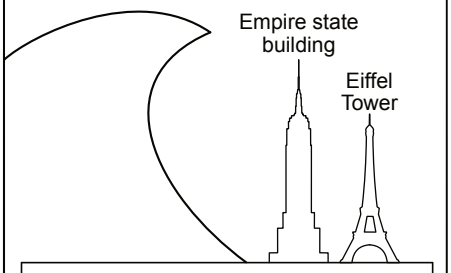
Making Waves

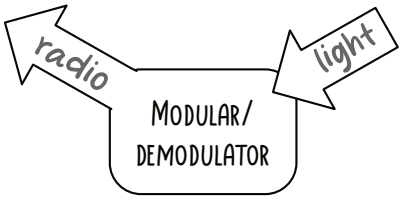
FACT OR FICTION? *Write your verdict below each statement:*

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



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

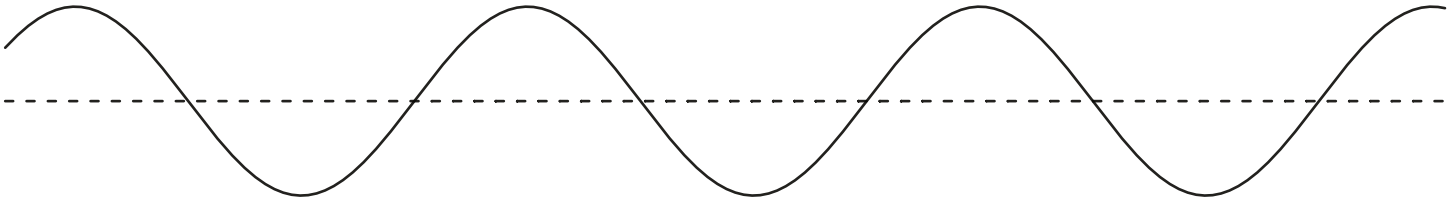
Most modern homes contain a machine that converts light into radio waves.



FILL IN THE BLANKS:

energy	*disturbance*	*medium*	*transmitted*

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

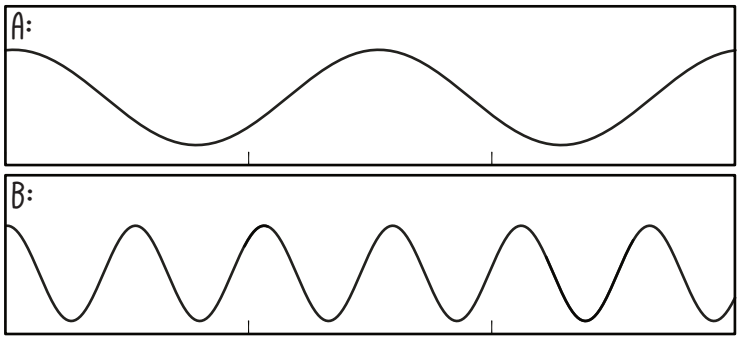


AMPLITUDE:

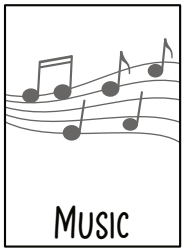
WAVELENGTH:

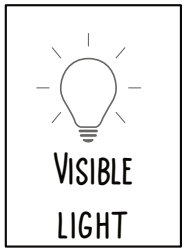
FREQUENCY:

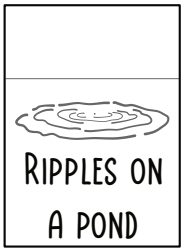
THE IMAGES BELOW SHOW HOW MANY OSCILLATIONS OCCUR IN 3 SECONDS. WHICH WAVE HAS A HIGHER FREQUENCY?



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

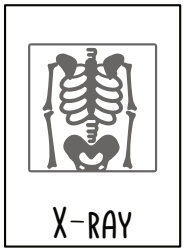

Music


Visible light


Ripples on a pond


Earthquake


tsunami


X-ray

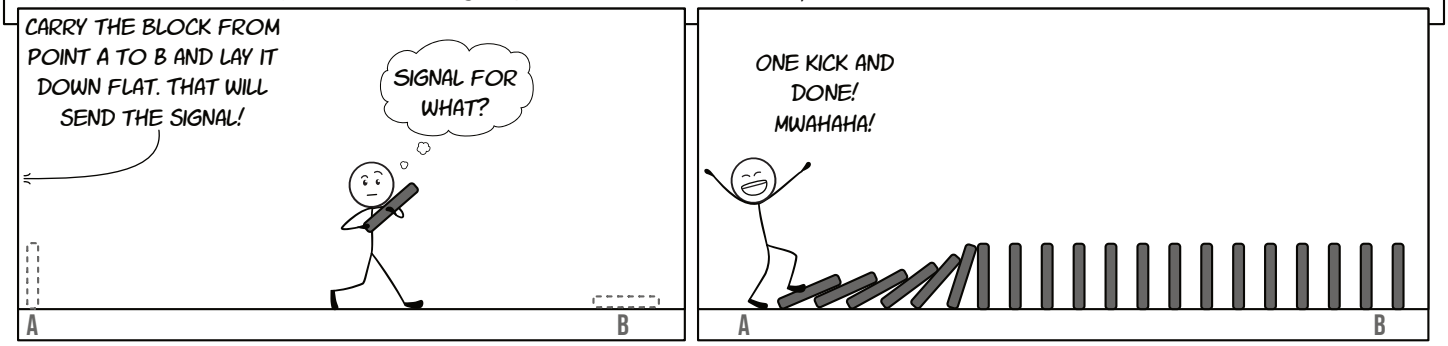

Infrared radiation

Mechanical wave: requires a medium

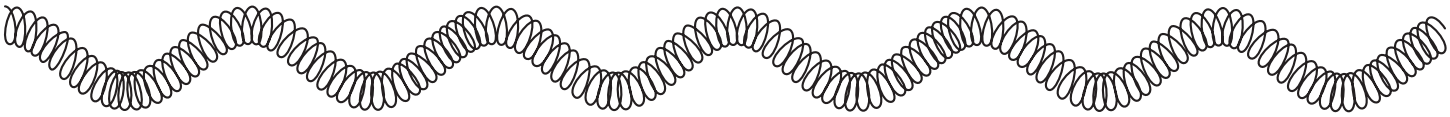
Electromagnetic wave: can travel through a vacuum of empty space.

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.



