Norfolk Public Schools
Science Learning in Place Plan: Science 8 Lessons

Week 10: May 18 – 22, 2020 (Characteristics of Waves and Sounds Waves)

Monday	Tuesday	Wednesday	Thursday	Friday
Reading & Text Annotation: • Read **"An Introduction to Waves"** • Use *Critical Reading Strategies* to make note of the key points in the passage.	Concept Analysis: • Reread **"An Introduction to Waves"** • Answer the questions on the handout **"An Introduction to Waves Concept Analysis Questions"**	Reading & Text Annotation: • Read **"Characteristics of Sound Waves"** • Use *Critical Reading Strategies* to make note of the key points in the passage.	Concept Analysis: • Reread **"Characteristics of Sound Waves"** • Answer the questions on the handout **"Characteristics of Sound Waves Concept Analysis Questions"**	Reading & Concept Analysis: • Read **"The Doppler Effect Explained"** • Answer the questions on the handout **"The Doppler Effect Explained Quiz"**

Week 11: May 25 – 29, 2020 (Light Waves)

Monday	Tuesday	Wednesday	Thursday	Friday
Reading & Concept Analysis: • Read **"Light"** • Answer the Concept Analysis questions that follow the passage.	Reading & Concept Analysis: • Read **"Light: Reflection & Refraction"** • Answer the Concept Analysis questions that follow the passage.	Reading & Concept Analysis: • Read **"Light: How Refraction Works"** • Answer the Concept Analysis questions that follow the passage.	Reading & Concept Analysis: • Read **"Light: Diffraction"** • Answer the Concept Analysis questions that follow the passage.	Reading & Concept Analysis: • Read **"What is the Visible Light Spectrum?"** • Answer the questions on the handout **"What is the Visible Light Spectrum? Quiz"**

Week 9: May 11 – 15, 2020 (Electromagnetic Spectrum & Applications of Light)

Monday	Tuesday	Wednesday	Thursday	Friday
Reading & Text Annotation: • Read **"An Introduction to the Electromagnetic Spectrum"** • Use *Critical Reading Strategies* to make note of the key points in the passage.	Concept Analysis: • Reread **"An Introduction to the Electromagnetic Spectrum"** • Use the passage to complete the Electromagnetic Spectrum graphic organizer.	Reading & Text Annotation: • Read **"What is Cancer Radiotherapy and Why do we Need Proton Beam Therapy"** • Use *Critical Reading Strategies* to make note of the key points in the passage.	Concept Analysis: • Reread **"What is Cancer Radiotherapy and Why do we Need Proton Beam Therapy"** • Answer the questions on the handout **"What is Cancer Radiotherapy and Why do we Need Proton Beam Therapy Quiz"**	Concept Analysis: • Review the passages from this week. • Analyze the image entitled, **"Wave Town"** and identify all of the applications of the electromagnetic spectrum.

CRITICAL READING *strategies*

Marking the Text

- # → Number the paragraphs
- → Circle key terms
- → Underline essential info
  (...based on the reading purpose)
- → Box new vocab words
  (...and define them in the margins)

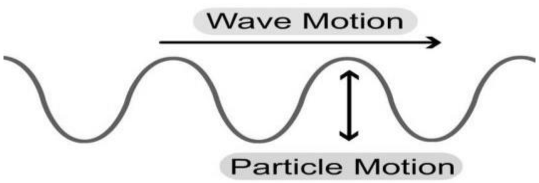
Additional Ways to Mark the Text

- → [Bracket] information
  (when underlining has been used for another purpose)
- → Write labels in the margins
  (double underline labels to stand out from other marks)

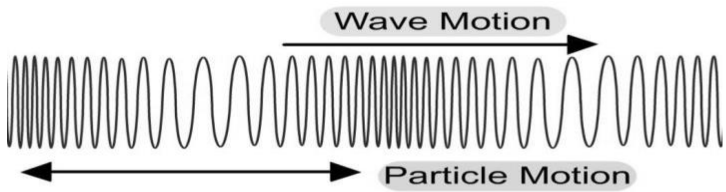
An Introduction to Waves

A wave is a transfer of energy through a medium from one point to another. Some examples of waves include water waves, sound waves, and radio waves. Waves come in two different forms; a **Transverse** Wave which moves the medium *perpendicular* to the wave motion, and a **Longitudinal** Wave, which moves the medium *parallel* to the wave motion.

Transverse Wave



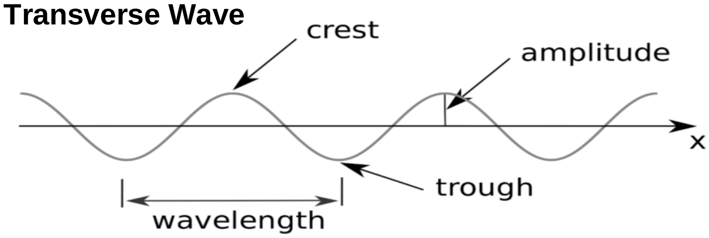
Longitudinal Wave



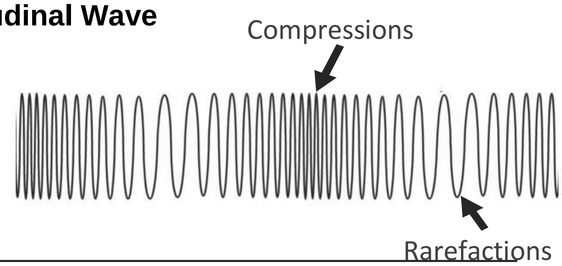
Examples of Transverse waves would be a vibrating guitar string or electromagnetic waves, while an example of a Longitudinal wave would be a "Slinky" wave that you push and pull.

Waves have several properties which are represented in the diagrams below. In a Transverse wave the **Crest** and Troughs are the locations of maximum displacement up or down. The **Amplitude** is the measurement of maximum displacement. The **Wavelength** is the distance of one complete wave cycle. For example, the distance from crest to crest or trough to trough would be 1 wavelength. In a Longitudinal wave, areas of maximum displacement are known as **Compressions** and **Rarefactions**. The stronger the wave, the more compressed and spread out the wave medium becomes.

Transverse Wave

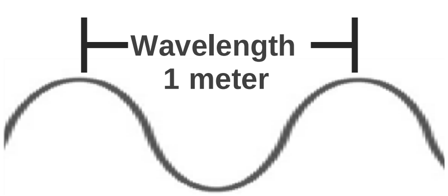


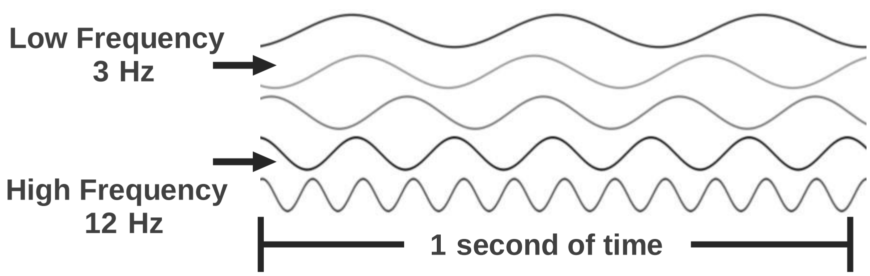
Longitudinal Wave



Waves: Velocity and Frequency

The velocity of a wave can be calculated if you have enough information. First you need to know the *Wavelength*, or the length of one complete wave cycle. This could be measured Crest to Crest, Trough to Trough, or any other complete cycle of a wave. The second aspect you need is the wave *Frequency*, or the number of waves or vibrations produced per second. The frequency is measured in Hertz and the Wavelength is measured in meters.





