog, dolphin, elephant, snake, or whale?

Dolphin (150-150,000 Hz)

Dog (15-50,000 Hz)

Elephant (5-12,000 Hz)

PITCH: Determined by the FREQUENCY of the wave.



VOLUME: Determined by the AMPLITUDE of the wave

$$\lambda = v/f$$

meters

meters/second

hertz: one (cycle) per second

Wavelength (Greek letter lambda (λ) is equal to the speed (v) of a wave divided by its frequency (f).

Bats emit ultrasonic sounds at 40 kHz to navigate and locate prey. If the speed of sound in air is approximately 340 m/s, what is the wavelength of these ultrasonic sounds?

Using the wavelength equation λ = v / f, where v = 340 m/s and f = 40 kHz (or 40 x 10^3 Hz).

$$\lambda = \frac{340\text{m/s}}{40{,}000\text{Hz}} = 0.0085\text{m}$$

Note that the hertz is the reciprocal of the second ($Hz = s^{-1}$), so the hertz and seconds cancel each other out.

So, the wavelength of the bats' ultrasonic sounds is 0.0085 meters, or 8.5 millimeters.

If the wavelength of a WiFi signal is 0.12 meters and the speed of electromagnetic waves is 3×10^8 meters per second, what frequency band is the WiFi signal using?

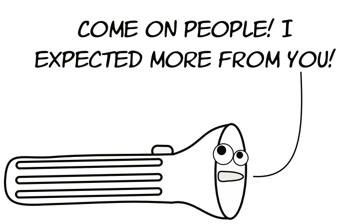
The wavelength equation λ = v / f can be rearranged to solve for frequency (f=v/λ)

$$f = \frac{3\times10^8 \text{ m/s}}{0.12 \text{ m}} = 2.5\times10^9 \text{ Hz (or 2.5 GHz)}$$

So, the frequency of the WiFi signal is 2.5 gigahertz.

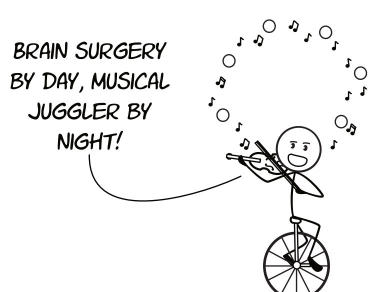
FACT OR FICTION? *Write your verdict below each statement:*

10 million people talking at once would barely produce enough energy to operate a flashlight.



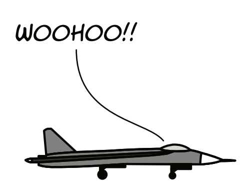
FACT – Sound is relatively low in energy.

Sound can make objects levitate in the air.



FACT – While acoustic levitation wouldn't be possible with a violin and juggling balls, a subwoofer can easily levitate small pieces of styrofoam.

The first sonic boom in history happened on Oct 14, 1947 when Chuck Yeager flew a Bell X-1 jet at an altitude of 45,000 ft.



FICTION – Whips can create sonic booms and have been around for hundreds of years.

Practice Problems – Good Vibrations

1. How does the speed of sound change in a gas as temperature increases?

The speed of sound increases as temperature rises because the molecules are moving at a faster rate. This allows them to transfer energy between each other more effectively.

2. How are microwaves different than sound waves?

A. Sound waves are longitudinal waves while microwaves are transverse waves
B. Sound waves are transverse waves while microwaves are longitudinal waves
C. Sound waves can travel through a vacuum of empty space but microwaves can't
D. Microwaves always have larger amplitude than sound waves

3. What formula is useful for determining the relationship between the frequency, wavelength, and speed of a wave?

A. $\lambda = v / f$
B. $f = v / \lambda$
C. $\lambda = f \cdot v$
D. $f = \lambda \cdot v$

The equation where wavelength (λ) is equal to the speed or velocity (v) of a wave divided by its frequency (f) can be written as:

$\lambda = v / f$ $\left(\text{wavelength} = \frac{\text{speed of wave}}{\text{frequency}}\right)$

$f = v / \lambda$ $\left(\text{frequency} = \frac{\text{speed of wave}}{\text{wavelength}}\right)$

$v = f \cdot \lambda$ (speed of wave = frequency · wavelength)

4. Which form of water would sound travel the fastest through?

A. Ice
B. Liquid water
C. Steam
D. Sound would travel at the same speed through water no matter what state it was in.

Sound moves faster through solid materials because the atoms are closer together

5. The larger the amplitude, the ________ the sound will be.

A. Quieter
B. Louder
C. Sound waves with different amplitudes will have same volume

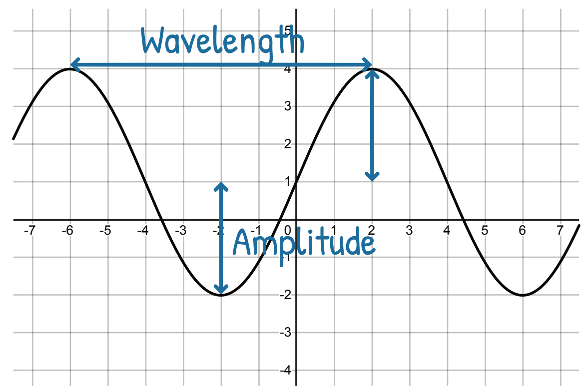
In general, greater amplitude = louder volume.

6. The pitch of a sound is primarily determined by the:

A. Amplitude
B. Frequency
C. Wavelength

The higher the frequency, the higher the pitch.

7. Find the amplitude and wavelength of the graph on the right. (For units, count the number of squares)



Amplitude: 3

Wavelength: 8

8. A lightning bolt strikes, and it takes 6 seconds before you can hear the thunder from the lightning strike. Approximately how far away was the lightning strike from your location?

The speed of sound is about 340 m/s, so in 6 seconds it travels about

$6 \text{ s} \times 340 \text{ m/s} = 2040 \text{ m}$ or roughly 2 km.

9. Explain how a sound is produced when you strike a drum.

When you strike a drum, the drum head (membrane) vibrates back and forth. This vibration causes the surrounding air molecules to vibrate, creating alternating regions of high and low pressure, which propagate as sound waves.

10. The longer a guitar string is, the:
   A. Higher its pitch
   B. Lower its pitch
   C. Louder its sound
   D. Softer its sound

A longer string has a longer wavelength and a shorter frequency, so the pitch will be lower.

11. Plucking a guitar string harder will do what to the sound wave it creates?
   A. Increase the wavelength
   B. Increase the frequency
   C. Increase the amplitude
   D. All of the above

Changing the frequency would change the wavelength and the pitch of the note. The increased volume corresponds to an increased amplitude.

MAKE YOUR OWN INSTRUMENT

MATERIALS (will vary depending on what type of instrument you make)

Panpipes

- ▫ scissors
- ▫ duct tape
- ▫ 8 pieces of pipe OR 8 straws cut to different lengths

Straw Flute or Trombone

- ▫ scissors
- ▫ 2 straws* or 1 straw and a piece of paper and tape

If using 2 straws, one straw needs to be able to slide inside of the other.

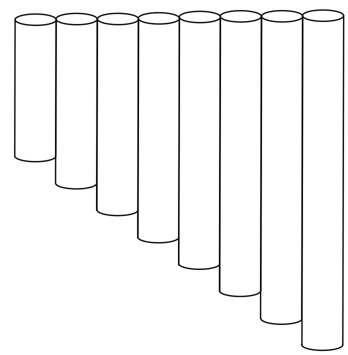
Rubber Band Banjo

- ▫ scissors
- ▫ rubber bands
- ▫ stapler or tape
- ▫ a cardboard container (an empty tissue box works well)

Bucket Drums

- ▫ buckets or metal cooking pots of several different sizes
- ▫ a wooden spoon or mallet

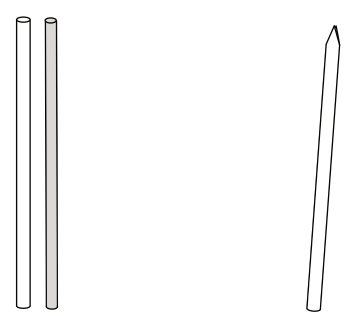
INSTRUCTIONS for Panpipes:

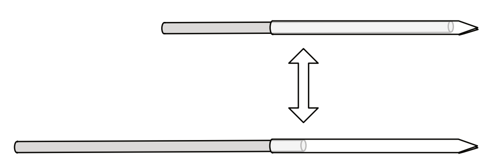


1. Cut the straws or pipes to different lengths.* For better sound quality, cap the bottoms by covering them securely with tape or (in the case of actual pipe) capping them with pipe fittings.
2. Use glue or tape to secure the tubes together in a straight line.
3. Blow over the top of each tube and listen to the pitch of the notes.
4. Optional: cover the bottoms of each tube with tape or paper and see how that changes the sound.

