Atmospheric Optics Learning Module

A sundog and halo display in Greenland.

Source

Everything we see is the reflection of light and without light, everything would be dark. In this learning module, we will discuss the various wavelengths of light and how it is transmitted through Earth's atmosphere to explain fascinating optical phenomena including why the sky is blue and how rainbows form! To get started, watch this video describing energy in the form of waves.

Electromagnetic Spectrum (0 – 6:30)

Electromagnetic Spectrum

Electromagnetic (EM) radiation is light. Light you might see in a rainbow, or better yet, a double rainbow such as the one seen in Figure 1. But it is also radio waves, x-rays, and gamma rays. It is incredibly important because there are only two ways we can move energy from place to place. The first is using what is called a particle, or an object moving from place to place. The second way to move energy is through a wave. The interesting thing about EM radiation is that it is both a particle and a wave **1**.

Figure 1. Double rainbow

Source

Created by Tyra Brown, Nicole Riemer, Eric Snodgrass and Anna Ortiz at the University of Illinois at Urbana-Champaign. 2015-2016. Supported by the National Science Foundation CAREER Grant #1254428.

There are many frequencies of EM radiation that we cannot see. So if we change the frequency, we might have radio waves, which we cannot see, but they are all around us! The same goes for x-rays you might get if you break a bone. We cannot perceive x-ray waves, but there are still there._All of these waves are a part of the **electromagnetic spectrum**, which varies all the way from radio waves at long wavelengths, which are about the size of a building, to waves with short wavelengths, about the size of an atom. The wavelength of a wave is the distance from top of one wave to the top of the next (Figure 3). They also have varying frequencies. The frequency is simply the number of waves per second. Longer waves such as radio waves, microwaves, and infrared waves have a lower frequency and carry smaller amounts of energy. Shorter waves such as gamma and x-rays have a higher frequency and are carrying more energy. As a result, these waves can be dangerous, but also useful to us 2.

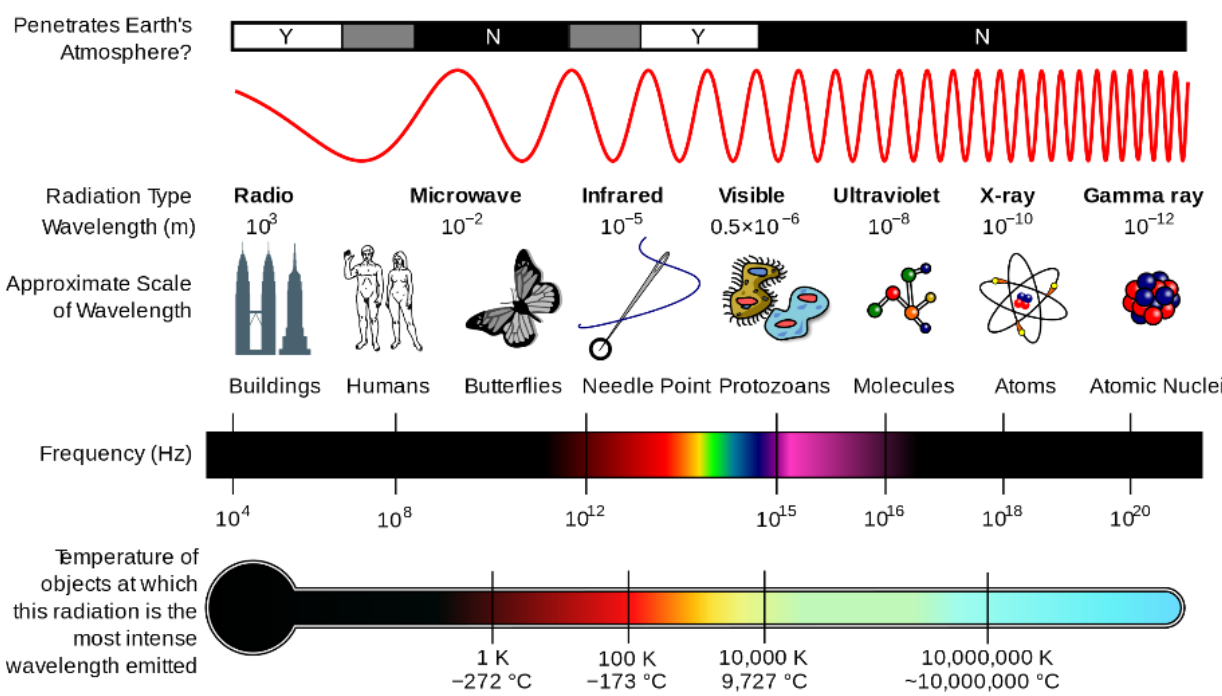

Figure 2. The Electromagnetic Spectrum showing the type of radiation, frequency and temperature based on the wavelength of energy 2, 3.

Source

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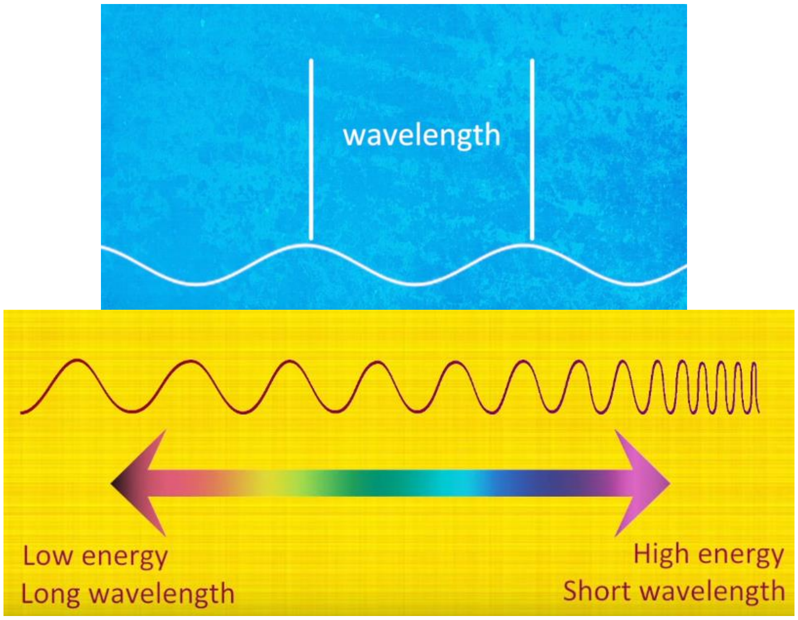

Figure 3. Top – Definition of wavelength; Bottom – Diagram showing the relationship between wavelength and energy of waves **2**.

Source

If you look at the x-ray in Figure 4, you notice that the light does not just bounce off our bodies like visible light does, it actually can move through our bodies. X-rays do not move through all the parts of the body equally. Instead, they bounce back when they hit dense objects like bones and move through soft tissue **1**.

Figure 4. X-ray image showing how waves are able to pass through the human body.

Source

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Visible Light

So what is light? Light that we see is EM radiation with a specific frequency. When you are looking at green light, green has a specific frequency such that we perceive it as green. Likewise, red would have a different frequency. The sun generates tremendous amounts of energy. Energy travels through space in waves. These waves come in many different wavelengths. The shorter the wavelength, the more powerful the energy. The sun emits short wavelength energy. Some of the more powerful wavelengths of energy such as ultraviolet get absorbed by the earth's atmosphere, which is good because too much of the shorter wavelengths of energy would make it impossible for life to be present on earth [2].