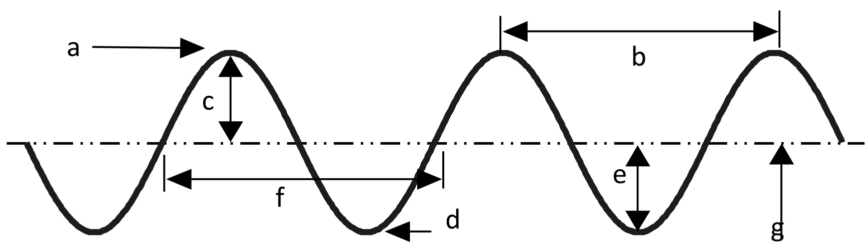
An Introduction to Waves

Concept Analysis

Complete each statement below (questions 1-13) using a BOLD word from the passage above.

1. Wave motion that is Parallel to wave direction describes a __________________ wave.
2. A _________ is the maximum upwards displacement in a Transverse wave.
3. One complete wave cycle is referred to as a ___________________.
4. Wave motion that is Perpendicular to wave direction describes a __________________ wave.
5. A ______________ or _______________ is the maximum displacement in a Longitudinal wave.
6. An Ocean wave would be an example of a ___________________ wave.
7. The distance from one trough to another trough is called a ____________________.
8. The measurement of displacement is called a wave's ___________________
9. The illustration below shows a series of transverse waves. Label each part in the space provided.

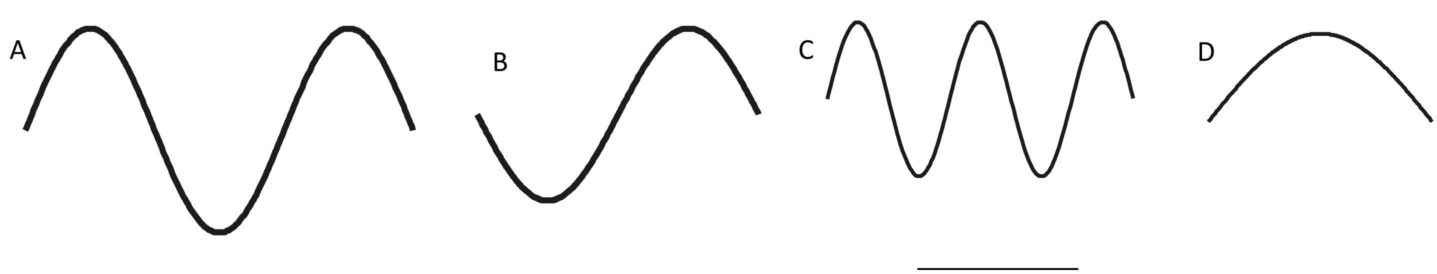
a. _______________
b. _______________
c. _______________
d. _______________
e. _______________
f. _______________
g. _______________



10. Waves carry _ from one place to another.
11. The highest point on a transverse wave is the _____ while the lowest part is the _.
12. The __ is the height of the wave.
13. The distance from one crest to the next is the _____.

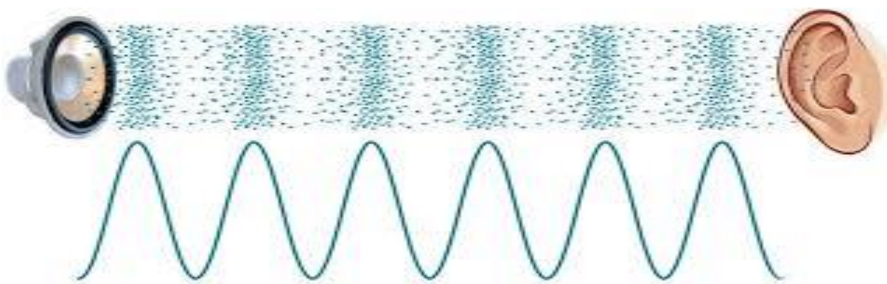
Use the following images to respond to questions 14-16.

Below are a number of series of waves. Underneath each diagram write the numbers of waves in the series.



14. Which of the above has the biggest amplitude? _____
15. Which of the above has the shortest wavelength? _____
16. Which of the above has the longest wavelength? _____

Characteristics of Sound Waves



Mechanical waves (also called **compression** or **longitudinal waves**) are caused by vibrations carried through a substance, sometimes referred to as a **medium** (solid, liquid. or gas). When energy is being transferred through a medium by a longitudinal wave, the particles of the medium **vibrate** back and forth along the same path that the wave travels (e.g., vocal chords of a person, the vibrating string and sound board of a guitar or violin, the vibrating prongs of a tuning fork, or the vibrating diaphragm of a radio speaker).

The speed of a longitudinal wave depends on several factors, including the medium through which it travels. For example, the speed of sound is slowest in a gas, faster in liquids, and fastest in solids. Sound does not go through **empty space (a vacuum)**. Temperature also affects the speed of a longitudinal wave. For example, the warmer the medium, the faster sound travels .

Sound, a form of **mechanical energy**, is propagated through **longitudinal waves** and needs a medium through which it is transmitted.

Sound is caused when something vibrates, making particles vibrate back and forth in the direction of the wave. **Loudness** (of sounds) is related to the **amplitude** of the mechanical wave. Greater amplitudes equate with louder sounds. **Pitch** (of sounds) is related to the **frequency** of the mechanical wave. Higher frequencies equate with higher pitches .

Interference is the addition of two or more waves, resulting in a new wave pattern. Interference can be c**onstructive** or **destructive.** Waves of the same type that encounter each other pass through each other and exhibit interference .

Resonance is the tendency of a system to vibrate at maximum amplitude at certain frequencies. For instance, when several musical instruments of the same kind play the same notes, the waves may combine to produce a louder sound .

Wave-based technology has many applications. Examples include (but are not limited to) sonar, ultrasonography, vehicle parking sensors, and wave power generator .

Characteristics of Sound Waves

Concept Analysis

Question	Concept	Drawing
1. What is sound?		
2. What are sound waves? Draw		
3. How does sound travel?		
4. How do a vacuum affect sound?		
5. Through which medium does sound travel the fastest? Explain Why?		
6. How do wavelengths affect frequency?		
7. What is the relationship between pitch and frequency?		
8. What's the difference between pitch and loudness?		
9. What is the relationship loudness and amplitude?		

newsela

The Doppler effect, explained

By The Conversation, adapted by Newsela staff on 10.08.19
Word Count **992**
Level **1050L**

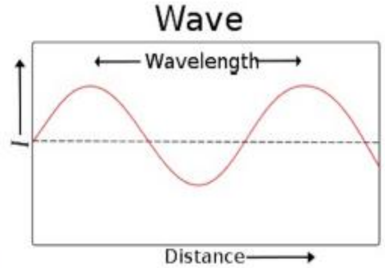
Image 1. Ripples in a pond help to illustrate wave motion and the Doppler effect. Image credit: Zen Rial/Getty Images

When an ambulance passes with its siren blaring, you hear the pitch of the siren change: As it approaches, the siren's pitch sounds higher than when it is moving away from you. This change is a common demonstration of the Doppler effect.

The Doppler effect describes the change in the observed frequency of a wave. The effect occurs when there is relative motion between the wave source and the observer. It was first proposed in 1842 by Austrian mathematician and physicist Christian Johann Doppler. While observing distant stars, Doppler described how the color of starlight changed with the movement of the star.

To explain why the Doppler effect occurs, we need to start with a few basic features of wave motion. Waves come in a variety of forms: ripples on the surface of a pond, sounds (as with the siren above), light, and earthquake tremors all exhibit periodic wave motion.