**The pitch depends on both the width and the length. But straw pipes cut to the following lengths in centimeters will usually produce a nice set of tunes: 9.5, 10, 11.5, 13, 14.5, 15.5, 17, and 19.5 cm. Err on the side of cutting too long because it's easier to trim a pipe shorter than to make it longer.*

INSTRUCTIONS for Straw Flute or Straw Trombone:

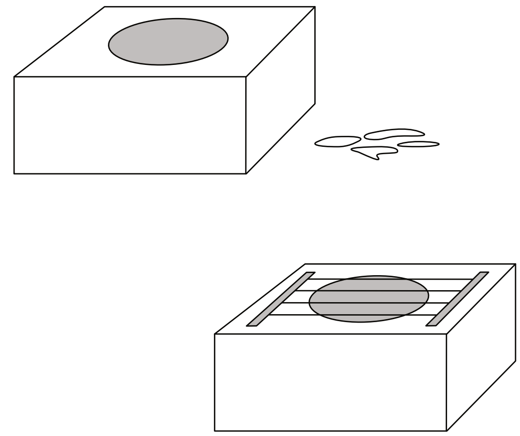




1. Blow into a straw and observe the sound made.
2. Flatten one end of the straw and then use scissors to trim that end to a point.
3. Place the flattened end of the straw in your mouth and blow again. Observe the sound made.
4. The flute is now complete. To make a Trombone, you may want to trim your straw flute with scissors to be shorter in length. Whether trimmed or not, make your trombone by fitting a smaller straw inside the straw flute OR make a cylindrical tube of paper that fits inside or just over the straw flute. Adjust the length by sliding the paper forward and back and observe how the sound changes.

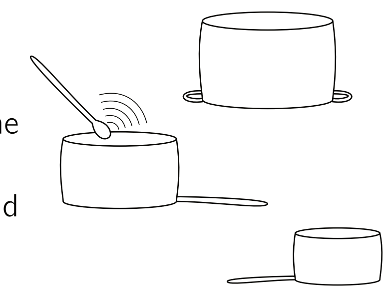
INSTRUCTIONS for Rubber Band Banjo:

1. Find a container made of cardboard or another material that can be used to amplify the sound of the rubber bands. An empty tissue box or cereal box with a hole cut in one end works well.
2. Stretch rubber bands over the opening of the container. Depending on the size of your rubber bands and container, you might be able to stretch them over or you may need to cut them with scissors and secure them to the box with a stapler. Placing a popsicle stick or pencil under the rubber bands at each end may help improve the sound.
3. Experiment with the placement of the rubber bands. Stretch them differently or change the sizes to get



INSTRUCTIONS for Bucket Drums:

1. Gather bucket-shaped objects of different sizes such as cans or pots.
2. Using a wooden spoon or an actual mallet, tap the buckets and notice the pitch of the sound made.
3. Arrange the bucket drums from highest to lowest pitch. Can you find shapes that correspond to pitches so you can play a song?



Questions to consider and explore:

There are 3 main types of instruments: wind, string, and percussion. Why does a note of the same pitch sound different when played on a violin versus a trumpet? How can someone tell the difference between a middle C being played on a flute vs a harp vs a xylophone?

The short answer: harmonics! When an instrument is played the pitch we hear is actually a blend of different vibrations that overlap together. Different instruments produce different harmonics.

What happens to the pitch of a stringed instrument when you shorten the string?

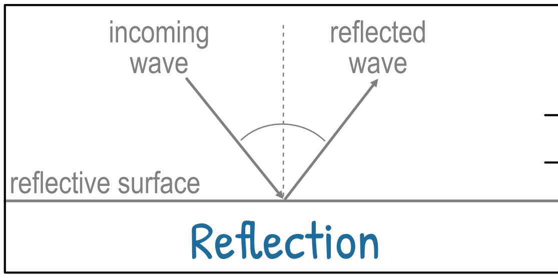
When the string is shortened the pitch increases (gets higher). If the string is shortened by ½ the pitch will be one octave higher.

In the instrument(s) you made, what part of the instrument vibrated and created sound waves?

Answers will vary depending on the instrument: for a drum or percussion instrument it will be whatever was hit. For the rubber band banjo, the rubber bands vibrate. For the straw flute/trombone, it's the angled pieces of straw. For the panpipes, it's the air that is going in and then out of the tube.

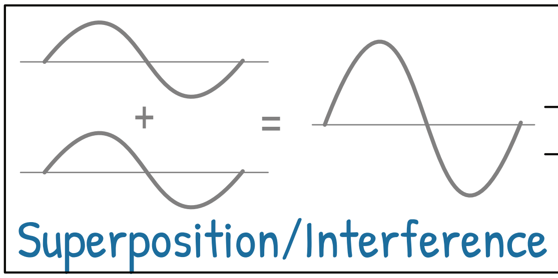
Resonance & Decibels

Interesting things happen when waves collide with objects or with other waves. When two waves collides, they don't destroy each other! Instead they pass *through* each other.



When a wave strikes a reflective surface it bounces back at the same angle. This is true for both mechanical waves like sound and EM waves such as light.

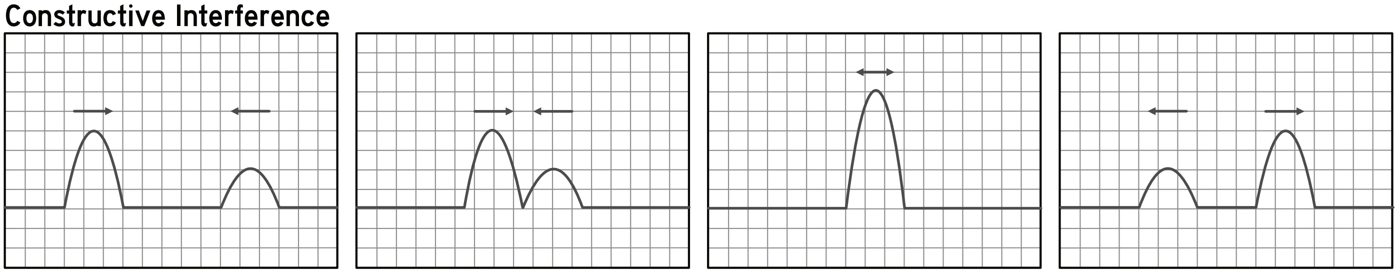
Ex. echoes, sonar, light bouncing off mirrors



Waves pass through each other and the combined forces change how particles move. When the waves are at the same position their AMPLITUDES are ADDED together.

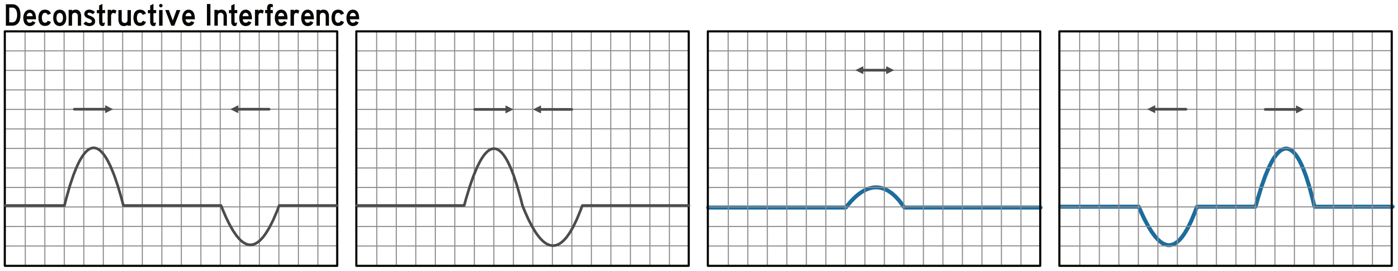
Ex. Rogue or sneaker waves in ocean, noise cancelling headphones, a dead spot with no WiFi, hot spot in a microwave

Constructive Interference

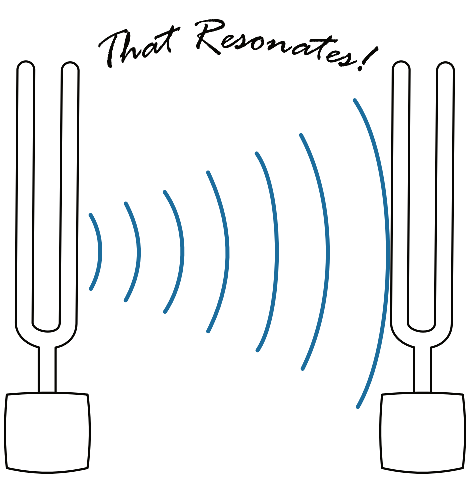


Two pulses with positive amplitude are moving towards each other. When they overlap, the resulting amplitude increases significantly. After passing through each other they return to their original shape and size.