Some of the sun's energy that comes through the atmosphere is not visible to us. Human eyes can only see a small portion of sun energy called the **visible spectrum**. As it turns out, this makes up a large portion of the energy that makes it to the earth's surface. Humans can see energy that ranges in wavelength from 380 to 700 nanometers. A nanometer is 1 billionth of a meter. For example, a human hair is about 90,000 nanometers wide. Within the visible spectrum, we see different wavelengths as different colors. A rainbow is a perfect example of seeing different wavelengths as colors. Violet is the shortest wavelength followed by blue, green, yellow, orange, and red. Red is the longest wavelength of energy we can see. To learn more about the visible light spectrum, watch this next video!

Visible Light (2:19)

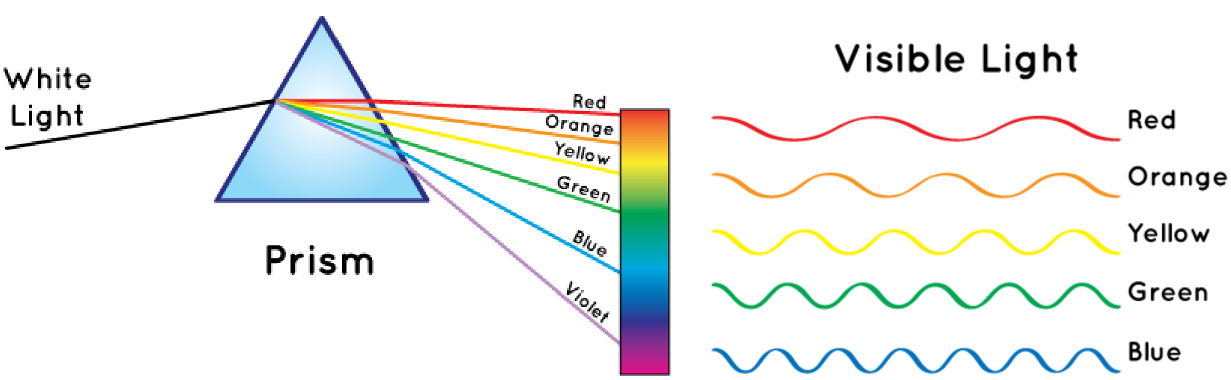

Figure 5. Visible light can be separated into different colors, which each have their own wavelength. Red light has the longest and violet has the shortest.

Source

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Energy that earth sends back to space is in the form of longer wavelengths of energy. This energy is invisible to us because it is outside of the visible spectrum. However, some creatures can see wavelengths that humans cannot. For example, it is believed some spiders can see ultraviolet energy, which have very short wavelengths. Some reptiles can see infrared energy, which are much longer wavelengths of energy [2].

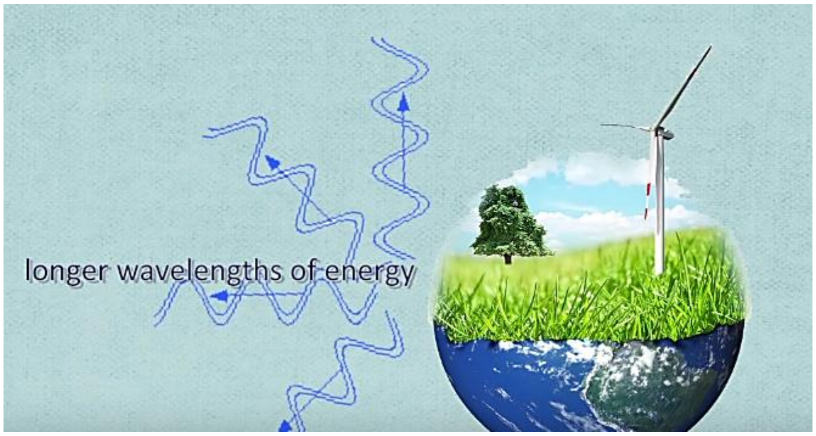

Figure 6. The earth emits longwave radiation, or energy, back to space.

Source

Properties of Energy

Light can be reflected, absorbed, refracted, or transmitted. We can allow light to move through a material by placing something clear, or transparent, in front of an object so that light is **transmitted** through it. We could also vary the transparency to be opaque so that the light cannot go through it, which produces a shadow on the other side [1].

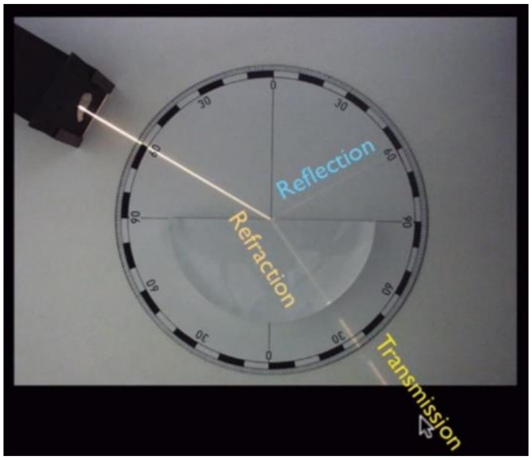

Figure 7. Light passing through a medium can be refracted, reflected, or transmitted.

Source

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In Figure 8, light is being reflected off the painting, but some light is also being **absorbed**. The frequency and wavelength of the light that is coming back to you is going to give its color. You see blue in one part of the painting because the other colors are being absorbed. The same goes for red and any other color in the visible light spectrum [1].

Figure 8. Light reflecting off and being absorbed by a painting. The colors shown on the painting are different wavelengths of visible light being scattered back to your eye [1].

Source

Everything we see is the reflection of light and without light, everything would be dark. What you see is light **reflecting** objects back to you. What about black and white? White is the reflection of all colors of visible light, while black is the reflection of none of that visible light [1].

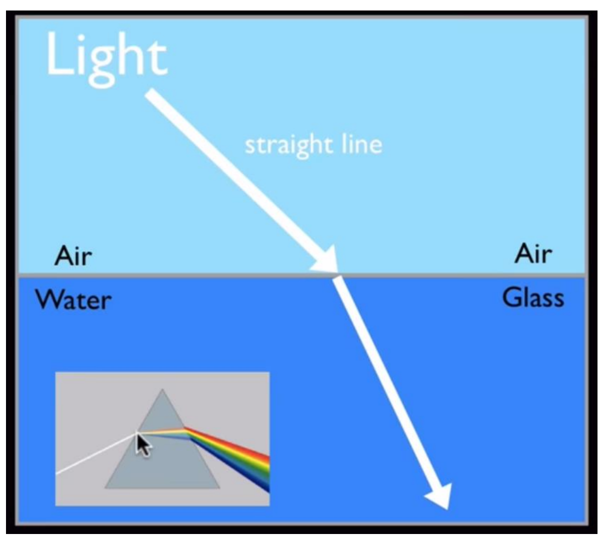

Figure 9. Incoming light passes through a medium (such as water or glass) is bent, or refracted. White light passing through a prism is separated into all the colors in the visible spectrum.

Source

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There are properties of EM radiation, like all waves, that light changes as light moves from one medium to another. Light always travels in a straight line and it travels at the speed of light until it moves from one medium to another. In other words, as light travels from air into water or air into glass, it can be refracted, or bent. **Refraction** occurs because the light is traveling at different speeds through the different media. As seen in Figure 9, each of the different wavelengths of light are going to bend different amounts. So, we can break apart the different colors of white light. As a result, you can see in Figure 9 that the glass prism is bending the light. Light can be redirected by an object such as a mirror or prism (Figure 10). A mirror reflects light off of it, while prisms change the angle at which the light is moving [1].

Figure 10. Mirrors reflect light, while prisms change the angle, or refract, visible light [1].

Source

There are some other phenomena to understand about EM radiation. As we increase the heat of an object, the object gives off different amounts of EM radiation. We can look out at space and based on the EM radiation that we're receiving, we can tell the temperature of objects like stars. Sometimes light is traveling millions of years before it reaches us and we can bend light using lenses to build telescopes that can magnify the amount of light to be able to see the universe better (Figure 11).