Two of the common characteristics used to describe all types of wave motion are wavelength and frequency. Waves have peaks and troughs, and the wavelength is the distance between peaks. The frequency is the number of peaks that pass a reference point in a given time period.



When we think about how waves travel in two- or three-dimensional space, we use the term wavefront. Imagine a pebble dropped in a calm pond. The linking of all of the wave peaks that come from where the pebble hit the water creates a series of circular wavefronts when viewed from above.

Concentric "Shells"

Consider a stationary source that's sending out waves in all directions with a constant frequency. The shape of the wavefronts coming from the source appears as a series of concentric, evenly-spaced "shells." Any person standing near the source will encounter each wavefront with the same frequency that it was emitted.

However, if the wave source moves, the pattern of wavefronts will look different. In the time between one wave peak and the next, the source will have moved so that the shells will no longer be concentric. The wavefronts will bunch up (get closer together) in front of the source as it moves and will be spaced out (farther apart) behind it.

Now imagine an observer standing still in front of the moving source. The observer will experience a higher frequency than before as the source travels toward him or her. In contrast, someone behind the source will experience a lower frequency of wave peaks as the source moves away.

A similar change in observed frequency occurs if the source is still and the observer is moving towards or away from it. Any relative motion between the two will cause a Doppler shift. In other words, movement by the source or observer will affect the frequency observed.

So why do we hear a change in pitch when a siren passes us? The pitch we hear depends on the frequency of the sound wave. A high frequency wave corresponds to a high pitch. So while the siren produces waves of constant frequency, as it approaches us the observed frequency increases, and our ear hears a higher pitch. After it has passed us and is moving away, the observed frequency and pitch drop.

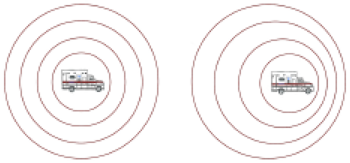
Higher Light Frequencies Run Blue

For light waves, the wave frequency determines the color we see. The highest frequencies of light are at the blue end of the visible spectrum, and the lowest frequencies appear at the red end of this spectrum.

If stars and galaxies are traveling away from us, the apparent frequency of the light they emit decreases and their color will move toward the red end of the spectrum. This phenomenon is known as red-shifting.

Stars moving toward us will appear blue-shifted because of the higher frequency. This observation was what first led Christian Doppler to document the effect named for him. It later allowed Edwin Hubble in 1929 to propose that the universe was expanding. He observed that all galaxies appeared to be red-shifted, in other words they are moving away from us and each other.

The Doppler effect has many other interesting applications beyond sound effects and astronomy. A Doppler radar uses reflected microwaves to determine the speed of distant moving objects. It does this by sending out waves with a particular frequency, then analyzes the reflected wave for frequency changes.



Police Speed Detectors Based On Doppler Effect

In weather observation, the Doppler effect is used to characterize cloud movement and weather patterns. It has other applications in aviation and radiology. It's even used in police speed detectors, which are essentially small Doppler radar units.

Medical imaging also relies on the Doppler effect. The effect makes it possible to monitor blood flow in the body. Doppler ultrasound technology uses high frequency sound waves. They let medical professionals measure the speed and direction of blood flow to provide information on blood clots, blocked arteries, and cardiac function.

Our understanding of the Doppler effect has allowed us to learn more about the universe we are part of. It is a tool for measuring the world around us and even looking inside our own bodies. Future development of this knowledge – including how to reverse the Doppler effect – could lead to technology once only read about in science-fiction, such as invisibility cloaks.

Quiz

1 The sound that a siren produces creates a frequency of around 2000 peaks per second.

How many peaks would pass a point in a 5 second period?

(A) 400 peaks

(B) 2,000 peaks

(C) 10,000 peaks

(D) 50,000 peaks

2 Read the selection from the introduction [paragraphs 1-5].

> *Waves have peaks and troughs, and the wavelength is the distance between peaks. The frequency is the number of peaks that pass a reference point in a given time period.*

Which two words would BEST replace "peaks" and "troughs" in the selection above?

(A) crests; dips

(B) centers; borders

(C) movements; breaks

(D) spikes; cribs

3 The Doppler effect has many applications and is used in many fields of science.

Which of the following situations would be likely to use the Doppler effect in its research?

1. *research involving the movement of tsunamis*
2. *research involving the prediction of forest fires*
3. *technology that locates the source of earthquakes*
4. *technology that measures the speed of incoming storms*

(A) 1, 2 and 3

(B) 1, 2 and 4

(C) 1, 3 and 4

(D) 2, 3 and 4

4 Read the paragraph from the section "Concentric "Shells."

> *Consider a stationary source that's sending out waves in all directions with a constant frequency. The shape of the wavefronts coming from the source appears as a series of concentric, evenly-spaced "shells." Any person standing near the source will encounter each wavefront with the same frequency that it was emitted.*

Which option is the BEST definition of the word "emitted" as used in the paragraph?

(A) take in

(B) give off

(C) pick up

(D) move away

5 Which of these scenarios would produce the same Doppler shift?

1. *The observer moves toward the source of the waves.*
2. *The observer moves away from the source of the waves.*
3. *The source of the waves moves toward the observer.*
4. *The source of the waves moves away from the observer.*

(A) 1 and 2

(B) 1 and 4

(C) 2 and 3

(D) 2 and 4

6 Which section from the article BEST explains how the Doppler effect is used in the healthcare field?

(A) Introduction [paragraphs 1-5]

(B) "Concentric Shells"

(C) "Higher Light Frequencies Run Blue"

(D) "Police Speed Detectors Based On Doppler Effect"

7 What do the many applications that use the Doppler effect have in common with each other?

(A) They use light in some way.

(B) They use sound in some way.

(C) They involve the visible spectrum.

(D) They involve movement of some kind.

8 Which piece of evidence explains the cause of different colored stars?

(A) The highest frequencies of light are at the blue end of the visible spectrum, and the lowest frequencies appear at the red end of this spectrum.

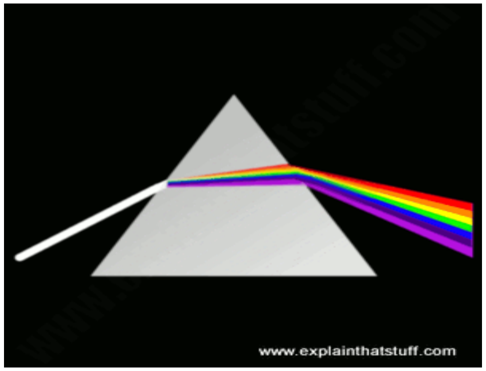
(B) If stars and galaxies are traveling away from us, the apparent frequency of the light they emit decreases and their color will move toward the red end of the spectrum.

(C) This observation was what first led Christian Doppler to document the effect named for him. It later allowed Edwin Hubble in 1929 to propose that the universe was expanding.

(D) He observed that all galaxies appeared to be red-shifted, in other words they are moving away from us and each other.

Light

by Chris Woodford. *Last updated: July 13, 2019.*



Were you ever scared of the dark? It's not surprising if you were, or if you still are today, because humans are creatures of the **light**, deeply programmed through millions of years of history to avoid the dark dangers of the night. Light is vitally important to us, but we don't always take the trouble to understand it. Why does it make some things appear to be different colors from others? Does it travel as particles or as waves? Why does it move so quickly? Let's take a closer look at some of these questions—let's shed some light on light!

What is light?

When we're very young, we have a very simple idea about light: the world is either light or dark and we can change from one to the other just by flicking a switch on the wall. But we soon learn that light is more complex than this.