Deconstructive Interference



Two pulses with opposite amplitude are moving towards each other. Draw the resulting amplitude when they overlap and after the waves pass each other. (After passing, these waves will also return to their original shape and size.)



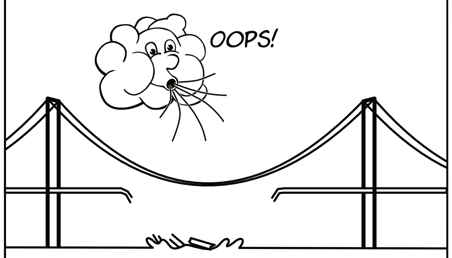
Natural frequency: All objects have a frequency they vibrate to in the absence of outside force. It's the frequency at which the object or system can store and transfer energy most easily.

Resonance: When a wave (periodic force) transfers energy to an object at its natural frequency, this results in large amplitudes!

If 2 tuning forks have the same frequency, the sound from one can cause the other to vibrate!

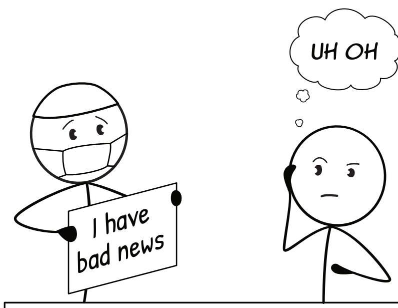
FACT OR FICTION? *Write your verdict below each statement:*

In 1940, a mile-long bridge collapsed because of a moderate wind.



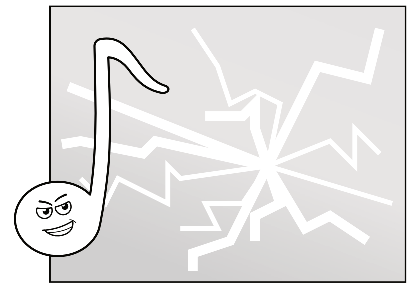
FACT- Tacoma Narrows

A broken eardrum will result in permanent hearing loss.



FICTION - Most ruptured eardrums heal within a few weeks

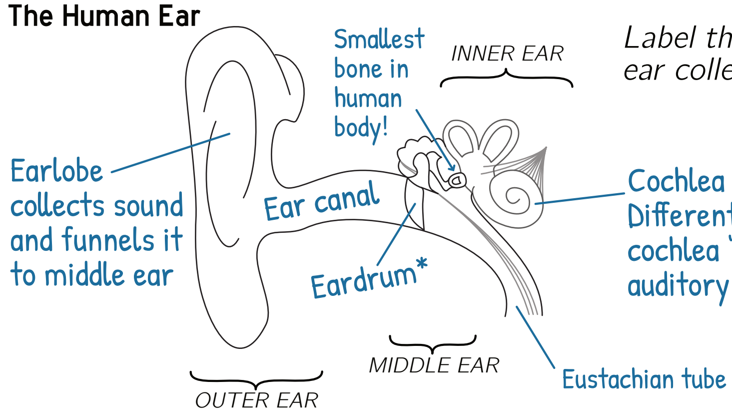
If you sing loudly enough, you can break glass using just your voice!



FACT- With crystal cups or glasses using resonance!

The Human Ear

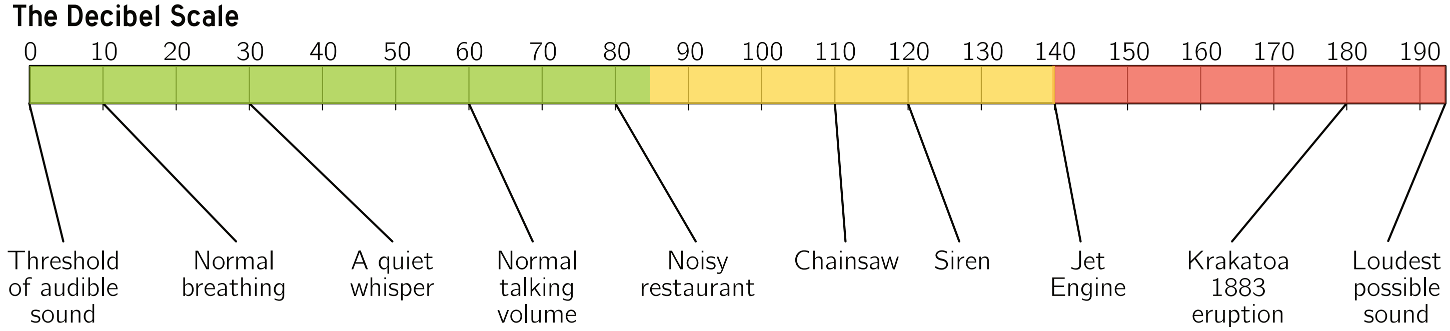
Label the earlobe, eardrum, and cochlea. Which parts of the ear collect, transfer, and sort or interpret sound waves?



Cochlea is filled with fluid that vibrates small hairs. Different hairs vibrate at different frequencies so the cochlea 'sorts' the sound. This sends signals to the auditory nerve cells connected to the brain.

*The eardrum and 3 bones (hammer, anvil, and stirrup) transfer the vibrations of the collected sound waves to the inner ear.

The Decibel Scale



Color the decibel scale above to show the range of decibels associated with the following:

GREEN: Safe. Little or no risk of hearing loss.

YELLOW: Caution. Sustained exposure will result in permanent hearing loss.

RED: Danger. Short term exposure causes pain and hearing loss.

FILL IN THE BLANKS:

10 100 1,000 logarithmic

The decibel scale is a logarithmic scale, which means that an increase of 10 dB changes the sound intensity by a factor of 10. An increase of 20 dB changes the sound intensity by a factor of 100, and an increase of 30 dB means the sound is 1,000 times more intense!

Practice Problems – Resonance and Decibels

1. Bob is standing 100 meters away from a large wall with a stopwatch. He bangs a pair of cymbals together and records the time until he hears an echo. Today he hears the echo in 0.6 seconds. What is the speed of sound through the air today?

$$\text{Speed} = \frac{\text{distance}}{\text{time}} \qquad \text{Speed of sound} = \frac{2 \cdot 100\text{ m}}{0.6\text{ s}} \qquad \text{Speed of sound today} = 333\text{ m/s}$$

*Multiply by 2 because we need the total distance the sound traveled (to the wall and back)

2. The speed of a wave depends on:

The speed depends on the medium. The same sound (same wavelength and frequency) will travel faster in a solid and slower in a gas.

   A. The medium through which it is traveling
   B. The wavelength. Shorter wavelengths travel faster than longer wavelengths.
   C. The frequency. Higher frequency waves travel at higher speeds.

3. Which of these has a bigger impact on the frequency of a wave?
   A. The medium through which it travels
   B. The source producing the wave

4. Which of the following are examples of resonance?
   A. The 1850 collapse of the Angers Bridge in France
   B. A child pumping their legs to move higher on a swing
   C. The balance wheel in a mechanical clock
   D. All of the above
   E. None of the above

5. What does the decibel scale measure?
   A. The pitch of a sound
   B. The frequency of a sound
   C. The intensity of a sound
   D. The duration of a sound

The decibel scale measures the intensity or loudness of a sound.