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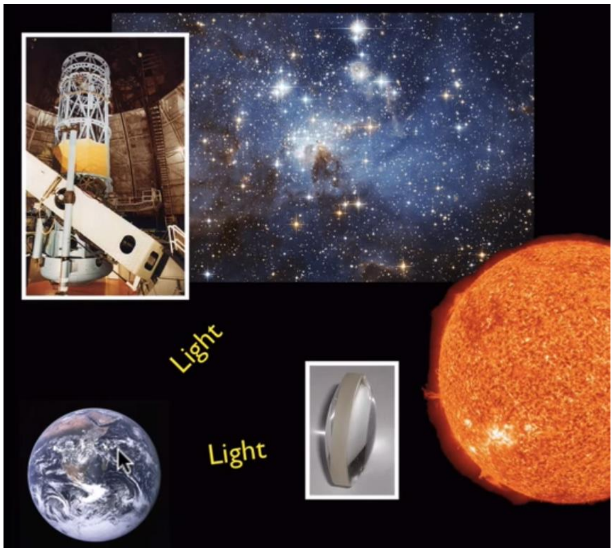

Figure 11. An engineering application of using lenses and refraction to make a telescope.

Source

Why the Sky is Blue

Have you ever wondered why the sky is blue? Watch this next video to learn how the scattering of light energy causes us to see a blue sky.

Why is the Sky Blue? (2:34)

When you look at the sky at night, it's black and there are stars and the moon. Stars form points of light on a black background (Figure 12). So why is it that during the day the sky does not remain black with the sun acting like just another point of light? During the daytime, the sky turns a bright blue and all the stars except for the sun seem to disappear. This can be explained. First, the sun is an extremely bright point of light. The second thing to recognize is that the molecules of nitrogen and oxygen in the atmosphere have an effect on the sunlight that passes through them (Figure 12). The molecules in the atmosphere cause light to scatter throughout the sky (Figure 13) 1.

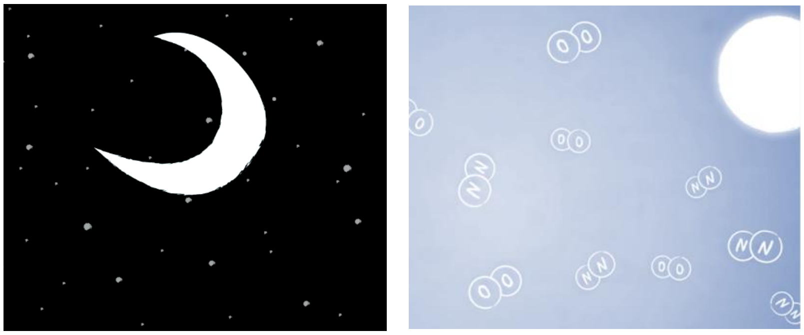

Figure 12. Left – The night sky; Right – The sky during the daytime showing nitrogen and oxygen in our atmosphere.

Source

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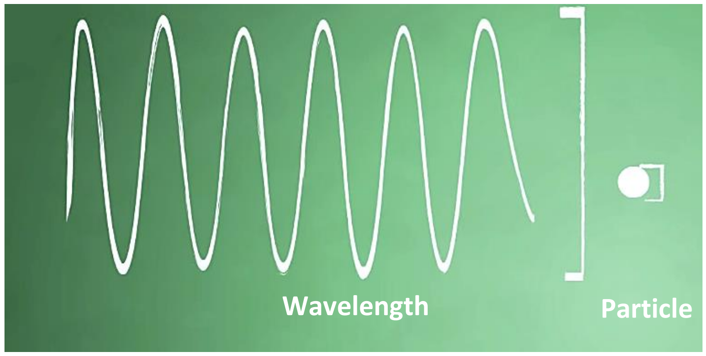

Figure 13. The atmosphere causes light to scatter throughout the sky when it passes through particles that have a diameter that is 1/10 that of the wavelength or the color of the light.

Source

Sunlight is made up of all different colors of light, but because of the gases in our atmosphere, the color blue is scattered much more efficiently than all of the other colors. Looking at the sky on a clear day, we can see the sun as a bright disk and the blue that we see everywhere else is all of the molecules in the atmosphere scattering blue light toward us. That is because the red, yellow, green, and all of the other colors of light are not scattered nearly as well. So we see the sky as blue as a result and that blue color is so bright that all the other stars become invisible because they are dim in comparison [1].

Red Sunsets

You just learned why the sky is blue, but the sky can also appear red, orange, or even pink. What causes the sky to change color as the sun sets? You will be able to answer this question and more after watching this next video!

Why is the Sunset Red? (4:21)

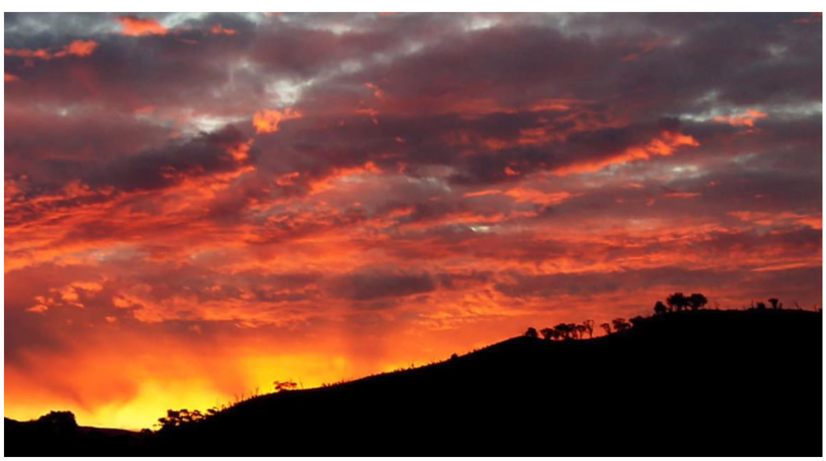

Figure 14. The sky at sunset appears red, orange, yellow, and sometimes pink.

Source

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We can see all of the colors: red, orange, yellow, green, blue, and violet with our eyes. This is very important because everything that we look at seems to have color including the sunset. Each color that we can see has a certain wavelength as we discussed before. The long wavelengths are found in colors such as red, orange, and yellow. The shorter wavelengths are found in the colors such as blue and violet.

When light comes from the sun to the earth, it comes in a straight line and this contains all of the colors of the spectrum (Figure 15). Each color is traveling at its own wavelength. By the time the light reaches the atmosphere it may encounter water molecules, dust, or ice. Since the light waves are incredibly small, smaller than one millionth of a meter, light waves will interact with even the tiniest gas molecules in the air. Then they begin to bounce off the molecules or particles, which is referred to as light **scattering** (Figure 15). The direction in which the waves are scattered depends on how large the scattering object was compared to the wavelength (Figure 16). When particles are small compared the wavelength, the particles will scatter blue light (or shorter wavelengths) more than strongly than red light (or longer wavelengths). This is called **Rayleigh scattering**, which is what causes our daytime sky to appear bright blue [1].