Light arrives on our planet after a speedy trip from the Sun, 149 million km (93 million miles away). Light travels at 186,000 miles (300,000 km) per second, so the light you're seeing now was still tucked away in the Sun about eight minutes ago. Put it another way, light takes roughly twice as long to get from the Sun to Earth as it does to make a cup of coffee!

Light is a kind of energy

But why does light make this journey at all? As you probably know, the Sun is a nuclear fireball spewing energy in all directions. The light that we see it simply the one part of the energy that the Sun makes that our eyes can detect. When light travels between two places (from the Sun to the Earth or from a flashlight to the sidewalk in front of you on a dark night), energy makes a journey between those two points. The energy travels in the form of waves (similar to the waves on the sea but about 100 million times smaller)—a vibrating pattern of electricity and magnetism that we call **electromagnetic energy**. If our eyes could see electricity and magnetism, we might see each ray of light as a wave of electricity vibrating in one direction and a wave of magnetism vibrating at right angles to it. These two waves would travel in step and at the speed of light.

How light behaves

Light waves (let's assume they are indeed waves for now) behave in four particularly interesting and useful ways that we describe as reflection, refraction, diffraction, and interference.

Light Analysis Questions

1. How long does it take for light to reach the Earth?
2. What is light?
3. Does how light travels.

Light: Reflection & Refraction

by Chris Woodford. *Last updated: July 13, 2019.*

Photo: Now that's what I call a mirror! A solar mirror used to gather and focus energy from the Sun. Picture by courtesy of NASA Glenn Research Center (NASA-GRC).

Reflection

The most obvious thing about light is that it will reflect off things. The only reason we can see the things around us is that light, either from the Sun or from something like an electric lamp here on Earth, reflects off them into our eyes. Cut off the source of the light or stop it from reaching your eyes and those objects disappear. They don't cease to exist, but you can no longer see them.

Reflection can happen in two quite different ways. If you have a smooth, highly polished surface and you shine a narrow beam of light at it, you get a narrow beam of light reflected back off it. This is called **specular reflection** and it's what happens if you shine a flashlight or laser into a mirror: you get a well-defined beam of light bouncing back towards you. Most objects aren't smooth and highly polished: they're quite rough. So, when you shine light onto them, it's scattered all over the place. This is called **diffuse reflection** and it's how we see most objects around us as they scatter the light falling on them.

If you can see your face in something, it's specular reflection; if you can't see your face, it's diffuse reflection. Polish up a teaspoon and you can see your face quite clearly. But if the spoon is dirty, all the bits of dirt and dust are scattering light in all directions and your face disappears..

Refraction

Light waves travel in straight lines through empty space (a vacuum), but more interesting things happen to them when they travel through other materials—especially when they move from one material to another. That's not unusual: we do the same thing ourselves.

Have you noticed how your body slows down when you try to walk through water? You go racing down the beach at top speed but, as soon as you hit the sea, you slow right down. No matter how hard you try, you cannot run as quickly through water as through air. The dense liquid is harder to push out of the way, so it slows you down. Exactly the same thing happens to light if you shine it into water, glass, plastic or another more dense material: it slows down quite dramatically. This tends to make light waves bend—something we usually call **refraction**.

Light: Reflection & Refraction Analysis Questions

1. Describe reflection.
2. What are the two types of reflection?
3. What is refraction?

Light: How Refraction Works

by Chris Woodford. *Last updated: July 13, 2019.*

How refraction works

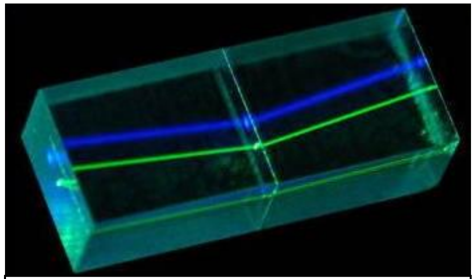
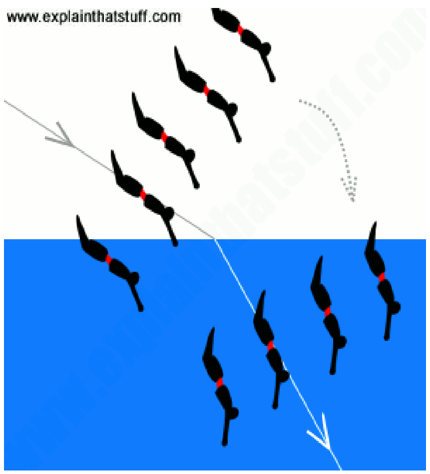


Photo: Laser beams bending (refracting) through a crystal. Photo by Warren Gretz courtesy of US Department of Energy/National Renewable Energy Laboratory (DOE/NREL)

You've probably noticed that water can bend light. You can see this for yourself by putting a straw in a glass of water. Notice how the straw appears to kink at the point where the water meets the air above it. The bending happens not in the water itself but at the junction of the air and the water. You can see the same thing happening in this photo of laser light beams shining between two crystals. As the beams cross the junction, they bend quite noticeably.

Why does this happen? You may have learned that the speed of light is always the same, but that's only true when light travels in a vacuum. In fact, light travels more slowly in some materials than others. It goes more slowly in water than in air. Or, to put it another way, light slows down when it moves from air to water and it speeds up when it moves from water to air. This is what causes the straw to look bent. Let's look into this a bit more closely.



Imagine a light ray zooming along through the air at an angle to some water. Now imagine that the light ray is actually a line of people swimming along in formation, side-by-side, through the air. The swimmers on one side are going to enter the water more quickly than the swimmers on the other side and, as they do so, they are going to slow down—because people move more slowly in water than in air. That means the whole line is going to start slowing down, beginning with the swimmers at one side and ending with the swimmers on the other side some time later. That's going to cause the entire line to bend at an angle. This is exactly how light behaves when it enters water—and why water makes a straw look bent.

Refraction is amazingly useful. If you wear eyeglasses, you probably know that the lenses they contain are curved-shape pieces of glass or plastic that bend (refract) the light from the things you're looking at. Bending the light makes it seem to come from nearer or further away (depending on the type of lenses you have), which corrects the problem with your sight. To put it another way, your eyeglasses fix your vision by slowing down incoming light so it shifts direction slightly. Binoculars, telescopes, cameras, camcorders, night vision goggles, and many other things with lenses work in exactly the same way (collectively we call these things **optical equipment**).

Although light normally travels in straight lines, you can make it bend around corners by shooting it down thin glass or plastic pipes called fiber-optic cables. Reflection and refraction are at work inside these "light pipes" to make rays of light follow an unusual path they wouldn't normally take.

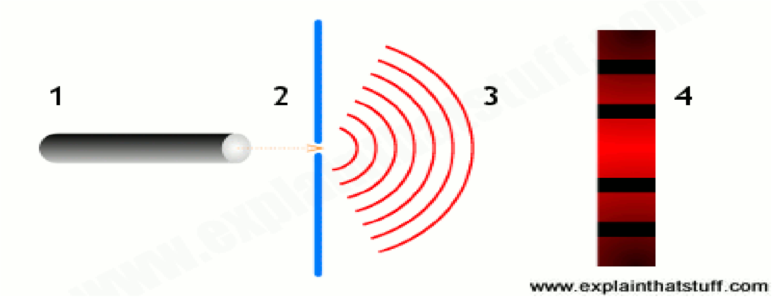
Light: How Refraction Works Analysis Questions

1. Why does water bend light?
2. How do eyeglasses “fix” sight?
3. How can light be made to bend around corners?

Light: Diffraction

by Chris Woodford. *Last updated: July 13, 2019.*

Diffraction



Artwork: When light from a laser (1) passes through a narrow slit (2), the waves spread out (3) and form a diffraction pattern of light and dark bands (4). Different numbers, shapes, and sizes of slits produce more complex diffraction patterns.