6. Prolonged exposure to sounds above which decibel level can lead to hearing loss?
   A. 50 decibels
   B. 60 decibels
   C. 85 decibels
   D. 100 decibels

Sounds of 85 decibels can cause hearing loss if someone is exposed to them for more than 8 hours at a time

Practice Problems – Resonance and Decibels

7. What is the approximate threshold of human hearing? Or in other words, what is the quietest sound a human can hear?

   0 decibels is the threshold of human hearing

8. On the decibel scale, a sound that is 30 decibels is _____ times more intense than a sound that is 20 decibels.

   A. 2 times
   B. 5 times
   C. 10 times
   D. 100 times

9. What statement about resonance is true?

   A. When resonance happens, more energy is being added to the object or system
   B. Tuning forks vibrate in the presence of any sound
   C. When an oscillating force is applied at a frequency that matches the natural frequency of an object, this vibration will cause the system to vibrate at a lower amplitude
   D. Objects must be completely still for resonance to occur.

   An oscillating force that matches the natural frequency of an object will cause it to vibrate at HIGHER amplitude

10. Give two examples of situations where you might encounter superposition or interference in everyday life. One example should be for constructive interference. The other example should be deconstructive interference.

    Answers will vary but here are some possible examples:

    Constructive interference:

    A hot spot in a microwave

    Rogue or "sneaker" waves in the ocean that travel far further up a beach than typical waves

    A place in a room where sounds are louder

    Deconstructive interference:

    Noise cancelling headphones

    A dead spot for a wifi signal

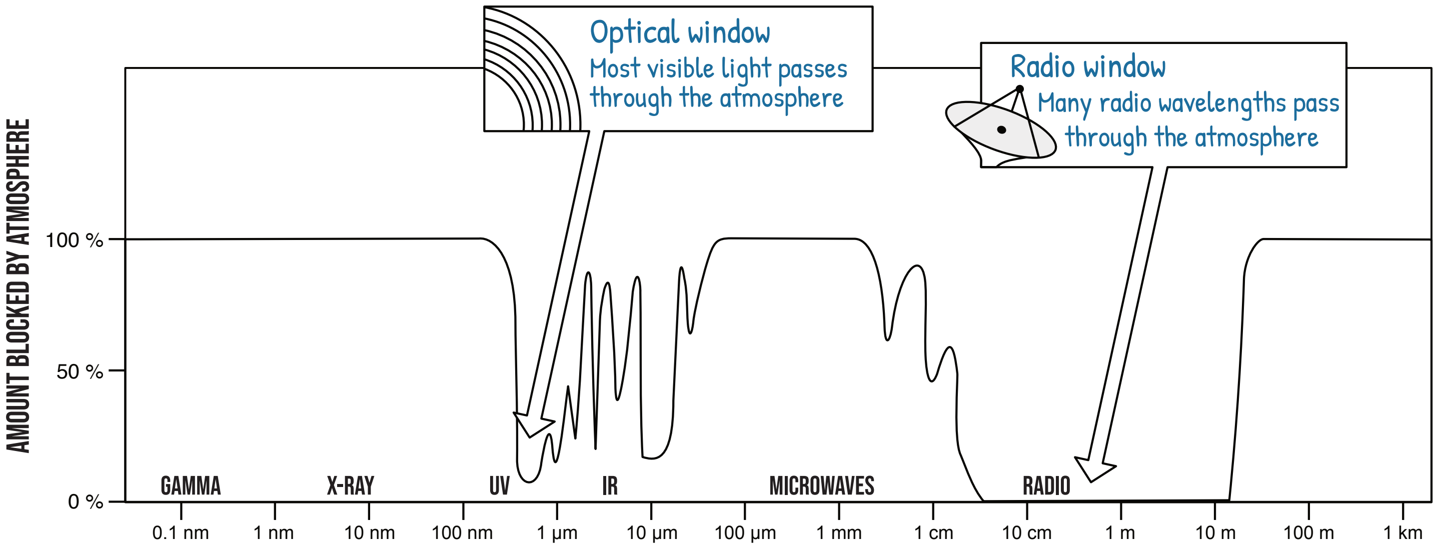
    A place in a room where sounds are muffled or quieter

The Electromagnetic Spectrum

Fill in the blanks:

visible   wavelengths   eyes   radiation   radio   gamma

The electromagnetic spectrum is the full range of electromagnetic radiation organized by frequency or wavelength. Radio waves have wavelengths longer than a football field. The shortest wavelengths are found in gamma waves, which have a wavelengths as small as the width of an atomic nuclei. Human eyes can only perceive a narrow band of radiation with wavelengths from 400 to 700 nm. This radiation is called visible light.



Why are these waves called electromagnetic?

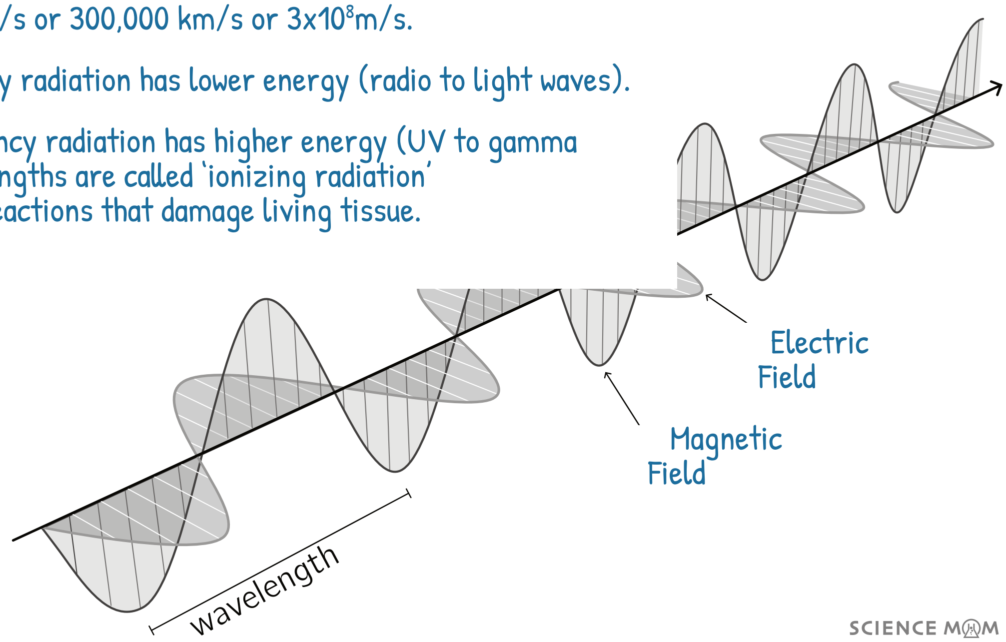
They have both electric and magnetic fields that oscillate at right angles to each other.

EM radiation has both particle-wave properties. It can be described as a stream of particles without mass (photons) traveling in a wave like pattern at the speed of light.

Speed in a vacuum is 186,000 miles/s or 300,000 km/s or 3×10^8 m/s.

Longer wavelength/lower frequency radiation has lower energy (radio to light waves).

Shorter wavelength/higher frequency radiation has higher energy (UV to gamma rays). These higher-energy wavelengths are called 'ionizing radiation' because they can cause chemical reactions that damage living tissue.



Match each definition and example with the correct term:

When a wave strikes a reflective surface it bounces back at the same angle.

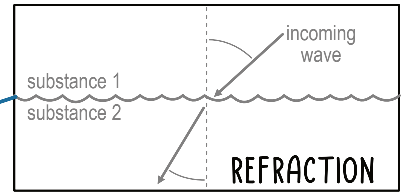
Ex: echoes, mirrors

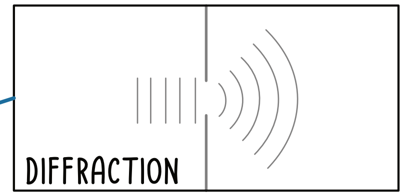
The apparent speed of a wave changes as it moves from one medium to another.

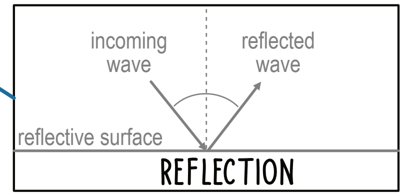
Ex: underwater objects look distorted, rainbows

A wave spreads out around obstacles.