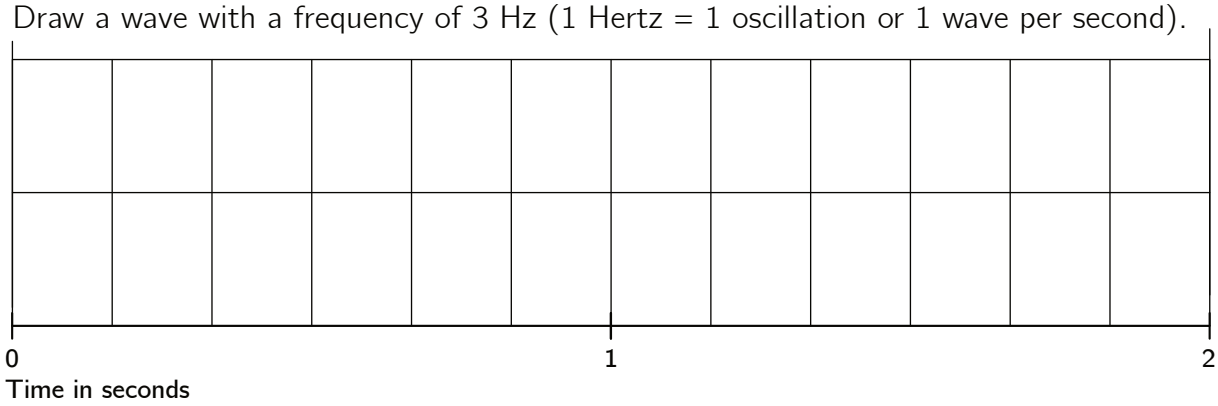
Transverse Wave:



Longitudinal Wave:

Practice Problems - Making Waves

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



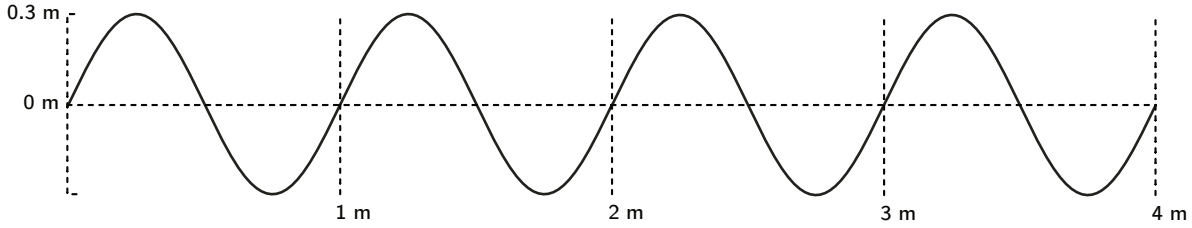
2. Explain the difference between a mechanical wave and an electromagnetic wave and give an example of each.

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? _____

   B. What is the amplitude? _____

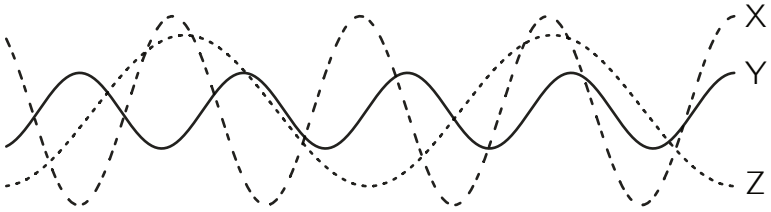
   C. What is the speed of the wave in meters per second? _____



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

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

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



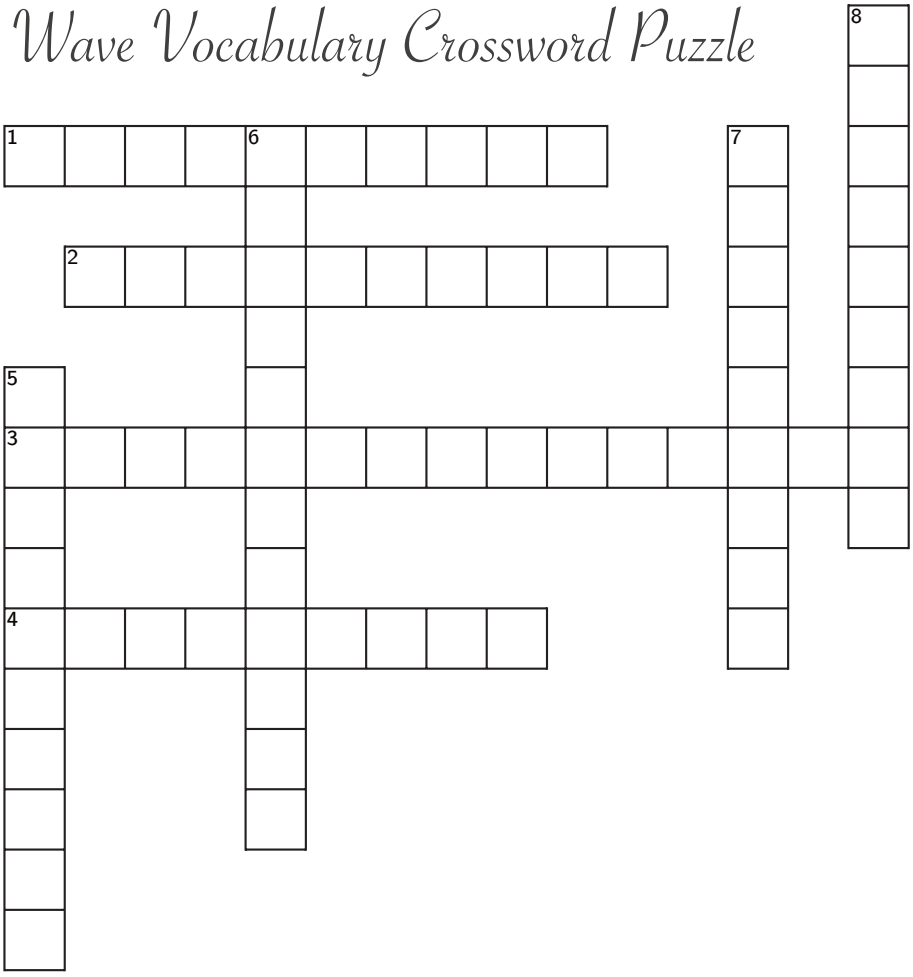
Practice Problems - Making Waves

(5) Are earthquake waves mechanical or electromagnetic? Explain.

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

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

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)

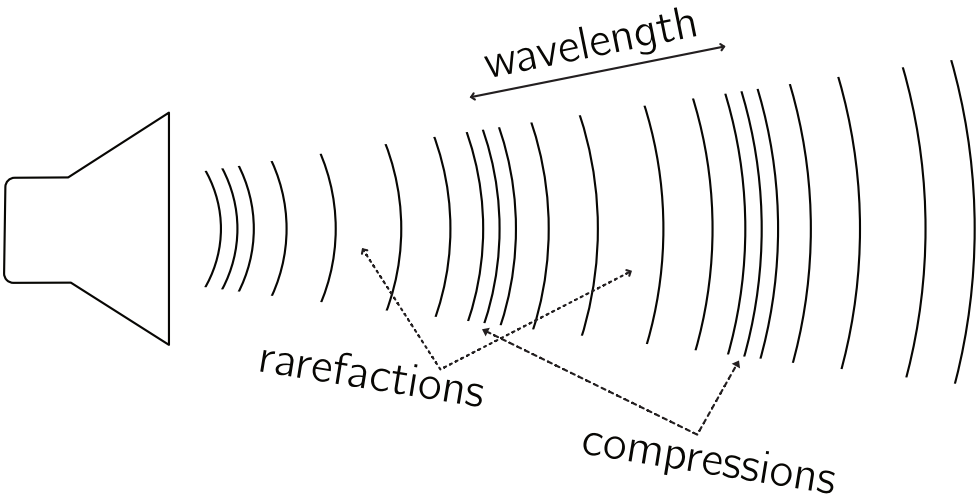
Vertical Words

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.