We can hear sounds bending around doorways, but we can't see around corners—why is that? Like light, sound travels in the form of waves (they're very different kinds of waves, but the idea of energy traveling in a wave pattern is broadly the same). Sound waves tend to range in size from a few centimeters to a few meters, and they will spread out when they come to an opening that is roughly the same size as they are—something like a doorway, for example. If sound is rushing down a corridor in your general direction and there's a doorway opening onto the room where you're sitting, the sound waves will spread in through the doorway and travel to your ears. The same thing does not happen with light. But light will spread out in an identical way if you shine it on a tiny opening that's of roughly similar size to its wavelength. You may have noticed this effect, which is called **diffraction**, if you screw your eyes up and look at a streetlight in the dark. As your eyes close, the light seems to spread out in strange stripes as it squeezes through the narrow gaps between your eyelids and eyelashes. The tighter you close your eyes, the more the light spreads (until it disappears when you close your eyes completely).

Interference

If you stand above a calm pond (or a bath full of water) and dip your finger in (or allow a single drop to drip down to the water surface from a height), you'll see ripples of energy spreading outwards from the point of the impact. If you do this in two different places, the two sets of ripples will move toward one another, crash together, and form a new pattern of ripples called an **interference** pattern. Light behaves in exactly the same way. If two light sources produce waves of light that travel together and meet up, the waves will interfere with one another where they cross. In some places the crests of waves will reinforce and get bigger, but in other places the crest of one wave will meet the trough of another wave and the two will cancel out.

Photo: Thin-film interference makes the colors you see swirling around on the surface of soap bubbles.

Interference causes effects like the swirling, colored spectrum patterns on the surface of soap bubbles and the similar rainbow effect you can see if you hold a compact disc up to the light. What happens is that two reflected light waves interfere. One light wave reflects from the outer layer of the soap film that wraps around the air bubble, while a second light wave carries on through the soap, only to reflect off its inner layer. The two light waves travel slightly different distances so they get out of step. When they meet up again on the way back out of the bubble, they interfere. This makes the color of the light change in a way that depends on the thickness of the soap bubble. As the soap gradually thins out, the amount of interference changes and the color of the reflected light changes too. Read more about this in our article on thin-film interference.

Interference is very colorful, but it has practical uses too. A technique called interferometry can use interfering laser beams to measure incredibly small distances.

Light: Diffraction Analysis Questions

1. Describe diffraction.
2. What is interference?
3. What is interferometry?

What is the visible light spectrum?

By NASA, adapted by Newsela staff on 02.13.20
Word Count **500**
Level **980L**

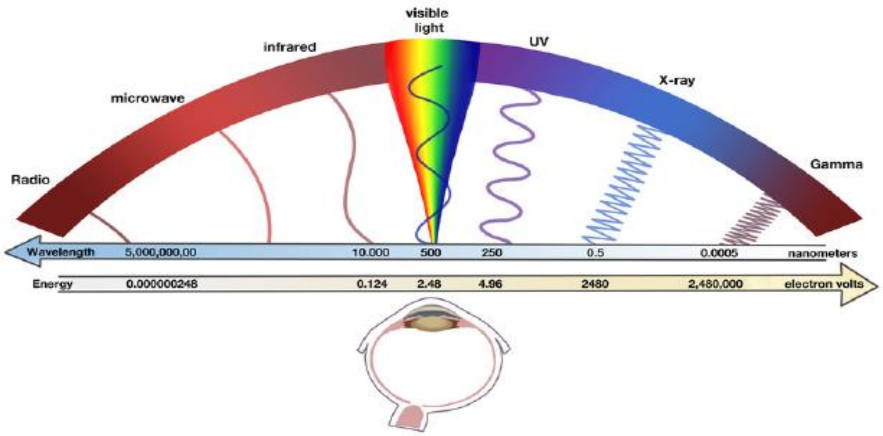


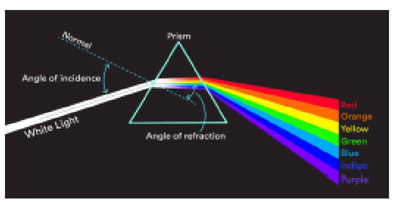
Image 1. Isaac Newton's experiment in 1665 showed that a prism bends visible light and that each color refracts at a slightly different angle depending on the wavelength of the color. Graphic: Spencer Sutton/Science Source

Electromagnetic radiation is the form of energy that makes up light. It moves as a wave through space. We show light as a spectrum organized by how long or short the waves are. This is called wavelength, and it tells us how much energy a specific type of light has. The light we can see is somewhere in the middle of the spectrum, ranging from 380 nanometers to 700 nanometers.

Visible Light Has Different Colors

Visible light is the part of the electromagnetic spectrum that you're most familiar with. It's what we see from the sun and from light made by electricity. We see this light because of cone-shaped cells in our eyes that pick up the wavelengths of visible light. The wavelengths in other parts of the spectrum are too large or too small for our eyes to detect.

Within visible light, there are different colors that we can see. In 1665, the scientist Isaac Newton showed that a prism refracts visible light into a spectrum. A prism is a piece of clear glass that looks like a triangle or a pyramid. The smooth sides and sharp angles affect how light passes through it.



When white light travels through a prism, the light that comes out is a range of colors that looks like a rainbow. The prism bends the light slightly, which causes the colors to separate from each other. This happens because each color has a different wavelength that causes it to bend differently from other colors. Violet is at one end of the rainbow because it has the shortest wavelength. Red is at the other end because it has the longest wavelength.

Some Flames Are Hotter Than Others

Sometimes, color gives us information about temperature. As things grow hotter and release more energy, the wavelengths that are released get smaller. The flames from a fire are a good example of how color reflects temperature.

Flames from a fire can be red, yellow or blue. The flames that look red have the longest wavelength, which means they have the least energy. While all fire is hot, red flames have cooler temperatures. Blue is closer to violet in the rainbow and has shorter waves than red light. This also means that blue light has more energy than red light, and blue flames have the hottest temperature in a fire.

Knowing how color and temperature are related helps scientists study the stars. Our sun produces more yellow light than any other color because its surface temperature is 5,500 degrees Celsius (9,932 degrees Fahrenheit). If the sun's surface were a cooler 3,000 degrees Celsius (5,432 degrees Fahrenheit), it would look reddish like the star Betelgeuse. If the sun were a hotter 12,000 degrees Celsius (21,632 degrees Fahrenheit), it would look blue like the star Rigel.

Quiz

1 Which statement BEST describes the difference between gamma rays and visible light?

(A) Gamma rays have shorter wavelengths and greater energy than visible light waves.

(B) Gamma rays have longer wavelengths and greater energy than visible light.

(C) Gamma rays have shorter wavelengths and less energy than visible light waves.

(D) Gamma rays have longer wavelengths and less energy than visible light waves.

2 Read the section "Some Flames Are Hotter Than Others."

Select the sentence from the section that suggests that yellow light has more energy than red light.

(A) As things grow hotter and release more energy, the wavelengths that are released get smaller.

(B) This also means that blue light has more energy than red light, and blue flames have the hottest temperature in a fire.

(C) The sun shines yellow light and has a surface temperature of 5,500 degrees Celsius (9,932 degrees Fahrenheit).

(D) If the sun's surface were a cooler 3,000 degrees Celsius (5,432 degrees Fahrenheit), it would look reddish like the star Betelgeuse.

3 How do our eyes detect the colors in visible light?

(A) Our eyes have tiny prisms inside.