Ex: hearing someone on other side of door, light shining through a pinhole

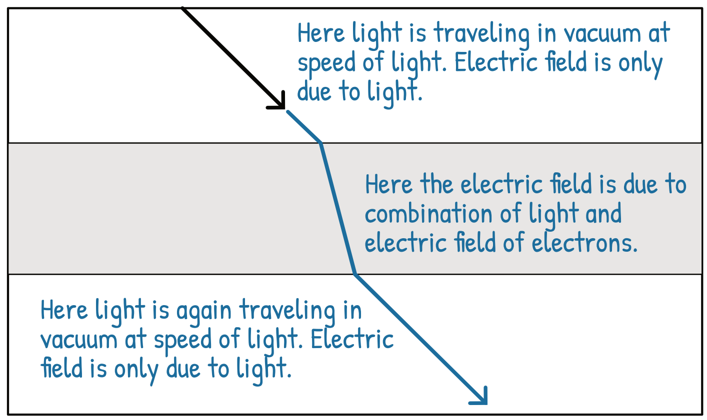




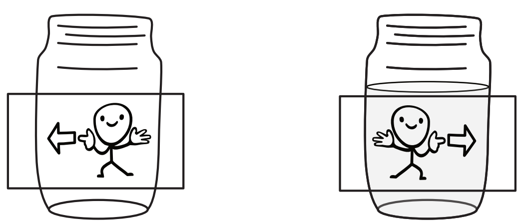


What path does light take through glass?

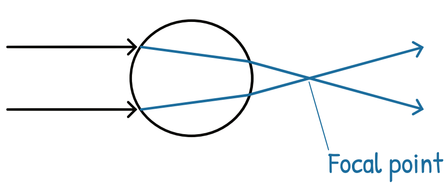
It bends or refracts! The angle of the light changes and so does the apparent speed. Remember light behaves as both a particle and a wave. As it moves through materials that have atoms, there are interactions between the electrons and the electric field of the light. The interference of these two waves change the light wave while it is in the material. The amount and angle of diffraction are predictable for different materials. This is the main principle behind why magnifying glasses, eye glasses, and telescopes work.



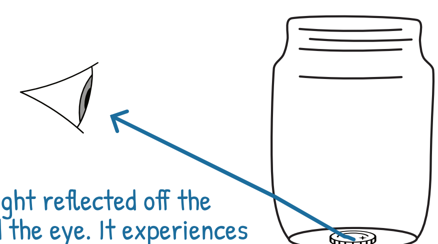
The image reverser - how it works!



In the water-filled jar, light refracts so that it forms a focal point on the other side of the jar. This is what causes the reversal. If the image is in front of the focal point, it will not be reversed; it will just appear smaller.



The disappearing coin trick - how it works!



In the air-filled jar, light reflected off the penny travels toward the eye. It experiences some refraction when moving from glass to air, but not enough to drastically change its overall direction.

In the water-filled jar, most of the light reflecting off the penny is INTERNALLY REFLECTED and travels out the top of the jar.

Note that this only happens if there is an "air-glass-water-glass-air" setup between the coin and the viewer. If the coin is wet, it will be visible just like it was in the glass full of air!

Practice Problems – The Electromagnetic Spectrum

1. **"Microwaves are just another color that humans can't see."**
Do you agree with this statement? Why or why not?
An argument for agreeing:
All wavelengths of the electromagnetic spectrum travel at the speed of light and are made of photons. Most humans can see the wavelengths of light from red to blue (400–700nm), but certain insects can see shorter wavelengths (UV) and longer wavelengths (IR).
An argument for disagreeing:
The word color should only be used to refer to the visible spectrum of light (400 to 700 nm). Microwaves have much longer wavelengths than visible light.

2. Rank the following from shortest wavelength to longest wavelength. Then label which one is most energetic and which has the least amount of energy. EM wavelengths: *gamma, infrared, microwave, radio, ultraviolet, visible light, x-ray.*

gamma	x-ray	ultraviolet	visible light	infrared	microwave	radio
SHORTEST WAVELENGTH Most energetic						*LONGEST WAVELENGTH* Least energetic

3. X-rays are used in medicine because:
   - $\boxed{\text{A. They can easily pass through soft tissues but not through bones}}$
   - B. They are completely safe and have no side effects
   - C. They are easily visible to the human eye
   - D. They provide warmth and help with healing

4. Which of the following are made of photons traveling at the speed of light in a vacuum?
   - A. s-waves in an earthquake
   - $\boxed{\text{B. Microwaves}}$
   - $\boxed{\text{C. Green light}}$
   - $\boxed{\text{D. Radio waves}}$
   - $\boxed{\text{E. Infrared light (heat) emitted from a sleeping marmoset}}$
   - F. The sound of middle C (a frequency of 261.62 hertz)

All forms of EM radiation are made of photons and travel at the speed of light in a vacuum. Earthquake waves and sound are mechanical waves.

5. The Sun emits all of the following. Which wavelengths are blocked by Earth's atmosphere?
   - A. Red light
   - $\boxed{\text{B. Microwaves}}$
   - $\boxed{\text{C. X-rays}}$
   - $\boxed{\text{D. Gamma rays}}$
   - E. Radio waves

All colors of visible light and radio waves pass through the atmosphere. The majority of the other EM wavelengths are blocked by Earth's atmosphere.

Practice Problems – The Electromagnetic Spectrum

(6) A remote control uses a pulse of electromagnetic radiation of 940 nanometers to turn on a television screen. This wavelength is invisible to human eyes but picked up by a cell phone camera. What type of electromagnetic radiation is used by this remote control?

A. Ultraviolet

B. X-ray

C. Infrared

D. Microwave

E. Radio

(7) What type of wave is a radio wave?

A. Sound wave

B. Light wave

To hear a song on the radio, the receiver in the radio has to convert the radio waves (which are light waves) into sound. The radio broadcast is either an FM (frequency modulated) or AM (amplitude modulated) electromagnetic wave. Since it is a light wave (not a sound wave!) it travels very fast and over long distances.

(8) How would light bend when it travels from air to water?

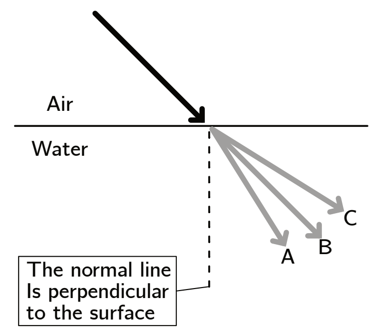
A. It would bend toward the normal line (line A)

B. It would not bend (line B)

C. It would bend away from the normal line (line C)

D. All of these options (the light would spread out in a cone)

E. None of these options



When light travels from a less dense to a more dense material, it bends toward the normal line and the apparent speed decreases

(9) When driving on a highway, Bob sees a mirage. It looks like there is a puddle of water in the middle of the highway. But as Bob continues driving the puddle moves. No matter how fast or slow Bob drives, the puddle is always about 100 meters in front of the car. This mirage is primarily caused by:

A. Reflection

B. Refraction

C. Water on the road quickly evaporating and then condensing

Difference in air temperature causes light from the sky at the horizon to bend and appear on the road. This refracted light is the cause of the "puddle"

(10) How would light bend when it travels from glass to air?