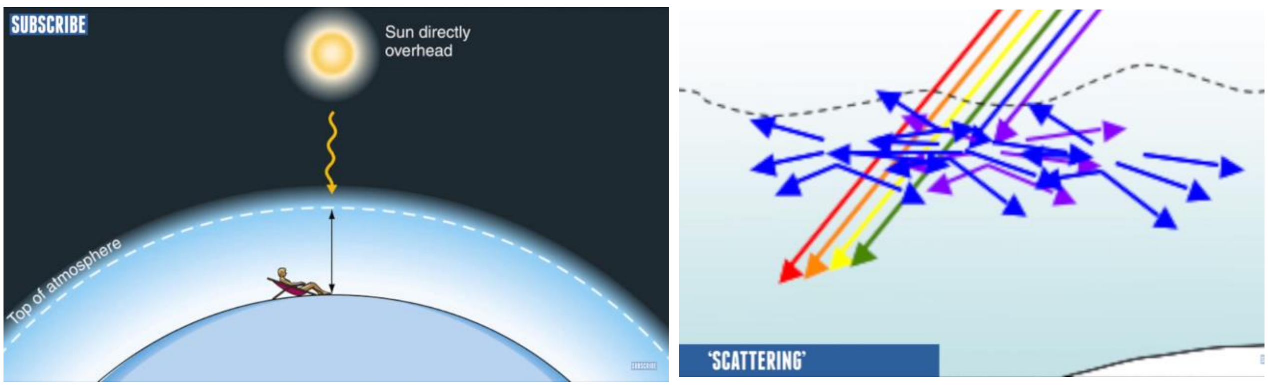

Figure 15. Left – Incoming sunlight moving in a straight line through Earth's atmosphere. Right – Scattering of blue light (shorter wavelengths) is most efficient because of the size of the particles compared to the wavelength of light.

Source

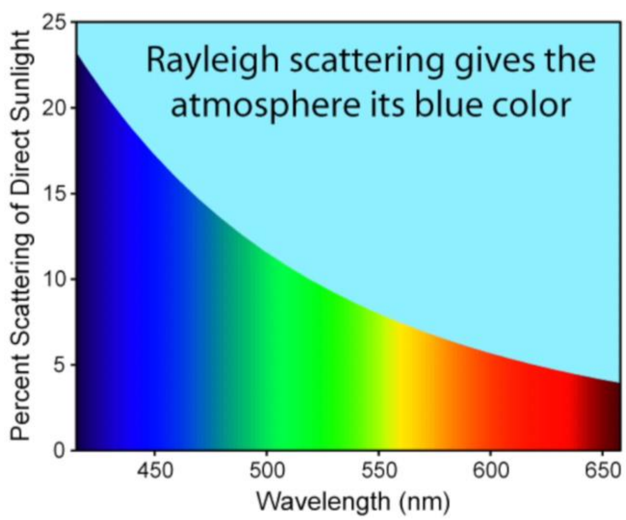

Figure 16. When particles are small compared to the wavelength, the particles will scatter blue light more efficiently, which is why we see a blue sky during the daytime.

Source

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Since the earth's atmosphere is made up of oxygen and nitrogen, blue will be scattered in more strongly than the red. This creates the blue sky that we see. So, when you see a sunrise or sunset, the sunlight is actually traveling through a longer path of atmosphere to your eyes compared to when the sun is high in the sky (Figure 17) [1].

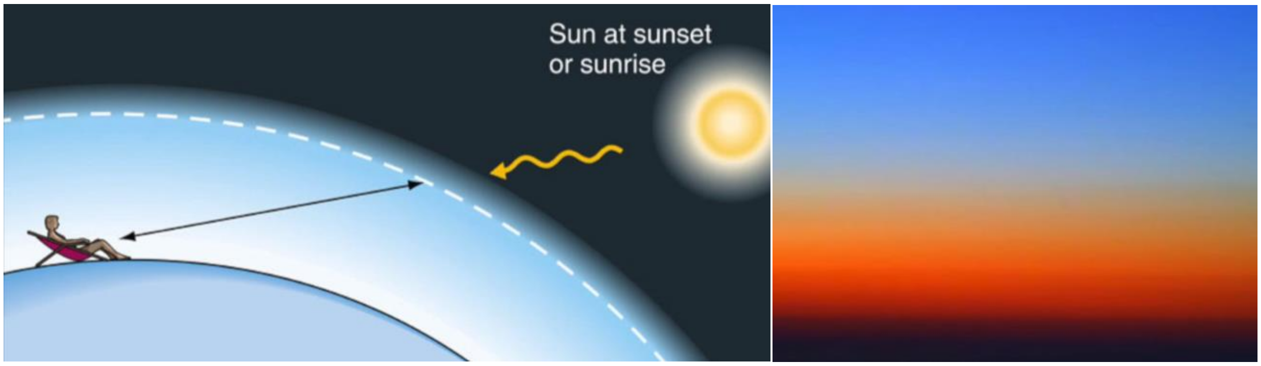

Figure 17. Incoming sunlight moves in a straight path across a longer distance at sunset allowing all of the shorter wavelengths (blue) to be removed leaving only reds and oranges to appear.

Source

During its travel through the atmosphere, the blue light has almost been completely removed, but that still leaves the red and yellow light (Figure 17). This is why when you see a sunset, you are actually seeing the colors of red, orange, and yellow. And if there are any clouds in the sky, they will reflect these colors (Figure 18). The colors are being reflected from the water and ice particles in the clouds [1].

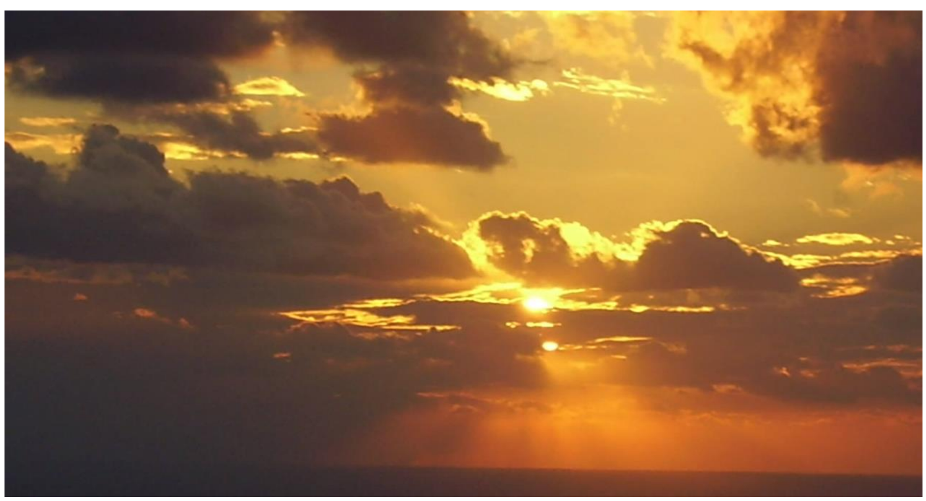

Figure 18. Water and ice particles within clouds reflect some of the red and orange light.

Source

We can now conclude that the sky is not blue or red, but rather it is white until the light hits something within the atmosphere that changes its color.

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Clouds

Water can exist in three states: solid, liquid, and gas (Figure 19). It is a common misconception that steam or clouds are made of water vapor. Recall from the 'Water in the Atmosphere' learning module that water vapor is invisible. Clouds, fog, and steam are all made up of tiny water droplets that are suspended in the air (Figure 21). To learn more about the properties of water and clouds, watch this video!

Properties of Clouds (2:00)

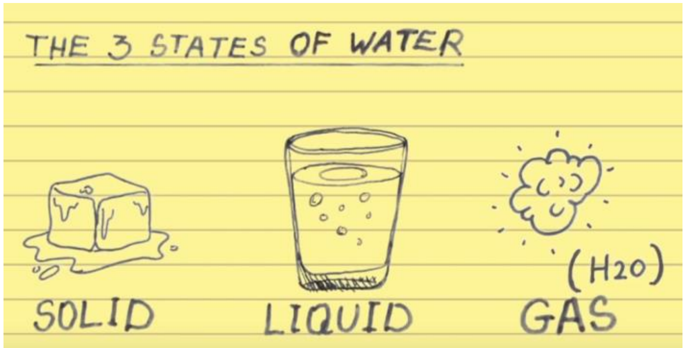

Figure 19. The 3 states of water including solid (ice), liquid (water), and gas (water vapor).