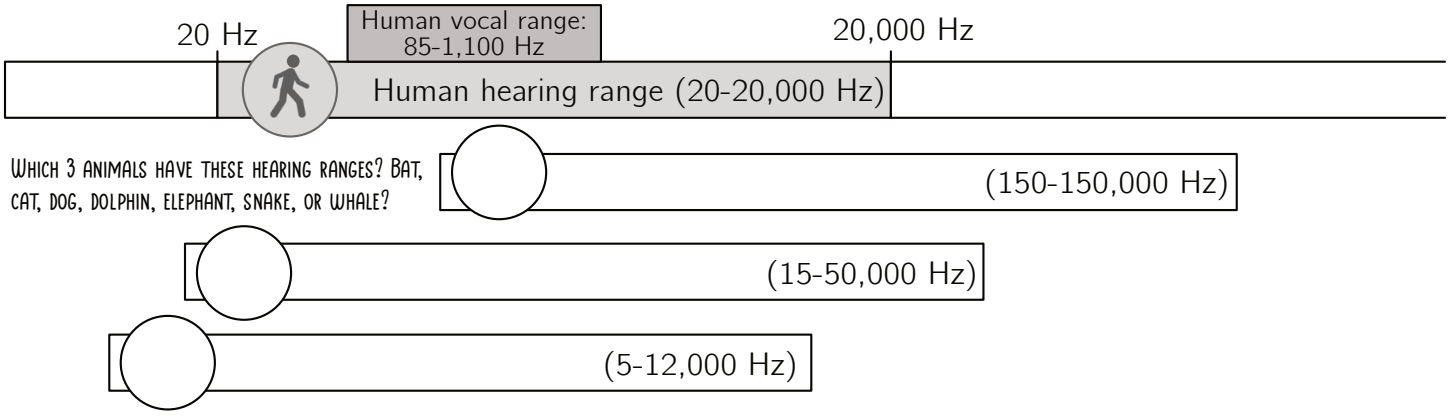
Good Vibrations

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

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



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**.



PITCH:

VOLUME:

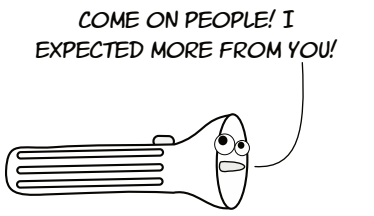
$$\lambda = v/f$$

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?

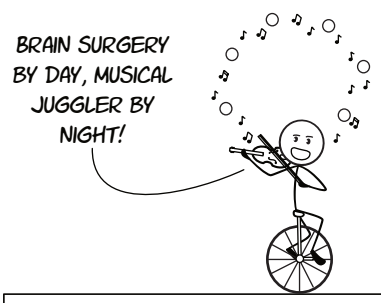
If the wavelength of a WiFi signal is 0.12 meters and the speed of electromagnetic waves is 3×10^8 meters per second, what frequency band is the WiFi signal using?

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

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



Sound can make objects levitate in the air.



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.

Practice Problems - Good Vibrations

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

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. $f = \lambda \cdot v$

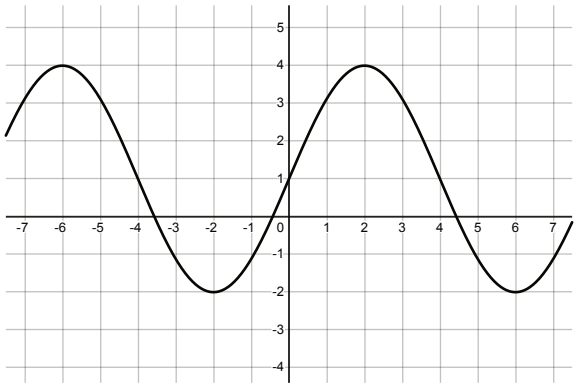
4. Which form of water would sound travel the fastest through?
   A. Ice
   B. Liquid water
   C. Steam
   D. Sound would travel at the same speed through water no matter what state it was in.

5. The larger the amplitude, the _____ the sound will be.
   A. Quieter
   B. Louder
   C. Sound waves with different amplitudes will have same volume

6. The pitch of a sound is primarily determined by the:
   A. Amplitude
   B. Frequency
   C. Wavelength

Practice Problems - Good Vibrations

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



(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?

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

(10) The longer a guitar string is, the:

A. Higher its pitch
B. Lower its pitch
C. Louder its sound
D. Softer its sound

(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

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.*

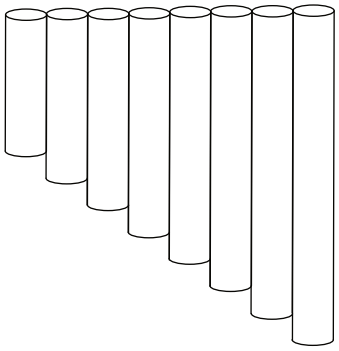
Rubber Band Banjo

- ▫ 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

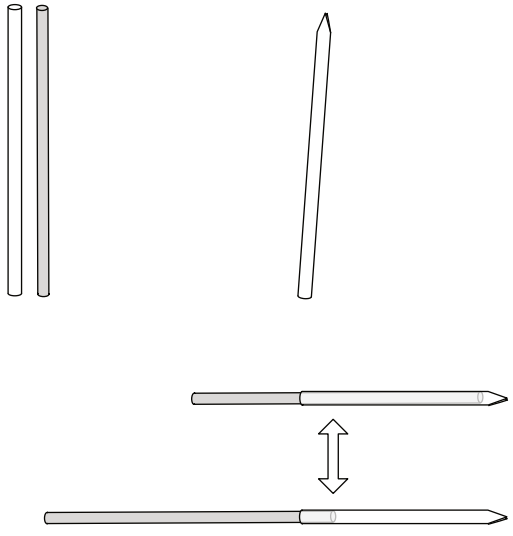
INSTRUCTIONS for Panpipes:



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.

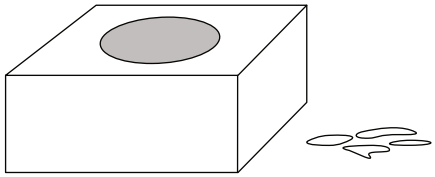
**The pitch depends on both the width and the length. But straw pipes cut to the following lengths in centimeters will usually produce a nice set of tunes: 9.5, 10, 11.5, 13, 14.5, 15.5, 17, and 19.5 cm. Err on the side of cutting too long because it's easier to trim a pipe shorter than to make it longer.*

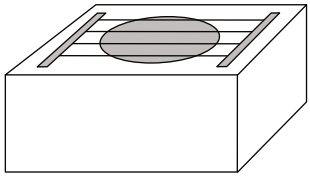
INSTRUCTIONS for Straw Flute or Straw Trombone:



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.