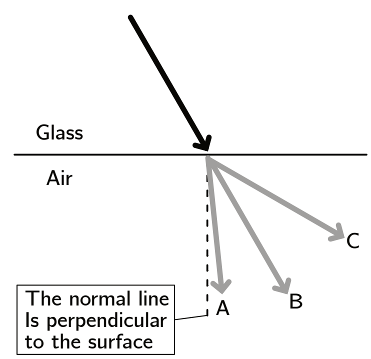
A. It would bend toward the normal line (line A)

B. It would not bend (line B)

C. It would bend away from the normal line (line C)

D. All of these options (the light would spread out in a cone)

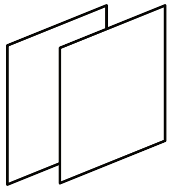
E. None of these options



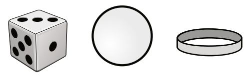
When light travels from a more dense to a less dense material, it bends away from the normal line and the apparent speed increases

TABLETOP KALEIDOSCOPE

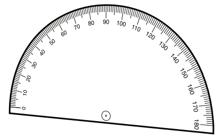
MATERIALS



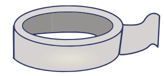
2 flat mirrors *



A small object to place in front of the mirror such as a pebble, ring, dice, or small figurine



Protractor



Tape

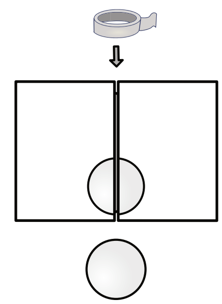
GOALS

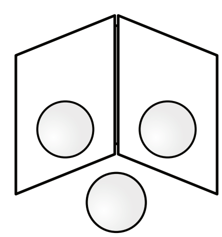
- Create a kaleidoscope effect with mirrors.
- Explore the angle of reflection of light in a mirror.

* If you only have one hand mirror available, you can hold it up to a bathroom mirror and get the same effects. It works best if your mirror has no border.

INSTRUCTIONS:

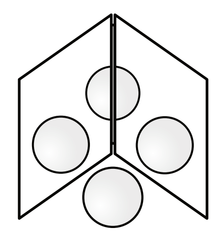
1. Tape two mirrors side-by-side with a little space between them and add tape along the back creating the spine of a mirror-book.
2. Place an object up on a table.
3. Stand the mirrors vertically upright so they form a 180° angle with each other. You should see exactly two copies of your object (one mirrored across the spine of the mirror-book).
4. How many objects do you predict you will see if the mirrors are rotated to form a 120° angle? Make a prediction before trying it. If you don't have a protractor, print the following page and use it as a guide.
5. Continue rotating the mirrors to form other angles, and try viewing different objects.





At what angle should you use to see exactly 4 copies of your object?

Is it possible to get exactly 5 copies of your object?

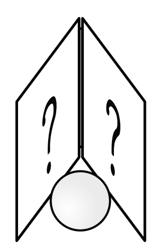


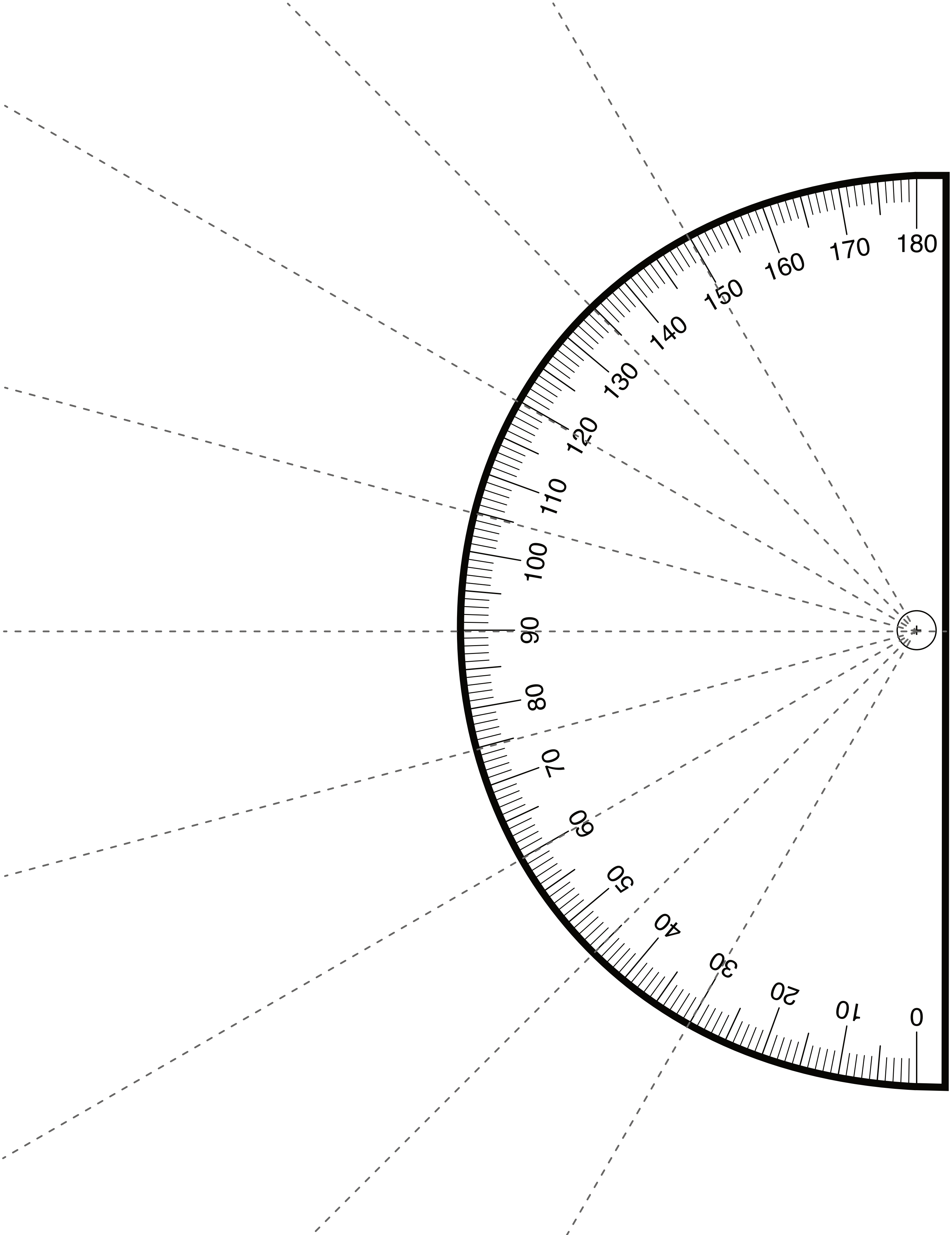
Fill in the table below to match the size of the angle with the number of objects you can see.

Describe any patterns you see.

angle	objects
180°	2
120°	3
	4
	5
	6
	8
	9
	10

Would it be possible to make 100 copies of an object visible using two mirrors? Explain.




0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180

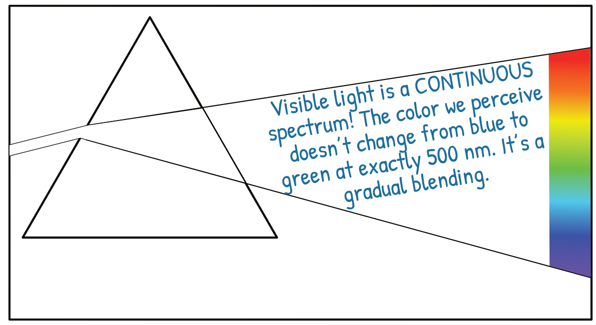
Colors & Sending Signals

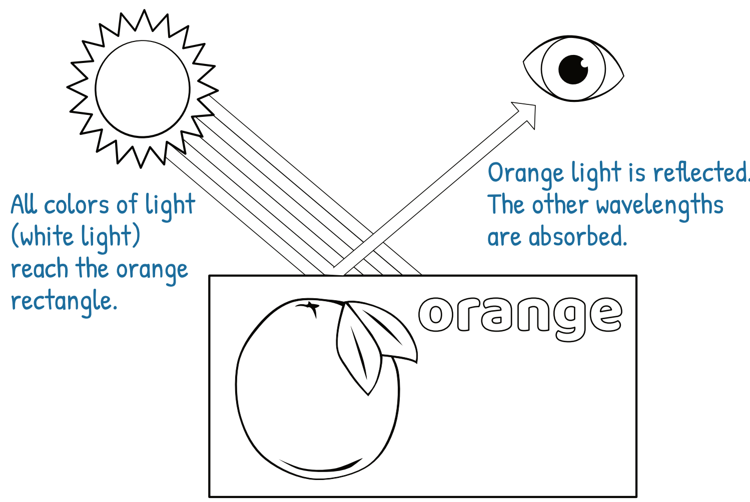
In reflection and refraction, light can change direction after interacting with an object, but there's another option we haven't talked much about yet: absorption! Draw your own comic or diagrams to go along with the text below:

WHEN LIGHT IS ABSORBED, THE ENERGY IS CONVERTED INTO OTHER FORMS LIKE HEAT.	EVERYTHING WE CAN SEE IS BEING HEATED UP?!?	YEP! THE AMOUNT OF TEMPERATURE INCREASE DEPENDS ON THE LIGHT INTENSITY. OFTEN IT'S VERY SMALL.	ALSO... MOST OBJECTS DON'T ABSORB ALL VISIBLE LIGHT. THEY REFLECT AT LEAST A FEW WAVELENGTHS.