(B) It is our brain that detects the colors.

(C) Our eyes filter out the other parts of the spectrum.

(D) Special cells in our eyes detect the different wavelengths.

4 One conclusion a reader could make after reading the article is that visible light has medium-length waves.

Which of the following statements accurately paraphrases evidence from the article to support the conclusion?

(A) The electromagnetic spectrum presents the length of waves from shortest to longest, and visible light is in the middle of the electromagnetic spectrum.

(B) We can see light from the sun and electricity because cone-shaped cells in our eyes pick up the wavelengths of visible light.

(C) We sort the different types of light based on how long or short the waves are, which tells us how much energy a specific type of light has.

(D) Radio waves have long waves, gamma rays have shorter waves and each color of light has a different wavelength.

5 Which color of visible light has the least amount of energy and the longest wavelengths?

(A) blue

(B) green

(C) red

(D) violet

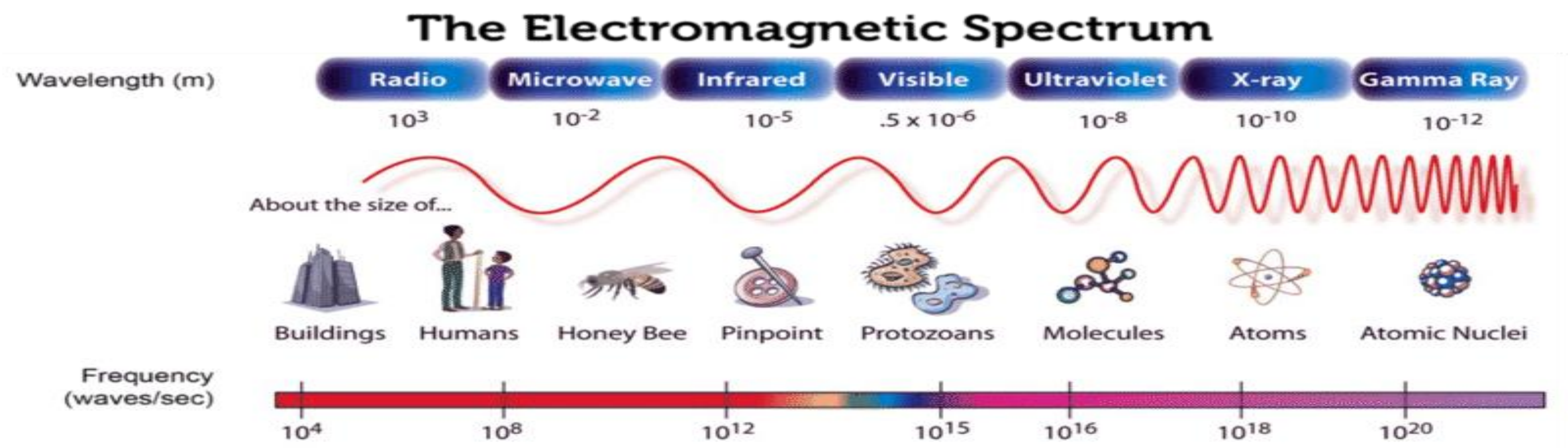
An Introduction to the Electromagnetic Spectrum

Imagine playing beach volleyball. They may not realize it, but they are being bombarded by electromagnetic radiation as play in the sunlight. The only kinds of radiation they can detect are visible light, which allows them to see, and infrared light, which they feel as warmth on their skin. What other kinds of electromagnetic radiation are they being exposed to in sunlight? In this lesson, you'll find out.

What Is the Electromagnetic Spectrum?

Electromagnetic radiation occurs in waves of different wavelengths and frequencies. Infrared light and visible light make up just a small part of the full range of electromagnetic radiation, which is called the **electromagnetic spectrum**. The electromagnetic spectrum is summarized in the diagram below:

- On the far left of the diagram are radio waves, which include microwaves. They have the longest wavelengths and lowest frequencies of all electromagnetic waves. They also have the least amount of energy.
- On the far right are X rays and gamma rays. The have the shortest wavelengths and highest frequencies of all electromagnetic waves. They also have the greatest amount of energy.
- Between these two extremes, wavelength, frequency, and energy change continuously from one side of the spectrum to the other. Waves in this middle section of the electromagnetic spectrum are commonly called light.



Radio Waves

Radio waves are the broad range of electromagnetic waves with the longest wavelengths and lowest frequencies. The wavelength of radio waves may be longer than a soccer field. With their low frequencies, radio waves have the least energy of electromagnetic waves, but they still are extremely useful. They are used for radio and television broadcasts, microwave ovens, cell phone transmissions, and radar.

In radio broadcasts, sounds are encoded in radio waves that are sent out through the atmosphere from a radio tower. A receiver detects the radio waves and changes them back to sounds. You've probably listened to both AM and FM radio stations. How sounds are encoded in radio waves differs between AM and FM broadcasts.

- AM stands for amplitude modulation. In AM broadcasts, sound signals are encoded by changing the amplitude of radio waves. AM broadcasts use longer–wavelength radio waves than FM broadcasts. Because of their longer wavelengths, AM radio waves reflect off a layer of the upper atmosphere called the ionosphere. This allows AM radio waves to reach radio receivers that are very far away from the radio tower.
- FM stands for frequency modulation. In FM broadcasts, sound signals are encoded by changing the frequency of radio waves. Frequency modulation allows FM waves to encode more information than does amplitude modulation, so FM broadcasts usually sound clearer than AM broadcasts. However, because of their shorter wavelength, FM waves do not reflect off the ionosphere. Instead, they pass right through it and out into space. As a result, FM waves cannot reach very distant receivers.

Television

Television broadcasts also use radio waves. Sounds are encoded with frequency modulation, and pictures are encoded with amplitude modulation. The encoded radio waves are broadcast from a TV tower. When the waves are received by television sets, they are decoded and changed back to sounds and pictures.

Microwaves

The shortest wavelength, highest frequency radio waves are called **microwaves.** Microwaves have more energy than other radio waves. That's why they are useful for heating food in microwave ovens. Microwaves have other important uses as well, including cell phone transmissions and **radar**, which is a device for determining the presence and location of an object by measuring the time for the echo of a radio wave to return from it and the direction from which it returns. Microwaves are used for cell phones and radar.

Light

Mid-wavelength electromagnetic waves are commonly called light. This range of electromagnetic waves has shorter wavelengths and higher frequencies than radio waves, but not as short and high as X rays and gamma rays. Light includes visible light, infrared light, and ultraviolet light.

Visible Light

The only light that people can see is called **visible light**. It refers to a very narrow range of wavelengths in the electromagnetic spectrum that falls between infrared light and ultraviolet light. Within the visible range, we see light of different wavelengths as different colors of light, from red light, which has the longest wavelength, to violet light, which has the shortest wavelength. When all of the wavelengths are combined, as they are in sunlight, visible light appears white. You can learn more about visible light in the chapter "Visible Light" and at the URL below.

Infrared Light

Light with the longest wavelengths is called **infrared light**. The term *infrared* means "below red." Infrared light is the range of light waves that have longer wavelengths than red light in the visible spectrum. You can't see infrared light waves, but you can feel them as heat on your skin. The sun gives off infrared light as do fires and living things. The picture of a cat that opened this chapter was made with a camera that detects infrared light waves and changes their energy to colored light in the visible range. Night vision goggles, which are used by law enforcement and the military, also detect infrared light waves. The goggles convert the invisible waves to visible images.