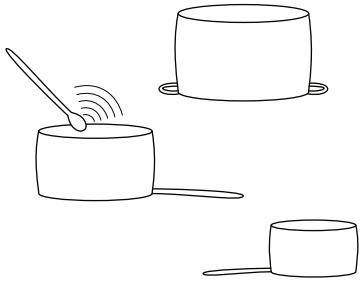
INSTRUCTIONS for Rubber Band Banjo:





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:

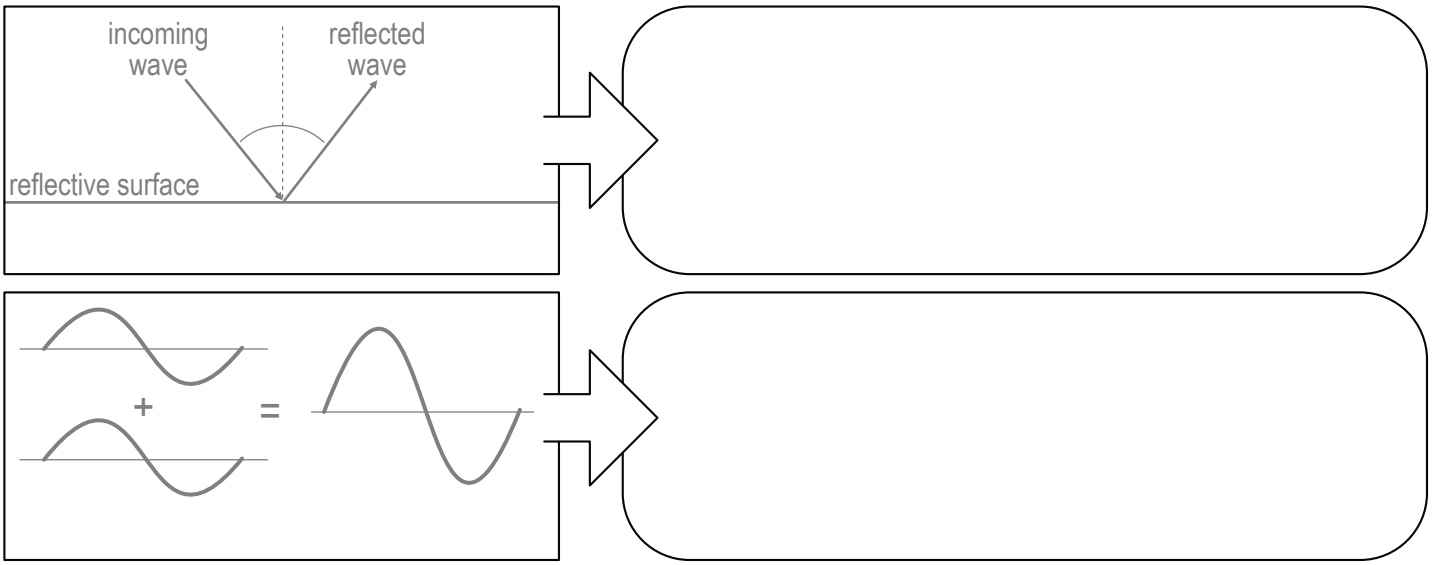
There are 3 main types of instruments: wind, string, and percussion. Why does a note of the same pitch sound different when played on a violin versus a trumpet? How can someone tell the difference between a middle C being played on a flute vs a harp vs a xylophone?

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

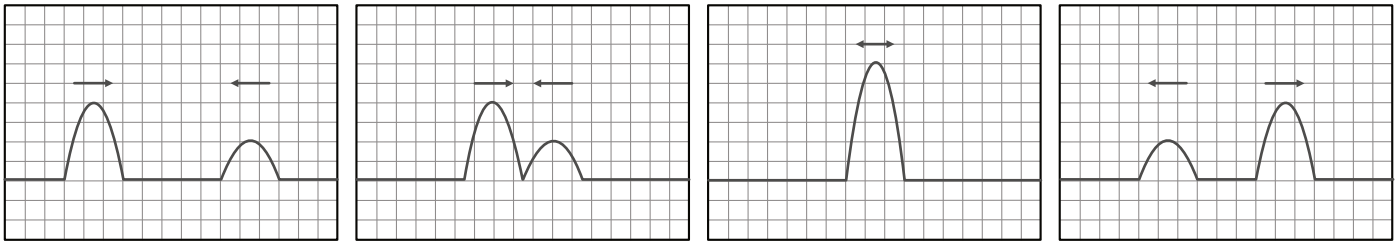
In the instrument(s) you made, what part of the instrument vibrated and created sound waves?

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.

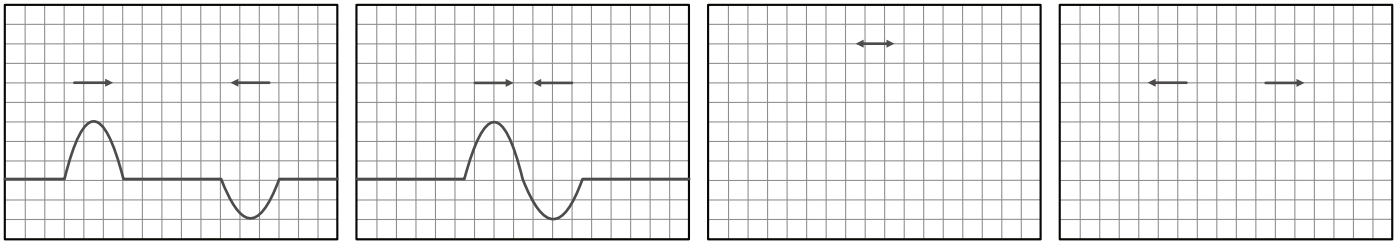


Constructive Interference

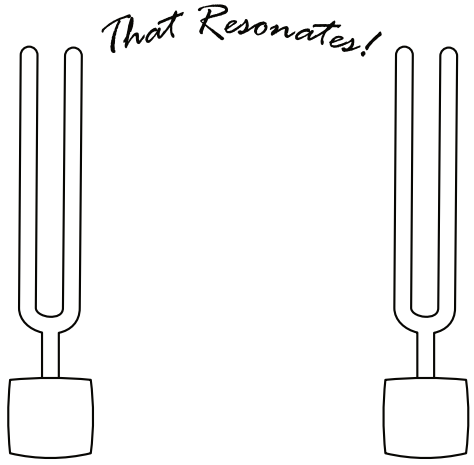


Two pulses with positive amplitude are moving towards each other. When they overlap, the resulting amplitude increases significantly. After passing through each other they return to their original shape and size.

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.)

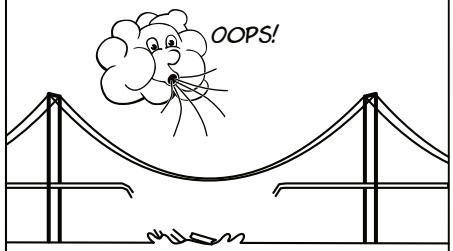


Natural frequency:

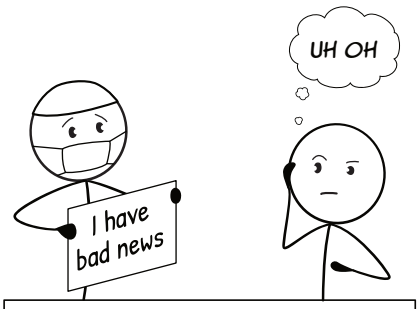
Resonance:

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

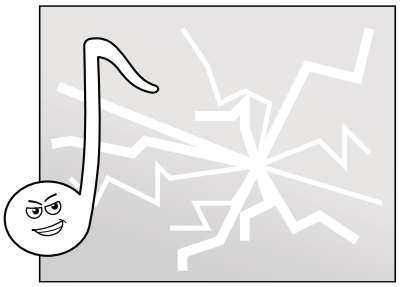
In 1940, a mile-long bridge collapsed because of a moderate wind.