White Light Contains These Wavelengths:

380-450 nm: Violet & Indigo
450-500 nm: Blue
500-570 nm: Green
570-590 nm: Yellow
590-610 nm: Orange
610-760 nm: Red





Black objects absorb most visible light. White objects reflect most visible light. This is why black cars or paper will get hotter when left in the Sun than white cars or paper.

It also explains why (when trying to start a fire using a magnifying glass) it's much easier to start the fire on a spot with black text.

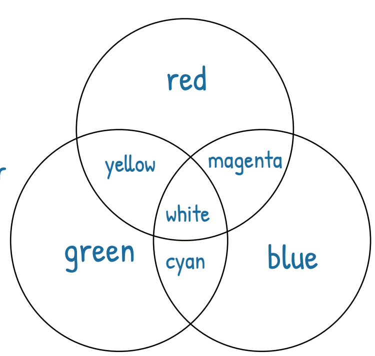
MIXING LIGHT

The Additive Color Model

RGB colors!

used in computer screens, electronics, etc.

Mixing all colors together makes white



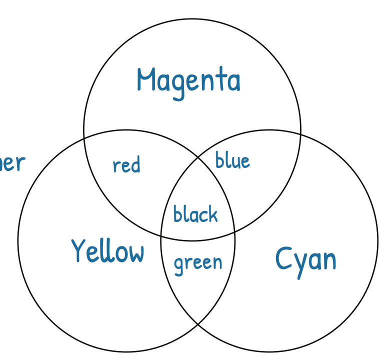
MIXING PIGMENTS

The Subtractive Color Model

CYMK colors!

used when printing with ink or painting etc.

Mixing all colors together makes black



ANALOG VS DIGITAL

ANALOG

The signal is continuously varying. A wave is either recorded or used to carry information. A clock with hands that move, old-school film tapes, VHS tapes, cassette tapes, and record players are all analog devices.

Ex. A cassette tape. The sound wave is recorded onto the tape in the form of waves. The analog waves can be read and converted back to sound but over time they will degrade and the tape can get static.

Advantage: can have richer tone quality (record player)

Disadvantage: with repeated use, the signal will degrade over time. Long distances can also cause a loss in signal quality.

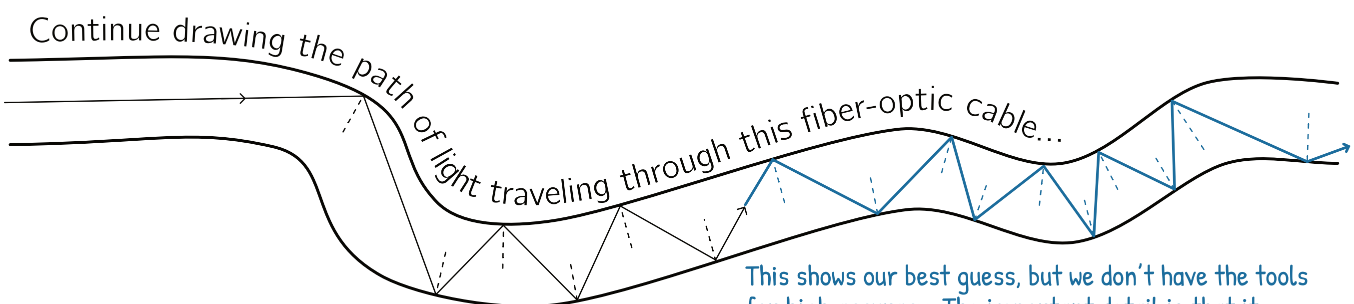
DIGITAL

The signal is discrete (such as a sequence of 1s and 0s). Information is stored in a sequence of numbers. DVDs, computers, CDs, digital clock with numbers, and cell phones are all digital devices.

Ex: A Compact Disk (CD) When making a music CD, the sound wave is sampled 44,000 times per second. The numbers can then be converted back into sound like the original sound wave.

Advantage: information will not deteriorate or degrade over time. Can be compressed. Can travel longer distances.

Disadvantage: compression can cause some (very slight) loss of tone quality. This is why vinyl records are still used by music aficionados.



This shows our best guess, but we don't have the tools for high accuracy. The important detail is that it bounces out with the same relative angle it comes in.

Communicating with waves

Bob uses a cell phone to call to a friend. What waves are involved? Label them and then describe whether the signals involved are analog or digital.

SOUND WAVES are created by a voice and reach the phone.

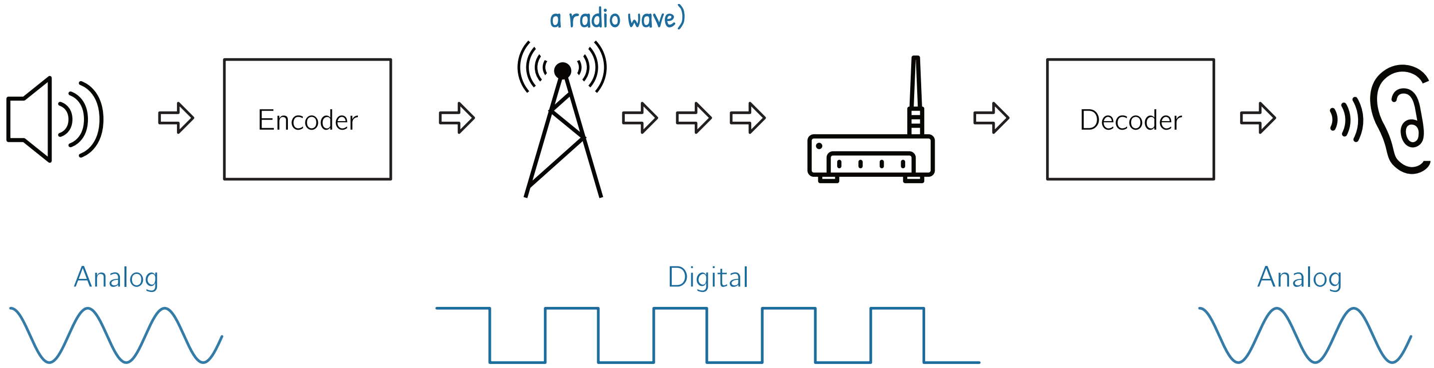
The phone converts the sound to a sequence of 0s and 1s and sends that signal in a low-frequency wave.

An EM wave signal is sent. The type can vary!

(e.g. microwave or radio wave to cell tower to light in fiber optic line to a modem where it is converted back to a radio wave)

The phone converts the sequence of 0s and 1s in the low-frequency wave into sound waves

Sound reaches your ears.



Practice Problems – Color & Sending Signals

1. Emily sends a text message to her brother. What type of electromagnetic wave is most likely used to send the text message?

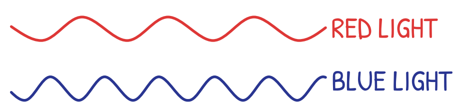
   A. Infrared
   B. Microwave
   C. Ultraviolet
   D. Violet

   Microwaves are EM radiation with a wavelength between 1 m and 1 mm. Most cell phones send their signals using microwaves. But this doesn't mean your phone can heat your lunch. A microwave oven uses much higher power (over 1,000 watts) than a cell phone (less than 2 watts) and has a specially-designed system that reflects and concentrates the waves inside the microwave. A microwave oven is also tuned to deliver the frequency that best causes water molecules to vibrate. A cell phone will use other wavelengths.

2. Which color of light has more energy, red light or blue light?

   A. Red light because it has a higher frequency
   B. Red light because it has a lower frequency
   C. Blue light because it has a higher frequency
   D. Blue light because it has a lower frequency

   Blue light has shorter wavelength (450 nm) and higher frequency. Red light has longer wavelength (600 nm) and therefore lower frequency.