Source

To get liquid water to change into ice, we can put it in the freezer to cool the temperature. How do we get water from gas? The answer is quite simple. We use the same process by taking water vapor and cool the temperature down to get liquid water. This is how clouds are created, which eventually lead to rain. The sun's heat evaporates water from rivers, lakes, oceans, or even from plants (Figure 20). This creates water vapor, or water in the form of gas, that rises in the air. As the water vapor rises, the surrounding temperature cools, turning vapor into tiny water droplets. Water droplets collide together making them heavier and once they are large enough, gravity takes over and they begin to fall toward Earth (Figure 20).

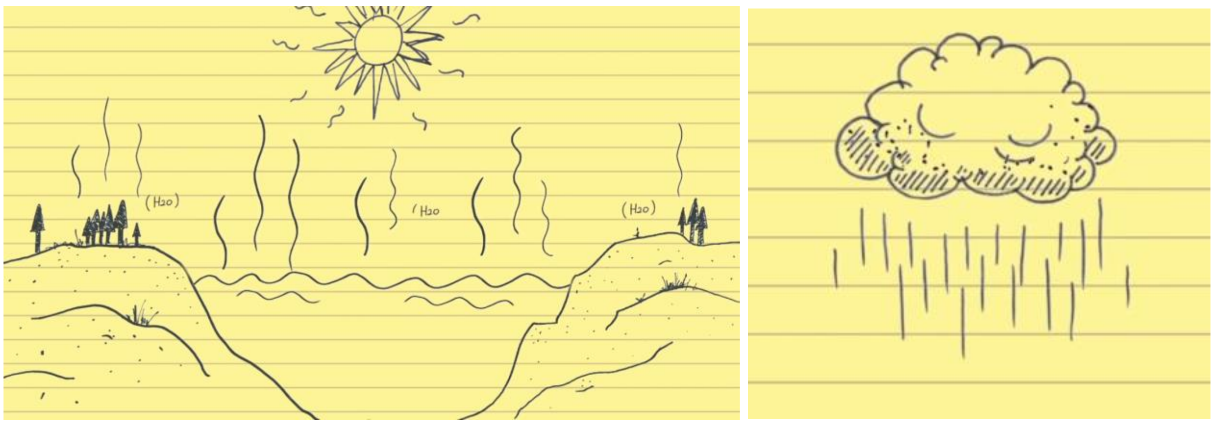

Figure 20. Clouds and rain form by cooling water vapor that has evaporated into the atmosphere. The water vapor condenses into tiny water droplets that make up clouds.

Source

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But we know that liquid water is transparent (or colorless), so why do clouds appear white? To find out why, watch this next video!

Why are Clouds White? (1:30)

Figure 21. Examples showing water in the liquid phase including (from left to right) fog, clouds, steam, water droplets, and a glass of water.

Source

Clouds are composed of liquid water droplets that scatter sunlight. The clouds are white because the interface between the tiny droplets and the air reflects light. This is the same effect that allows you to see your reflection in a calm pool of water as seen in Figure 22. However, if you disturb the water's surface, it becomes harder to see your reflection. This occurs because the disturbances of the mirror-like water surface cause light to be reflected at random angles, instead of every wave of light following the ideal straight path. If you disturb the water enough, the reflection will be so random that you will not be able to make out any images [1].

Figure 22. Left – A calm pool of water reflecting light. Right – A disturbed pool of water reflecting light in random directions showing an example of scattered light [1].

Source

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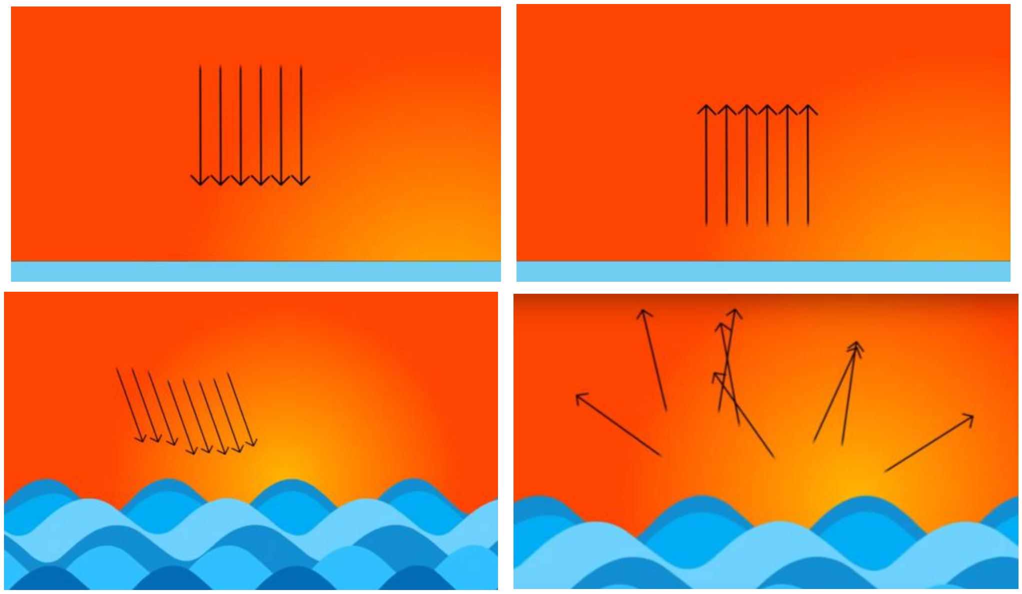

Figure 23. Top left – Incoming light onto a calm water surface. Top right – Outgoing light that has reflected off a calm water surface. Bottom left – Incoming light onto a disturbed water surface. Bottom right – Outgoing light that is scattered in random directions off a disturbed water surface 1.

Source

Different wavelengths of light are coming in and they are all scattered equally in random directions (Figure 23). Thus, when you look at any given point on the water surface, you see light of all wavelengths. The combination of all the colors of light creates white, which is exactly what happens when light from the sun is reflected in all directions equally inside a cloud (Figure 24) 1.

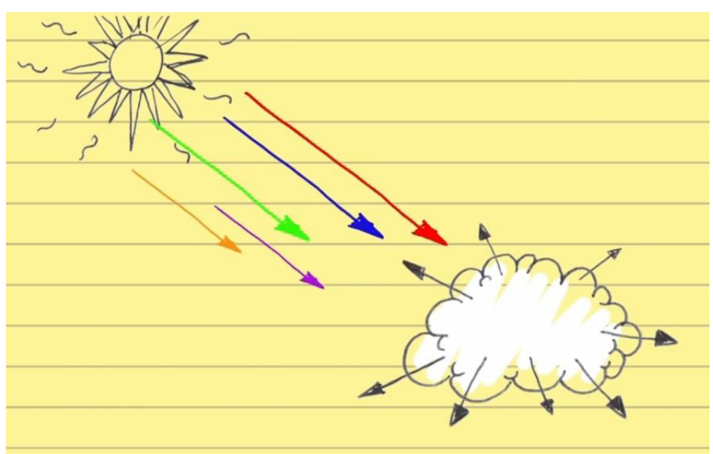

Figure 24. Incoming light from the sun is scattered equally in all directions within a cloud giving its appearance as white (all colors) 1.