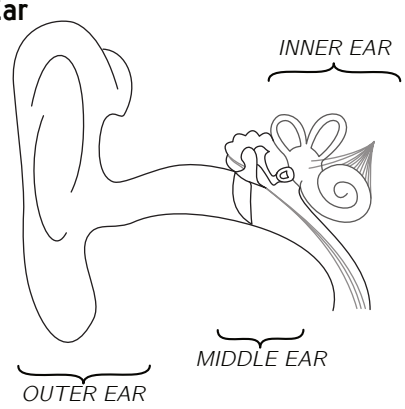
A broken eardrum will result in permanent hearing loss.



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

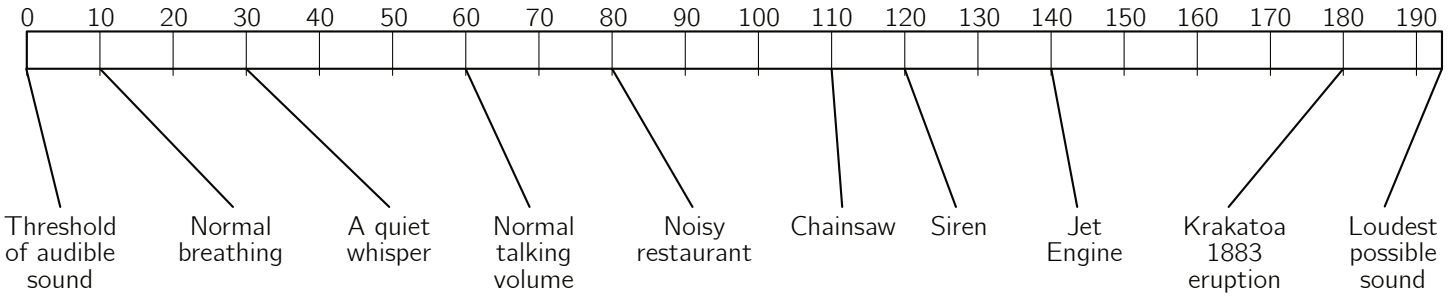


The Human Ear



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

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 _____ scale, which means that an increase of 10 dB changes the sound intensity by a factor of _____ . An increase of 20 dB changes the sound intensity by a factor of _____ , and an increase of 30 dB means the sound is _____ 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?

2. The speed of a wave depends on:
   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

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

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?

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.

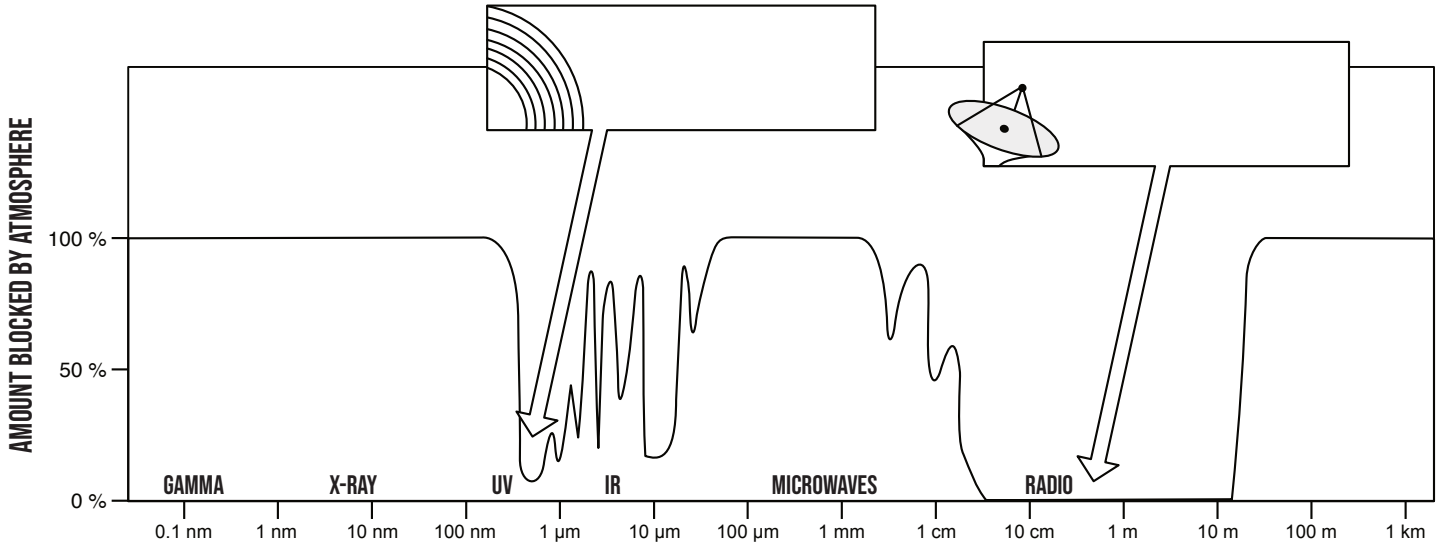
10. Give two examples of situations where you might encounter superposition or interference in everyday life. One example should be for constructive interference. The other example should be deconstructive interference.

The Electromagnetic Spectrum

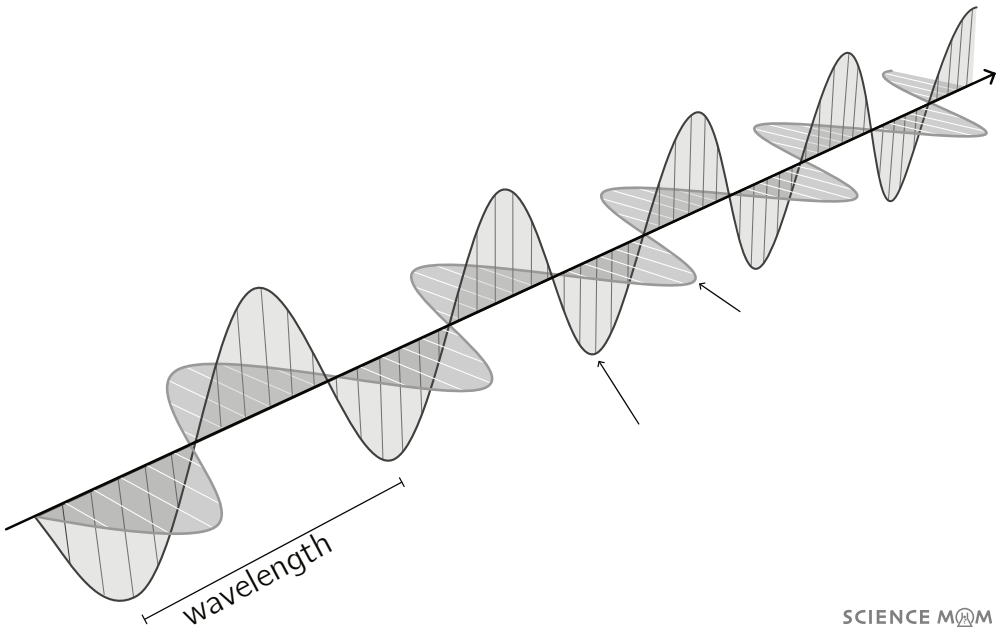
Fill in the blanks:

visible	*wavelengths*	*eyes*	*radiation*	*radio*	*gamma*

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



Why are these waves called electromagnetic?