3. Why are most plants green?

   A. They absorb green light.
   B. They reflect green light but absorb other wavelengths of color.

4. What color is produced when all wavelengths of light overlap or are "mixed" together?

   A. White
   B. Brown
   C. Black
   D. Magenta

   White light contains all wavelengths/colors of light.

5. A color printer can print photographs and other complex color images quickly and easily. It only has 4 ink cartridges. What color are the ink cartridges?

   A. Red, Yellow, Blue, and Brown
   B. Red, Green, Blue, and White
   C. Cyan, Yellow, Magenta, and Black
   D. Each of the cartridges contains many colors of ink

   The CYMK for printers or print settings stands for Cyan, Yellow, Magenta, and Key (the "Key" refers to black)

6. Which of the following statements is true?

   A. We don't see color in moonlight because only one wavelength is reflected from the Moon.
   B. Objects still have color in moonlight, it's just too faint for our eyes to detect.

7. Of the colors below, which has the longest wavelength?

   A. Violet
   B. Orange
   C. Green
   D. Yellow

Waves Unit Assessment

In your own words!

Define each of the following terms in your own words! Explain the terms without looking them up and give an example of each. Then compare what you wrote with the definitions in the notes. Make corrections as needed.

MECHANICAL WAVE: A vibration in matter that transfers energy through a material. Can be transverse (ocean wave) or longitudinal (sound).

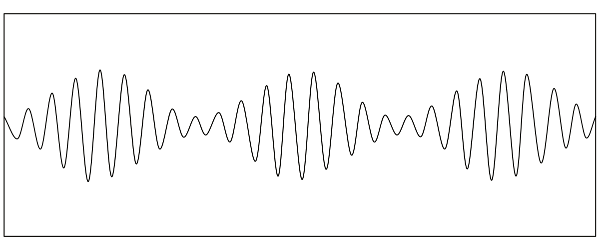
ELECTROMAGNETIC WAVE: Photons traveling at the speed of light! These waves can travel through a vacuum of empty space. Examples: gamma rays, x-rays, UV, visible light, IR, microwaves, radiowaves

AMPLITUDE: How tall the peaks of a wave are. From the middle (resting) part of the wave to the top of the crest.

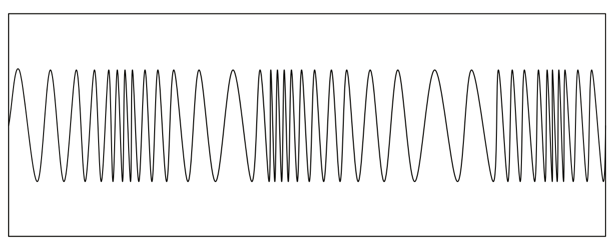
FREQUENCY: How fast the wave is oscillating up and down. Ex. Gamma rays have a much higher frequency than microwaves.

HERTZ: How many times something happens per second. Ex. A 100 hertz tone vibrates or oscillates 100 times per second.

Below are two diagrams of radio wave signals. One of them is an FM signal (Frequency Modulated) and one of them is an AM (Amplitude Modulated) signal. Which is which and why?



SIGNAL TYPE: AM (Amplitude Modulated) because the amplitude (rest to crest) varies from small to large.



SIGNAL TYPE: FM (Frequency Modulated) because the amplitude (rest to crest) stays the same but the frequency changes.

Waves Unit Assessment

1. What type of waves do NOT require matter to transport energy?
   A. Mechanical waves
   B. Electromagnetic waves
   C. Longitudinal waves
   D. Ocean waves

2. As the frequency of a wave *increases* its energy
   A. decreases
   B. increases
   C. remains the same

3. Why can't sound waves travel through the vacuum of outer space?
   A. It's too cold in outer space.
   B. Radiation from the Sun destroys them.
   C. Sound waves need physical matter to exist.
   D. There are sound waves in space, but no one is there to hear them.

4. What is the primary difference between radio waves and visible light?
   A. One travels faster than the other.
   B. One light is made of photons.
   C. One travels longer distances than the other.
   D. One has a longer wavelength than the other.

5. As the wavelength of a wave gets longer its energy will _______.
   A. decrease
   B. increase
   C. remain the same

6. What part of the electromagnetic spectrum can be seen by people?
   A. Infrared radiation
   B. Microwaves
   C. Ultraviolet light
   D. Visible light

7. What type of signal is made of continuously varying data or information?
   A. Analog
   B. Digital

8. What type of signal is commonly used in computers?
   A. Analog
   B. Digital

9. Which of the following statements is **false**?
   A. Digital signals are recorded and stored more easily than analog.
   B. Analog signals maintain their quality over long distances.
   C. Digital signals are considered more reliable than analog.
   D. Analog signals can be converted into digital signals.

10. When a straight pencil is placed in a glass that is half-full of water, it appears bent when viewed from the side. Which of these phenomena best explains why?
   A. Light being refracted
   B. Light being absorbed
   C. Light being reflected
   D. Light being diffracted

11. The ____________ of a wave is how many wavelengths pass a certain point each second.
   A. amplitude
   B. frequency
   C. wavelength

11. If a marmoset sees lightning strike a tree one mile away, which of the following is true?
   A. They will hear thunder at the same time they see lightning because sound and light travel at the same speed.
   B. They will hear thunder after seeing the lightening because sound travels more slowly than light.
   C. They will not hear any thunder because the lightning strike is too far away.

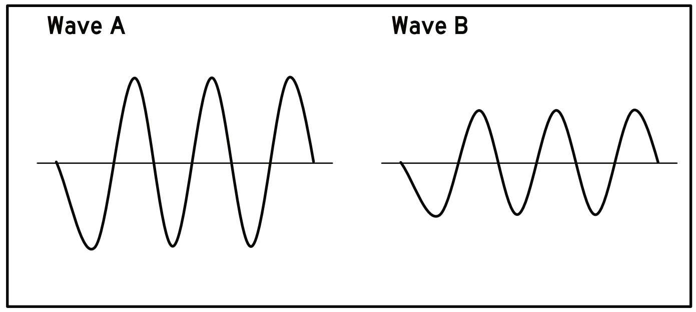
12. Why does a green ball appear green?
   A. It absorbs all wavelengths of light except for green.
   B. It only absorbs green light.

13. What are the primary colors of light?
   A. Red, Yellow, and Blue
   B. Red, Blue, and Green
   C. Orange, Green, and Purple
   D. Cyan, Magenta, and Yellow

Waves Unit Assessment

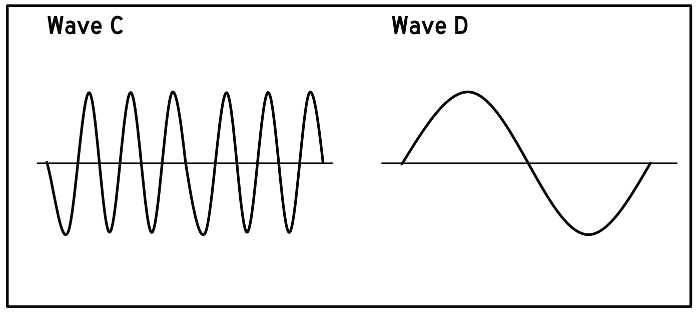
14 Of the colors listed below, which has the shortest wavelength?

A. Red
B. Yellow
C. Blue
D. Orange
E. Green



15 Look at the graphs of waves A and B drawn at the right. Which has greater energy and why?

A. Wave A carries more energy because it has higher amplitude.
B. Wave A carries more energy because it has higher frequency.
C. Wave B carries more energy because it has a shorter wavelength.
D. Wave B carries more energy because it has a lower amplitude.



16 Look at the graphs of sound waves C and D. What differs between these waves?

A. C has higher frequency than D.
B. D has lower amplitude than C.
C. C has shorter wavelength than D.
D. Both A and C
E. None of the above

17 Would you be able to see a full-body reflection of yourself in a mirror that is only half as tall as you? If so, how?

Yes, you would just need to stand further away. The further from the mirror you are, the smaller the reflected image in the mirror.

18 Bob wants to know why a red apple appear to be red during the day but looks grey at night when the light is dim. How would you explain it to him?

Human eyes have two different types of cells for detecting light. Rods just detect the presence of light and are much more sensitive. Cones detect color. When the only source of light is moonlight the light is enough to activate the rod receptors but not the cones. This is why everything appears to be in shades of gray.