Ultraviolet Light

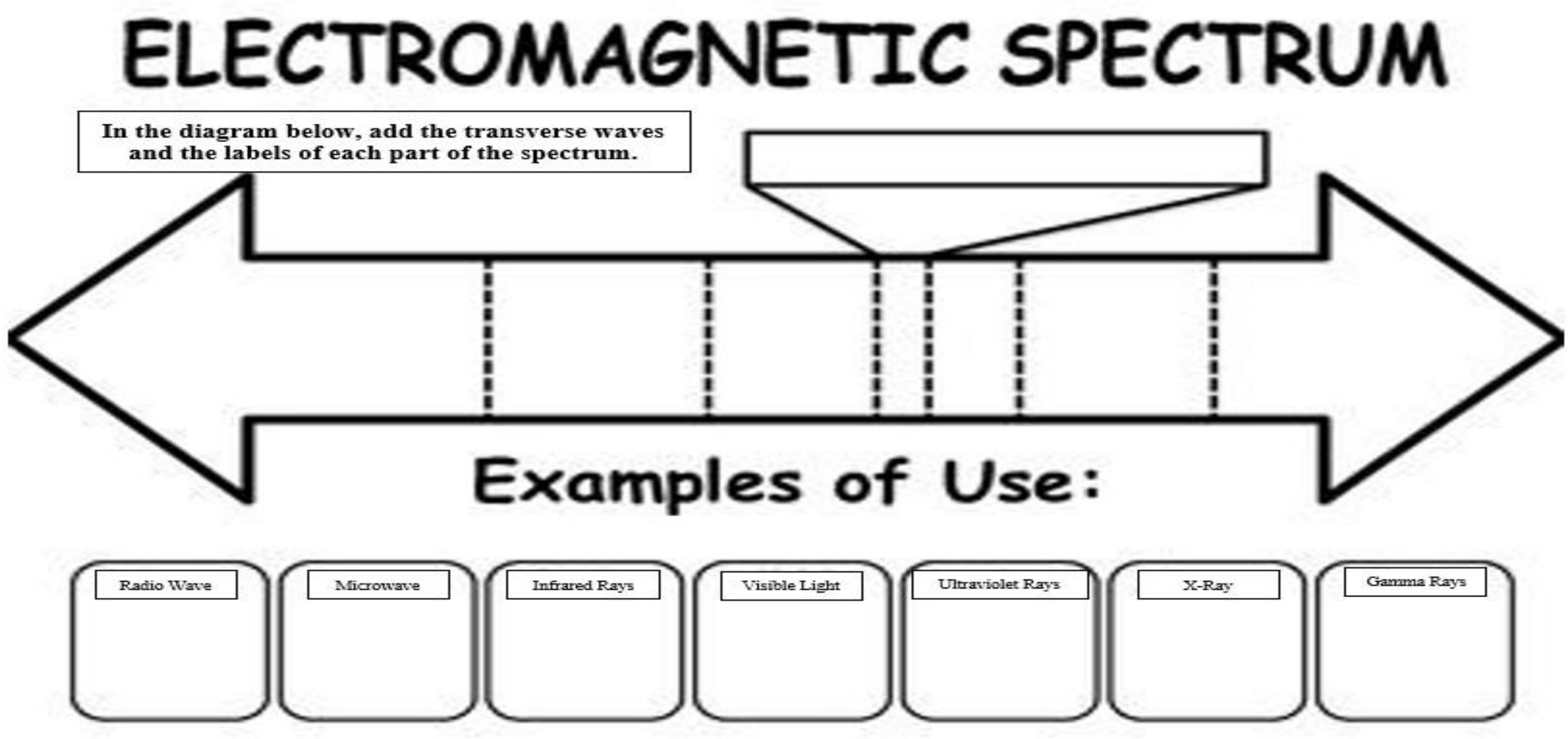
Light with wavelengths shorter than visible light is called **ultraviolet light**. The term *ultraviolet* means "above violet." Ultraviolet light is the range of light waves that have shorter wavelengths than violet light in the visible spectrum. Humans can't see ultraviolet light, but it is very useful nonetheless. It has higher-frequency waves than visible light, so it has more energy. The human skin also makes vitamin D when it is exposed to ultraviolet light. Vitamin D is needed for strong bones and teeth. It can be used to kill bacteria in food and to sterilize laboratory equipment. This sterilizer for laboratory equipment uses ultraviolet light to kill bacteria. Too much exposure to ultraviolet light can cause sunburn and skin cancer. You can protect your skin from ultraviolet light by wearing clothing that covers your skin and by applying sunscreen to any exposed areas. The SPF, or sun-protection factor, of sunscreen gives a rough idea of how long it protects the skin from sunburn. A sunscreen with a higher SPF protects the skin longer. You should use sunscreen with an SPF of at least 15 even on cloudy days, because ultraviolet light can travel through clouds. Sunscreen should be applied liberally and often.

X Rays and Gamma Rays

The shortest-wavelength, highest-frequency electromagnetic waves are X rays and gamma rays. These rays have so much energy that they can pass through many materials. This makes them potentially very harmful, but it also makes them useful for certain purposes.

X rays are high-energy electromagnetic waves. They have enough energy to pass through soft tissues such as skin but not enough to pass through bones and teeth, which are very dense. The bright areas on the X ray film in show where X rays were absorbed by the teeth. X rays are used not only for dental and medical purposes but also to screen luggage at airports. Too much X ray exposure may cause cancer. If you've had dental X rays, you may have noticed that a heavy apron was placed over your body to protect it from stray X rays. The apron is made of lead, which X rays cannot pass through.

Gamma rays are the most energetic of all electromagnetic waves. They can pass through most materials, including bones and teeth. Nonetheless, even these waves are useful. For example, they can be used to treat cancer. A medical device sends gamma rays the site of the cancer, and the rays destroy the cancerous cells.



newsela

What is cancer radiotherapy and why do we need proton beam therapy?

By The Conversation, adapted by Newsela staff on 08.28.19
Word Count **799**
Level **570L**

Image 1. A practitioner prepares his patient for a proton therapy treatment at the Proton Therapy Center in Munich, Germany. The center has the latest equipment for proton therapy treatment, which irradiates cancer cells by concentrating a proton beam on the heart of the tumor, while preserving the healthy surrounding tissue. Photo by: BSIP/UIG via Getty Images

A new kind of cancer treatment is now in use. It is called proton therapy. It is a type of radiotherapy. Radiotherapy shoots tiny, invisible particles at the cancer. It does this to stop the cancer from growing.

Radiotherapy is usually done with X-rays. Proton therapy is a little different. It shoots beams of tiny particles called protons.

Supporters of proton therapy say it is a better treatment than X-ray radiotherapy. They say it is safer and more accurate, too.

Cancer Treatment With X-Rays

In 1895, a scientist named Wilhelm Röntgen discovered X-rays. An X-ray is beam of energy. Doctors were excited about the discovery. They looked for ways to use it to treat patients. Soon, they started using X-ray radiotherapy to treat a terrible illness called cancer.

Our bodies are made up of cells. There are trillions of them inside us. They are very, very small. Cancer starts when some cells grow the wrong way. They become damaged, or broken. The broken cells grow out of control. They form lumps called tumors. Then they spread. If they keep spreading through the body, it can kill a person.

Radiotherapy is one way to treat cancer today. Surgery and chemotherapy are two others. In surgery, a tumor is removed from the body. In chemotherapy, the patient takes drugs to stop the cancer from growing. Doctors may use a combination of all of these treatments on one patient. About half of all cancer patients get radiotherapy, though.