Source

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Rainbows

From coloring books to record covers, rainbows are everywhere! I bet you can even remember the colors without thinking twice from the acronym ROY-G-BIV (red, orange, yellow, green, blue, indigo, and violet). As anyone who has tried to chase one finds out, a rainbow is not really there. You cannot go over it to find it, and you cannot get to the end of it to find a pot of gold. The rainbow has become a mythical representation of the unattainable. In Navajo and Norwegian mythology, it is a bridge that only gods could take between heaven and Earth. For Christians and Buddhists, rainbows are a state of peace and forgiveness.

Just because a rainbow is not really there, does not mean we cannot explain how it works. A rainbow exists because of light, water, and a little physics!

How Rainbows Form 1 (3:30)

How Rainbows Form 2 (0 – 1:50)

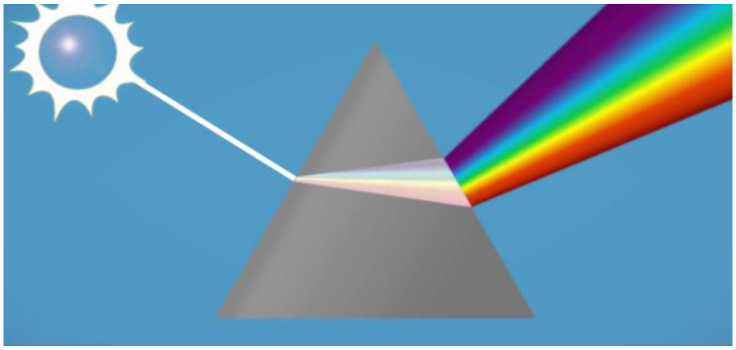

Figure 25. White light from the sun passing through a prism to show it is composed of all the colors of the visible spectrum.

Source

Let's begin with sunlight, which appears white. To some, white may seem like the absence of color, but thanks to Isaac Newton, we know that white is really the sum of all visible wavelengths (Figure 25). On a rainy or misty day, the sky is filled with tiny water droplets. Those suspended liquid prisms are surface tension on its smallest scale, and they are pulled into the shape of a sphere and each one can catch sunlight and become its own part of a rainbow. They are not quite as small as the droplets in clouds, which is why we do not have rainbow clouds. Some of you might say, "But, I've see a rainbow in a cloud before" such as the one in Figure 26. Well, that is not really a rainbow, it is actually called a sundog. A sundog forms from scattering of visible light off of ice crystals in cirrus clouds found high in the troposphere.

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Figure 26. An example of a sundog (not considered a rainbow), which forms from scattering of visible light off ice crystals in cirrus clouds.

Source

Here is where we add the physics. The bending of light as it moves from one medium, like air, to another medium, like water, at an angle is called refraction. Light actually slows down when it moves through water. Visible light would take 11 minutes, instead of the usual 8, to get from the sun to Earth if there were a giant body of water in between as seen in Figure 27. So, as light slows down when it enters water, the beam is forced to turn. Unlike the constant speed of light in a vacuum, the speed of light in water depends on the color (or wavelength). Violet light moves slower in water than red light, so it will bend more as it enters water as seen in Figure 28. An incoming beam of white light will be spread out and separated into a spectrum of colors. We call this **dispersion** of light [1].

Figure 27. Sunlight takes 8 minutes to reach Earth's surface through our atmosphere. It would take an additional 3 minutes if the sunlight had to pass through a body of water.

Source

What about if the light passes through a spherical water droplet? Sunlight starts by entering a raindrop from behind you. Some of the light will refract into the droplet, then reflect off the back, and refract back out to travel down to your eye, typically, at an angle of 42 degrees between the incoming and outgoing light (Figure 28). This can occur in a circle of droplets. So if the ground was not in the way, rainbows would appear as a full circle.

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This bent sunlight then reflects off the back of the raindrop, and refracts again on the way out. When we measure the angle between the light that went in and the red light that comes out, the answer is 42 degrees. Violet refracts more in a water droplet than red light, as we discussed, so violet light should end up exiting the droplet higher than red. But if we look in the sky, red light is clearly higher than violet light. If you are observing the sky from the ground, the water droplet will only send red light to your eyes and the violet light will pass above you. It is the droplets down below that send violet light to you. The violet light will appear to be coming from lower in the sky, as it does [1].

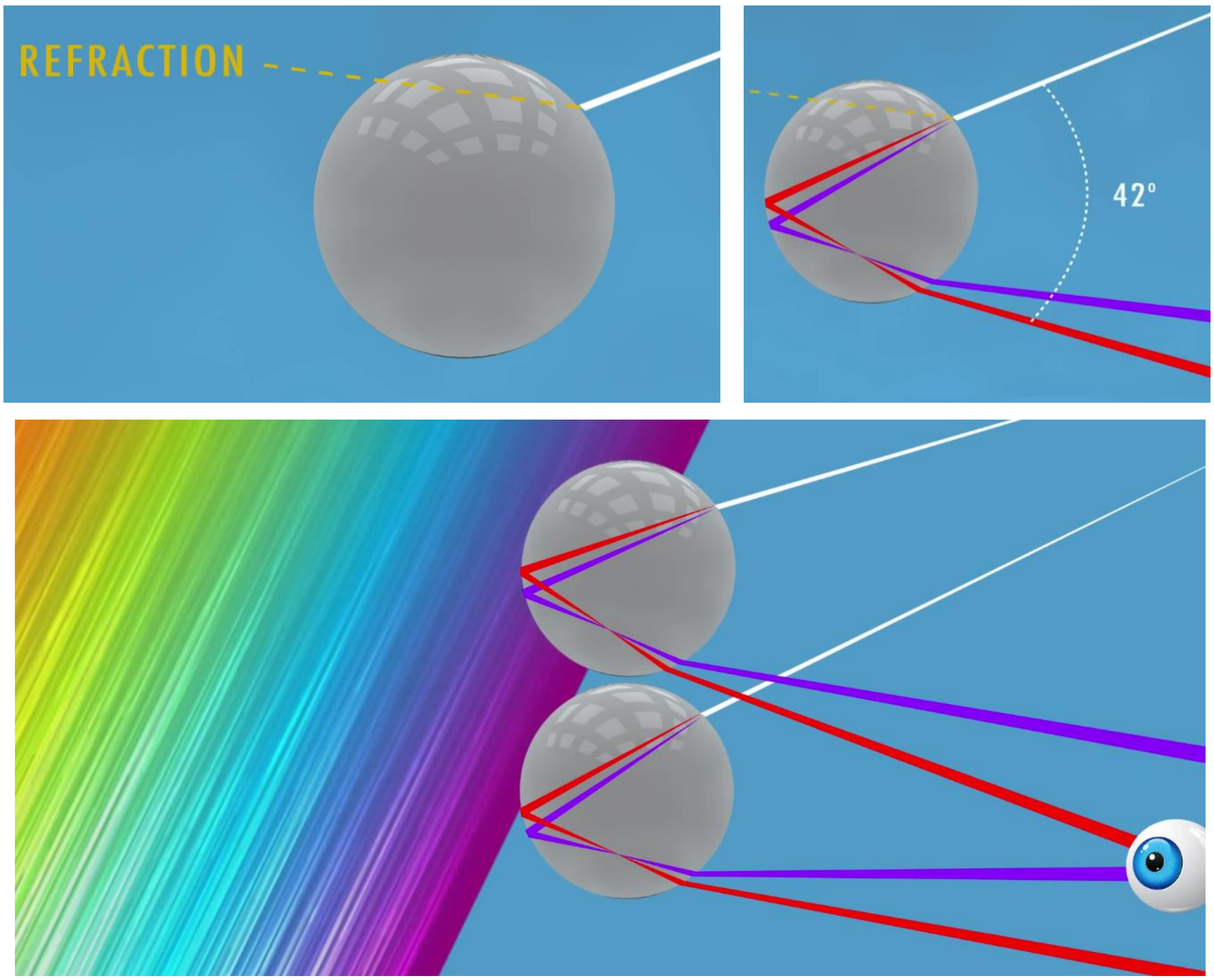

Figure 28. Sunlight enters a raindrop from behind you. Some of the light will refract into the droplet, then reflect off the back, and refract back out to travel down to your eye at an angle of 42 degrees.