Match each definition and example with the correct term:

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

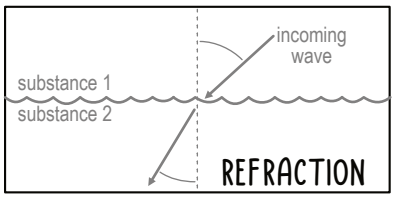
Ex: echoes, mirrors

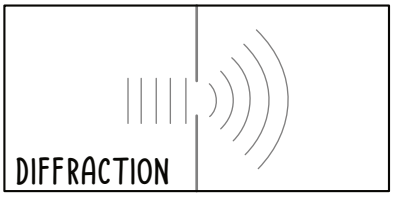
The apparent speed of a wave changes as it moves from one medium to another.

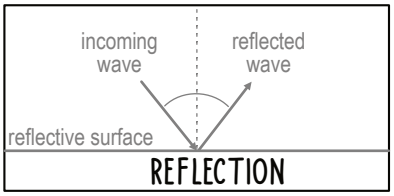
Ex: underwater objects look distorted, rainbows

A wave spreads out around obstacles.

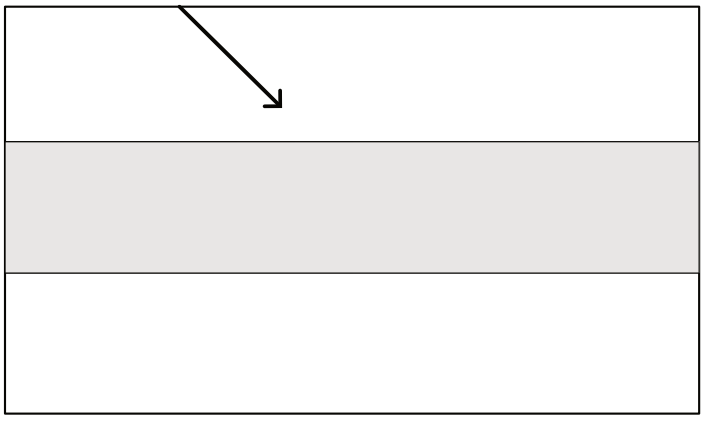
Ex: hearing someone on other side of door, light shining through a pinhole



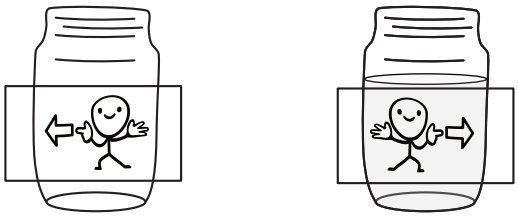


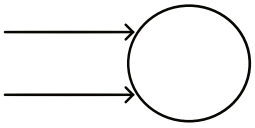


What path does light take through glass?

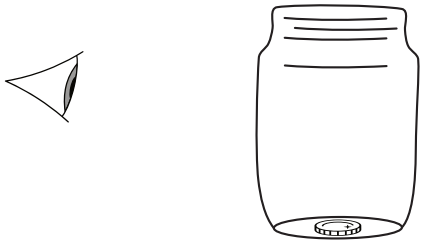


The image reverser - how it works!





The disappearing coin trick - how it works!



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?

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.*

_____ _____ _____ _____ _____ _____ _____

SHORTEST WAVELENGTH *LONGEST WAVELENGTH*

3. X-rays are used in medicine because:
   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
   B. Microwaves
   C. Green light
   D. Radio waves
   E. Infrared light (heat) emitted from a sleeping marmoset
   F. The sound of middle C (a frequency of 261.62 hertz)

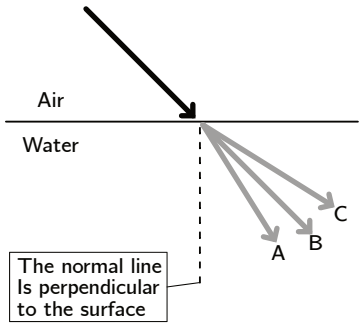
5. The Sun emits all of the following. Which wavelengths are blocked by Earth's atmosphere?
   A. Red light
   B. Microwaves
   C. X-rays
   D. Gamma rays
   E. Radio waves

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

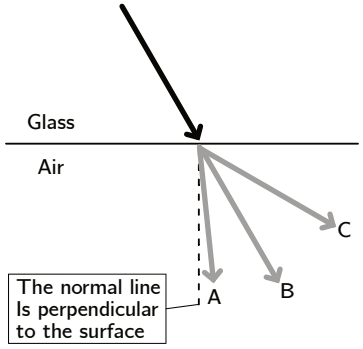
7. What type of wave is a radio wave?
   A. Sound wave
   B. Light wave

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



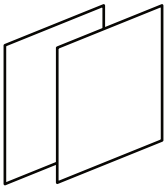
9. When driving on a highway, Bob sees a mirage. It looks like there is a puddle of water in the middle of the highway. But as Bob continues driving the puddle moves. No matter how fast or slow Bob drives, the puddle is always about 100 meters in front of the car. This mirage is primarily caused by:
   A. Reflection
   B. Refraction
   C. Water on the road quickly evaporating and then condensing

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

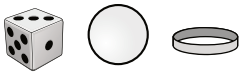


TABLETOP KALEIDOSCOPE

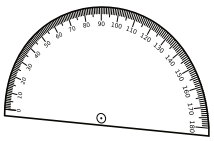
MATERIALS



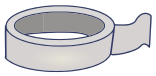
2 flat mirrors *



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



Protractor



Tape

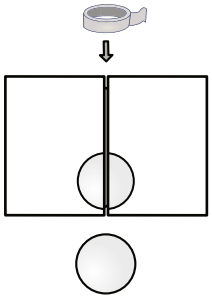
GOALS

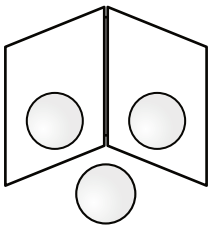
- Create a kaleidoscope effect with mirrors.
- Explore the angle of reflection of light in a mirror.

* 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:

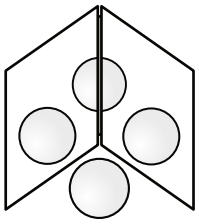
1. Tape two mirrors side-by-side with a little space between them and add tape along the back creating the spine of a mirror-book.
2. Place an object up on a table.
3. Stand the mirrors vertically upright so they form a 180° angle with each other. You should see exactly two copies of your object (one 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?

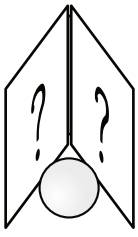
Is it possible to get exactly 5 copies of your object?