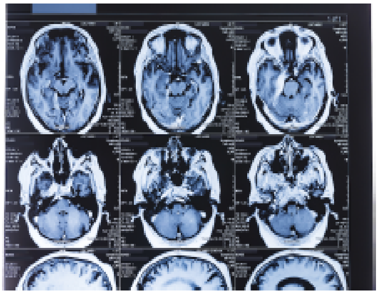
Aiming Beams At Tumors

Radiotherapy is mostly used when the cancer is in one spot. The beams are aimed at the tumor. They destroy cancer cells and keep them from spreading. There's a problem, though. X-ray beams cannot tell the difference between cancer cells and healthy cells. The treatment can harm healthy cells, too.

For this reason, using just the right amount of radiation is important. So is hitting just the right spot.

Radiotherapy's Three Steps

There are three main stages, or parts, of a radiotherapy treatment.



First, the patient's body is scanned. Doctors use high-tech machines to create an image. The image shows what is happening inside the patient's body. It helps doctors figure out how big the tumor is. It lets them pinpoint where it is, too.

Next, the doctors make a plan. They look over the scanned images. Then they map where they should aim the radiation.

The third and last stage is the treatment. During radiotherapy, the patient lies still. The radiation beam is aimed at the location of the tumor. The beam shoots radiation from several directions.

A treatment usually takes 15 to 30 minutes. The patient cannot feel the radiation beams. Some patients may need just one treatment. Others may have many more. It depends on the kind of cancer and how much it has already grown.

Beating Illness, But With Costs

Radiotherapy has helped many cancer patients beat their illness. Thanks to this treatment, many have lived longer lives. It is not perfect, though. Sometimes doctors do not agree on the location of a tumor. This makes it hard to aim the X-ray beam.

Even when the beam is aimed correctly, tiny movements can have an effect. The patient's heart keeps beating during radiotherapy. The patient breathes and swallows as usual. These tiny changes in their body can cause an X-ray beam to miss the tumor. Then the beam may hit healthy cells, instead.

Doctors also worry about long-term effects. For example, treating brain tumors with radiation can have long-lasting effects. It can change how the brain works later in life.

New Proton Therapy

Proton beam therapy is a new kind of radiotherapy. Many doctors are hopeful about it. They think it is more accurate than X-rays. This means it can more safely target tumors. It is less likely to harm healthy cells near the tumor.

A proton is a tiny particle. It is part of an atom. Atoms are the building blocks of all matter. Proton beam therapy uses a big machine called an accelerator. The accelerator speeds up the protons. This gives them energy. Then the proton beam is pointed at the patient. It is aimed at the location of the tumor.

Inside the patient, the protons slow down. They release their energy. Most of that energy release happens in the tumor. This means less damage to healthy cells around the cancer.

Proton therapy is not perfect, either. Still, doctors and other experts are hopeful. In April 2018, there were 27 proton therapy centers in the United States. Many more are being planned.

Quiz

1 Finish the sentence below.

One main idea of the article is that______.

(A) proton therapy might be safer than radiotherapy.

(B) proton therapy shoots tiny proton particles into patients.

(C) radiotherapy treatments are short and mostly effective.

(D) radiotherapy has been around since 1895.

2 Read the section "Aiming Beams At Tumors."

Which sentence from the section states the MAIN idea about why radiotherapy is a problem?

(A) The beams are aimed at the tumor.

(B) They destroy cancer cells and keep them from spreading.

(C) The treatment can harm healthy cells, too.

(D) For this reason, using just the right amount of radiation is important.

3 If readers are looking for information on how proton therapy works, which section should they read?

(A) "Cancer Treatment With X-Rays"

(B) "Radiotherapy's Three Steps"

(C) "Beating Illness, But With Costs"

(D) "New Proton Therapy"

4 What can a reader learn by looking at the article's section titles?

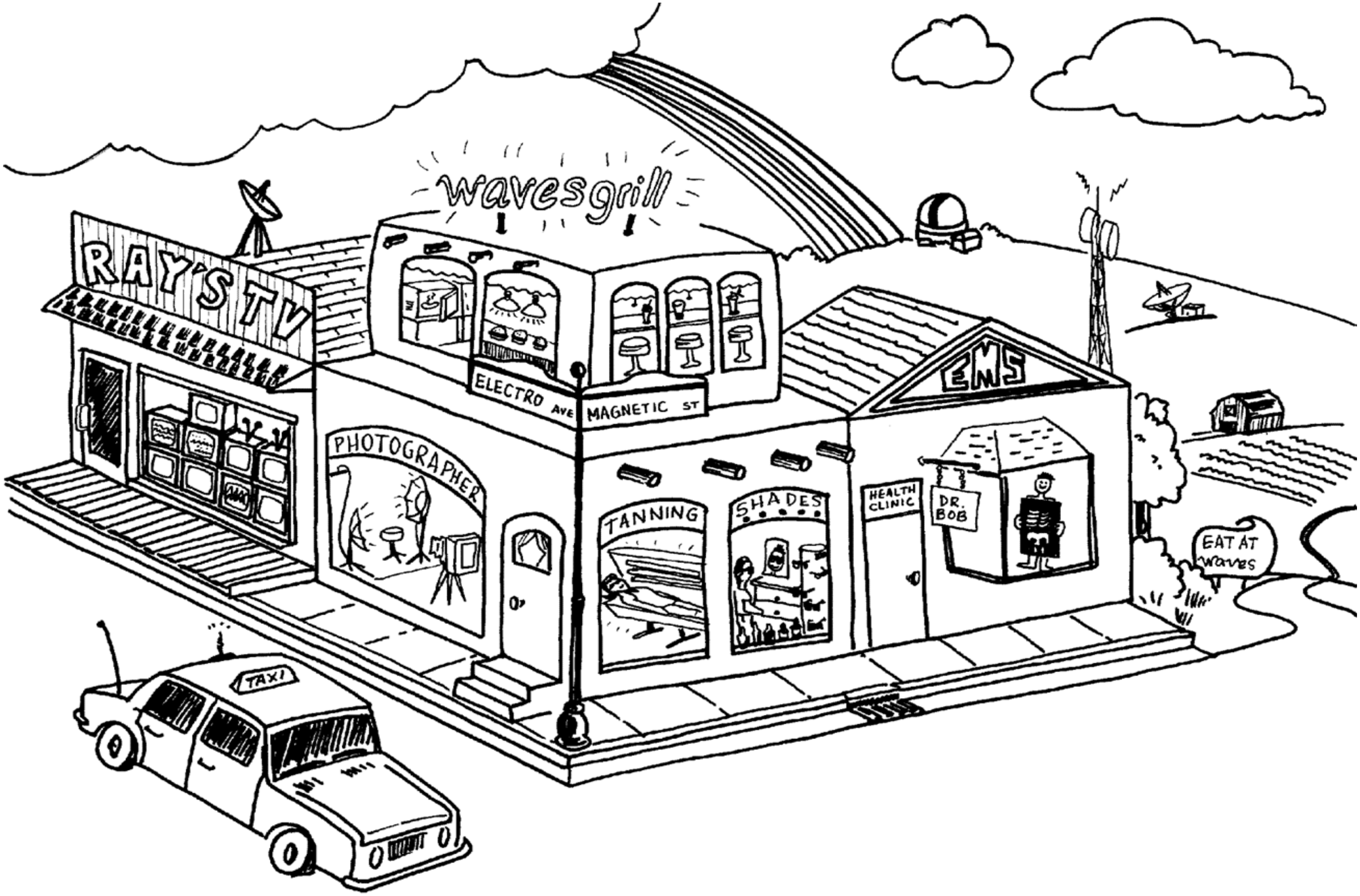
(A) why proton therapy is better than radiotherapy

(B) some ways that doctors treat cancer

(C) what types of cancer therapy are best

(D) the differences between proton therapy and radiotherapy

Wave Town



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