Source

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So how many drops does it take to make a rainbow? Well, a lot! Because each color exits at a different angle, one raindrop will send red light into your eye and another will send violet light. The same thing happens with all the colors in between, each coming from their own droplet.

What about the shape of a rainbow? We call it a rain*bow* for a reason. It is not a rain*line* or a rain*zig-zag*. You and your eyes are at the apex of a huge half cone, and at the other end is the water that makes the rainbow shape that we are all familiar with. Everything that you see is because that light is being directed right to where you are. No one else is experiencing exactly the rainbow as you.

Figure 29. View of a rainbow because our eyes are at the apex of a half cone.

Source

Double Rainbows

In a double rainbow, there is the primary rainbow and the secondary rainbow. How does the second rainbow form and why are the colors opposite of the first? Watch the next video to answer these questions!

Double Rainbows (3:08 – 3:54)

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Figure 30. A primary and secondary (inverted) rainbows combine to make a double rainbow.

Source

In a secondary rainbow, the colors are flipped. That indicates that the light had to reflect twice inside the droplet. In order to get the right angle down to your eye, the light actually had to enter the droplet from below the midpoint of the droplet to get a double reflection causing a second rainbow [1].

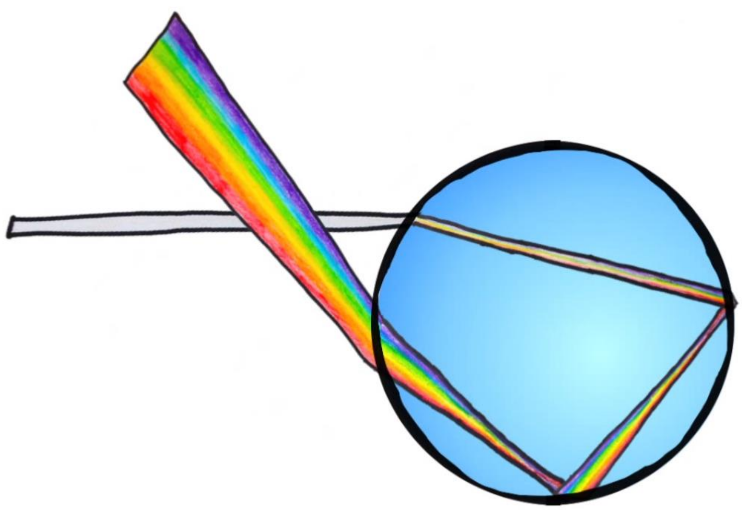

Figure 31. Light reflects inside a droplet twice to form a secondary rainbow where the colors are inverted.

Source

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Pre-Class Activity [1, 5]

Instructions: Before teaching about atmospheric optics, have the students answer the questions below, followed by a question for in-class discussion between you and your students.

1. What color is at the top of a rainbow?
    a. Red
    b. Orange
    c. Yellow
    d. Green
    e. Blue
    f. Indigo
    g. Violet

2. What are clouds made of?
    a. Water vapor
    b. Tiny water droplets
    c. Sleet
    d. Rain

3. What color is the sky during the day?
    a. White
    b. Blue
    c. Green
    d. Red
    e. Pink

4. Which of the following is <u>not</u> a type of electromagnetic energy?
    a. Radio waves
    b. X-rays
    c. Ultraviolet light
    d. Visible light
    e. Nuclear energy

5. What process causes the colors that we see?
    a. Absorption of light
    b. Refraction of light
    c. Reflection of light
    d. Transmission of light

Discussion Question: Earth's atmosphere is composed of numerous gases, particles, etc. List as many gases, particles, etc. that our atmosphere contains and brainstorm how they might affect incoming sunlight as it moves through the air before reaching Earth's surface. (Hint: Can sunlight move through them?)

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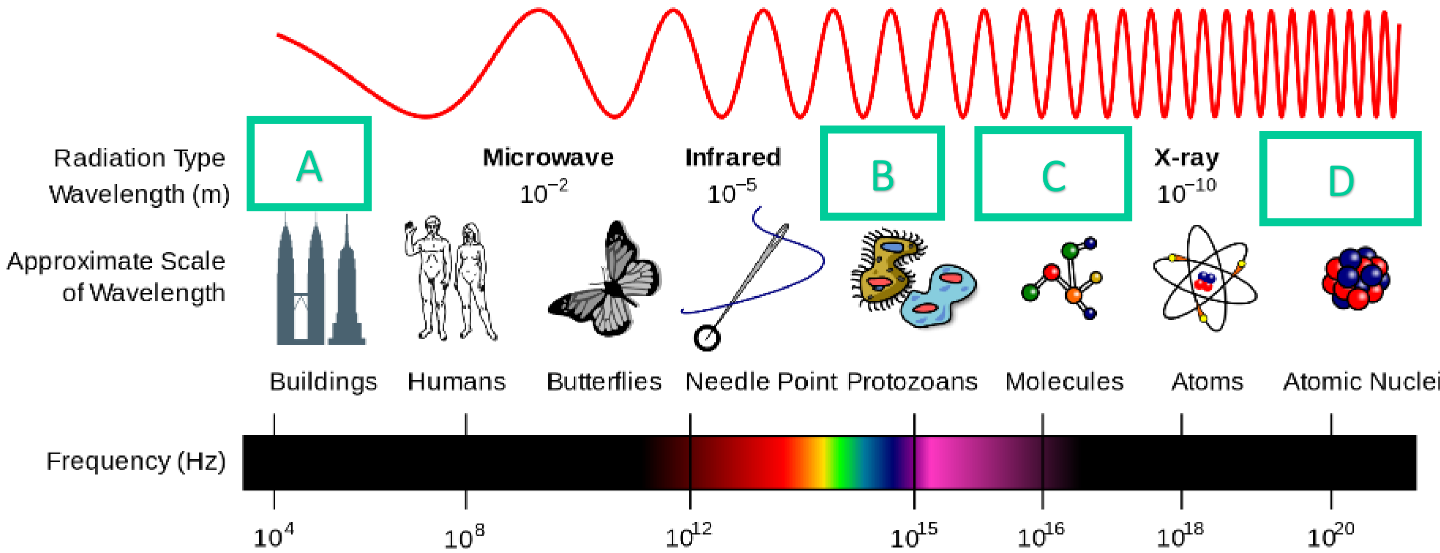
<u>In-Class Activity</u> [1, 2]

Part 1. The Electromagnetic Spectrum

<u>Instructions</u>: Fill in the blanks in the Electromagnetic Spectrum and answer the following questions.



A: ____________________ **C:** ____________________

B: ____________________ **D:** ____________________

<u>Questions</u>

1. Which radiation type from the chart above contains the most energy? What about the least amount of energy? How do you know?

   Highest energy: _______________________

   Lowest energy: ________________________

   <u>Explanation</u>:

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2. Which radiation type from the chart above has the longest wavelength? What about the shortest wavelength?