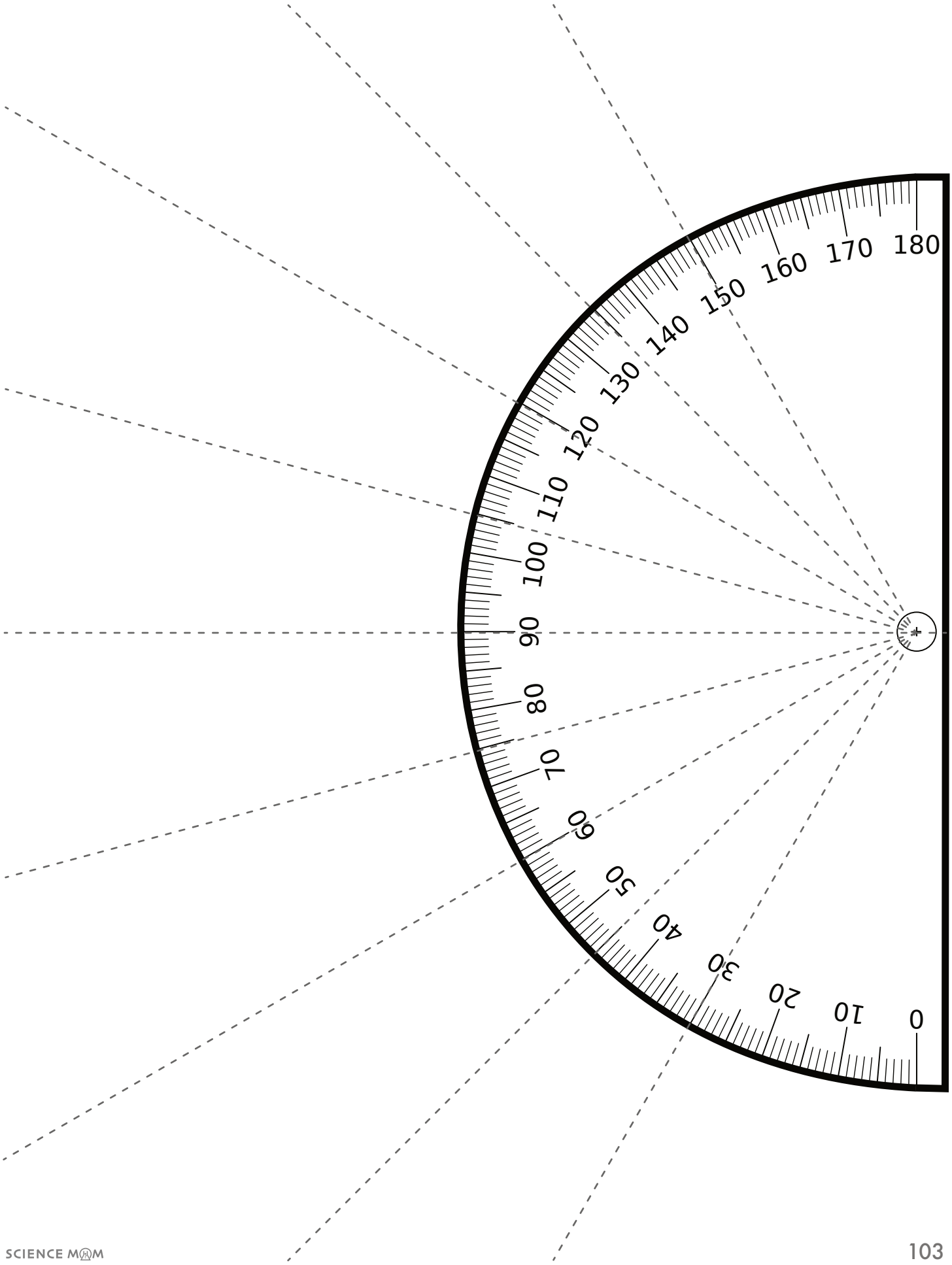
Fill in the table below to match the size of the angle with the number of objects you can see.

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

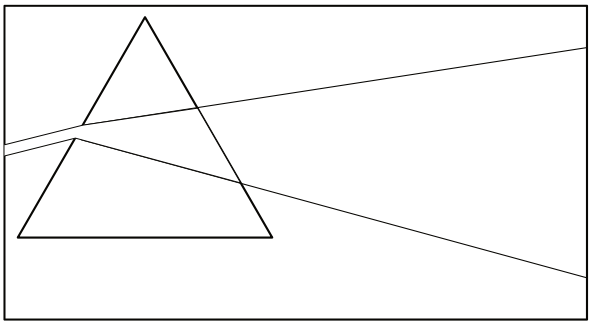
Colors & Sending Signals

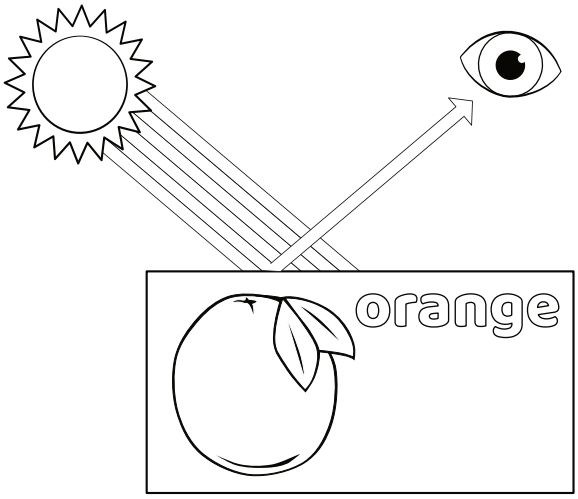
In reflection and refraction, light can change direction after interacting with an object, but there's another option we haven't talked much about yet: absorption! Draw your own comic or diagrams to go along with the text below:

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:

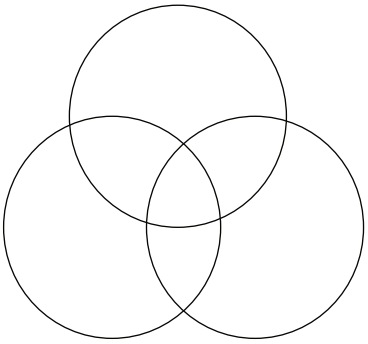
380-450 nm:
450-500 nm:
500-570 nm:
570-590 nm:
590-610 nm:
610-760 nm:





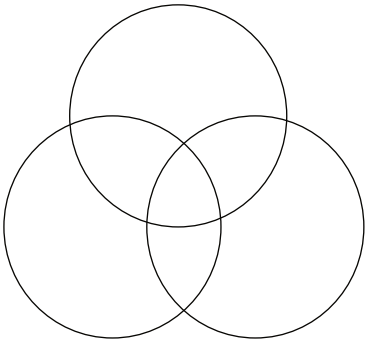
MIXING LIGHT

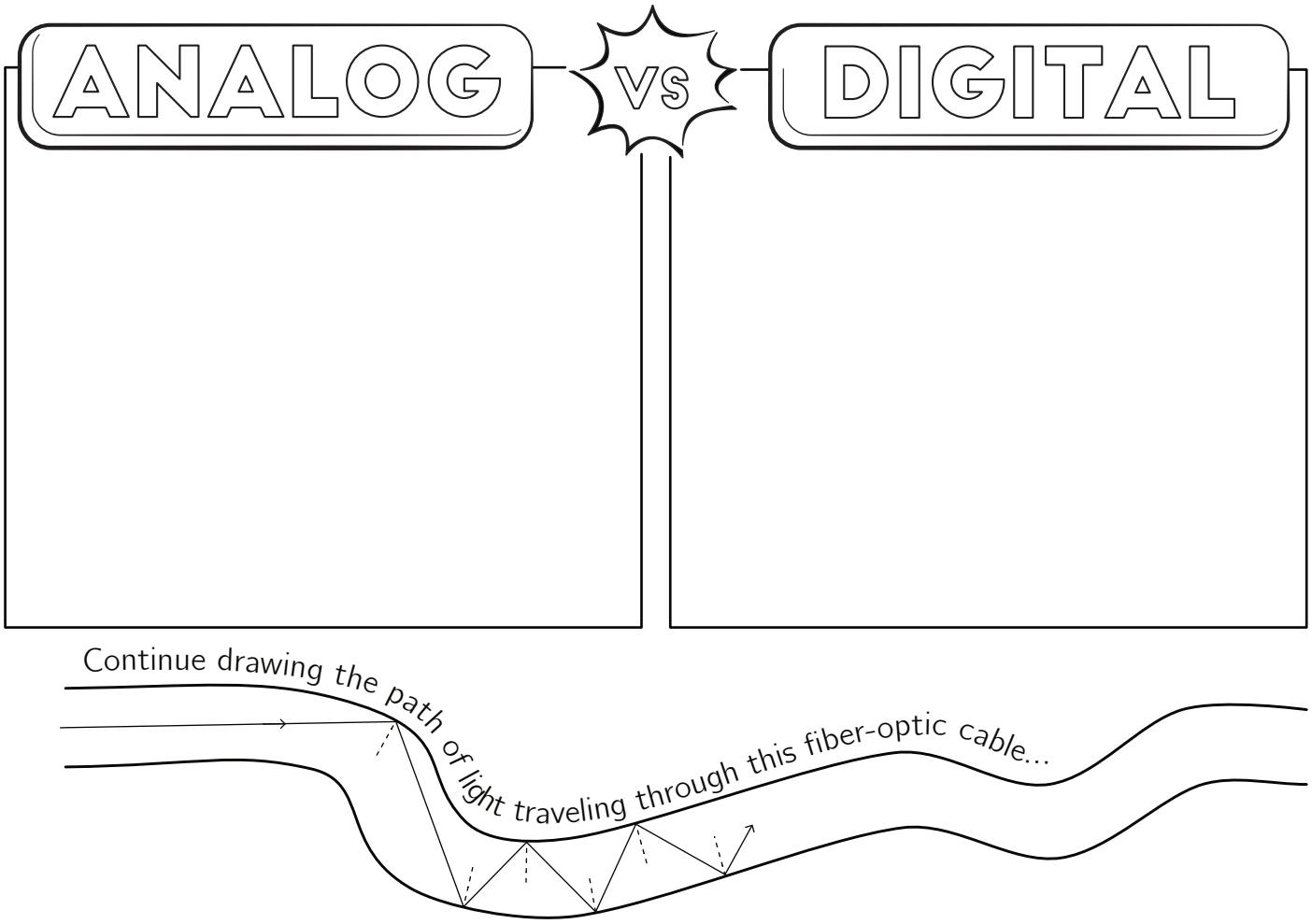
The Additive Color Model



MIXING PIGMENTS

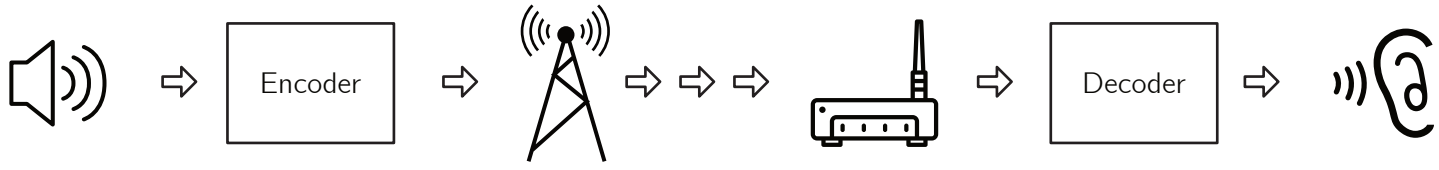
The Subtractive Color Model





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.



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

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

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

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

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: _____

_____

ELECTROMAGNETIC WAVE: _____

_____

AMPLITUDE: _____

_____

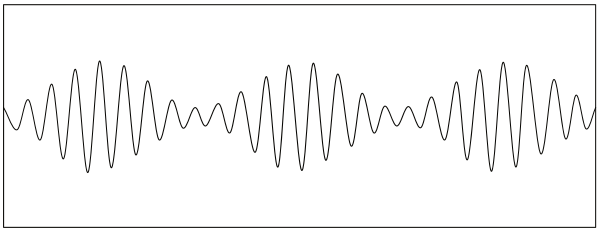
FREQUENCY: _____

_____

HERTZ: _____

_____

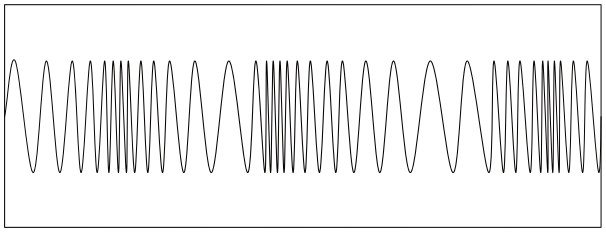
Below are two diagrams of radio wave signals. One of them is an FM signal (Frequency Modulated) and one of them is an AM (Amplitude Modulated) signal. Which is which and why?



SIGNAL TYPE: _____

_____

_____



SIGNAL TYPE: _____

_____

_____

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

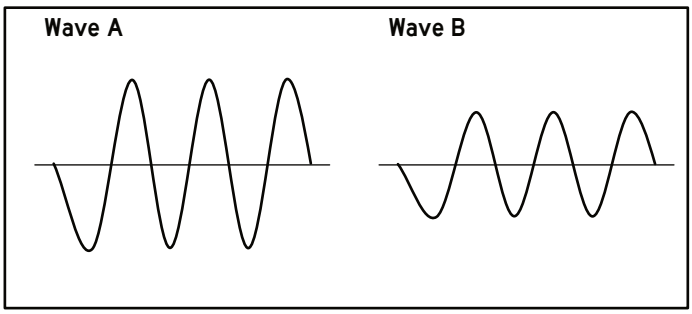
Waves Unit Assessment

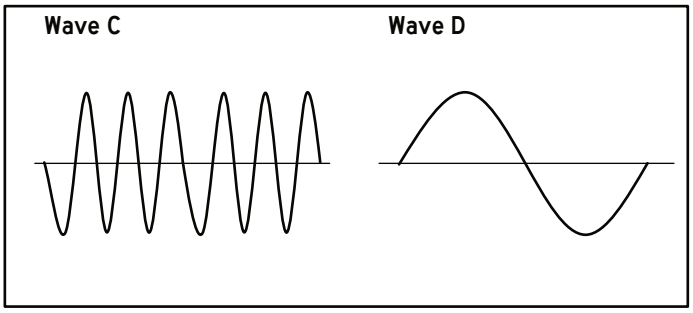
14 Of the colors listed below, which has the shortest wavelength?

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?

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