   Longest wavelength: ____________________

   Shortest wavelength: ____________________

3. Which radiation type from the chart above can humans see?

4. Which radiation type from the chart above is used in medicine?

5. Which radiation type from the chart above does the Earth emit?

Part 2. True or False (Circle One) 1, 4

1. Refraction is the bending of light as it passes through a medium.	T	F
2. Violet has the longest wavelength in the visible light spectrum.	T	F
3. White is the sum of all of the colors in a rainbow.	T	F
4. Everything we see is the absorption of light.	T	F
5. Steam is a form of liquid water.	T	F
6. Scattering of light gives us the blue sky, red sunsets, and white clouds.	T	F

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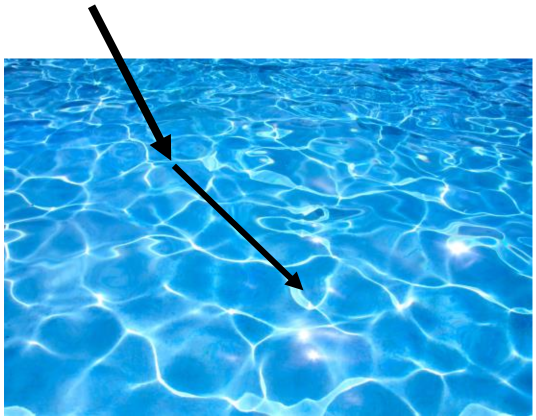
Part 3. Properties of Radiation [1, 5]

Instructions: Use the pictures below to identify which property of radiation is shown. Each property is used once. Choose from the following:

Transmission **Reflection** **Refraction** **Scattering** **Absorption**



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Take Home Assignment

Part 1. Short Answer [1]

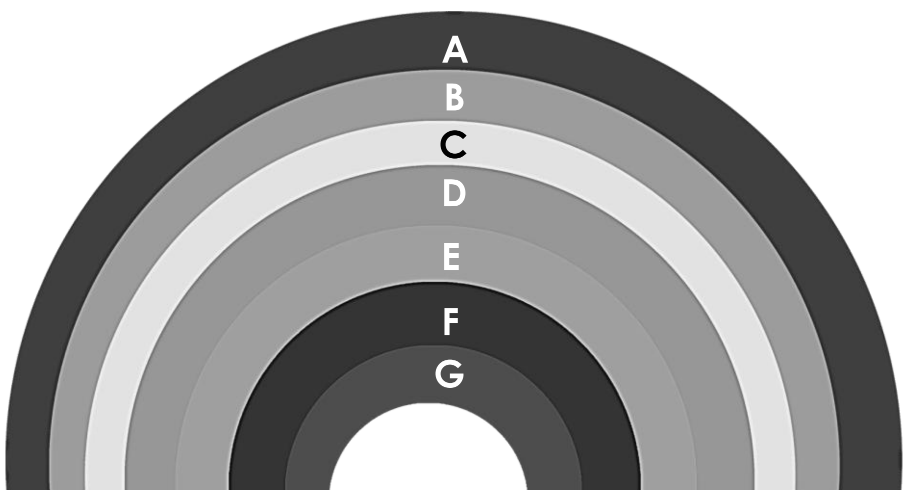
Instructions: Answer the following questions in 1 – 2 sentences.

1. Name 2 mediums that cause light to refract when it passes through.

    1. ____________________________

    2. ____________________________

2. Label the colors seen in a primary rainbow below.



A ________________ E ________________

B ________________ F ________________

C ________________ G ________________

D ________________

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3. Explain briefly why the sky is blue.

4. Explain briefly why sunsets appear red.

5. Explain briefly why clouds are white.

Part 2. Rainbows [1]

Instructions: Complete the following exercises on rainbows.

1. What are the two ingredients necessary to form a rainbow?

    ________________________ ________________________

2. What process (transmission, reflection, etc.) occurs that causes this optical phenomenon?

3. Where should you stand if you want to see a rainbow?

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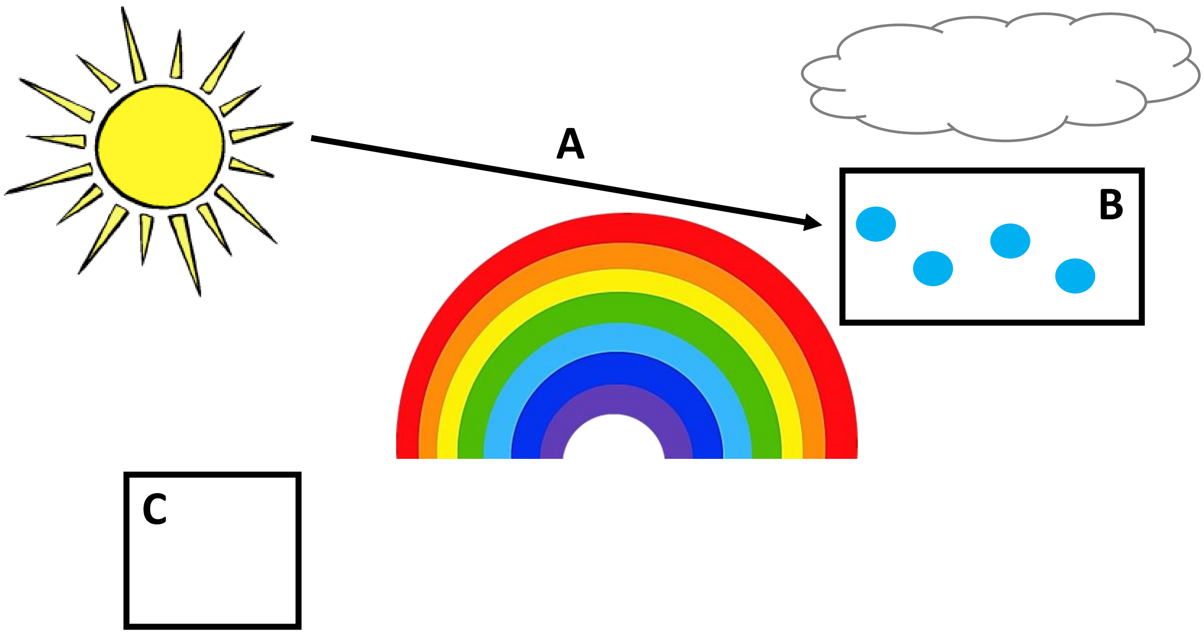
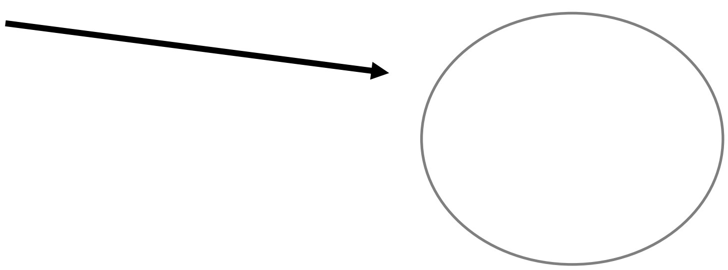
4. Complete the following diagram to show how rainbows are visible to humans.



A: What type of electromagnetic radiation is incoming from the sun? What color is this energy?

B: Sketch how light moves through raindrops.



C: What is the third object necessary to see a rainbow? Sketch a picture in the box above.

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Student Evaluation 1, 2, 3, 4, 5

Instructions: After completing the lesson on atmospheric optics, please have the students answer the following questions.

1. The electromagnetic spectrum is made up of
   a. all wavelengths of energy
   b. all the colors in the rainbow
   c. high frequency radiation
   d. UVA and UVB radiation from the sun

2. Which of the following has the shortest wavelength of energy?
   a. Radio waves
   b. Microwaves
   c. Visible light
   d. X-rays
   e. Blue light

3. What is refraction?
   a. The direct transmission of x-rays through the human body
   b. The trapping of heat in Earth's atmosphere by greenhouse gases
   c. The bending of visible light as it passes through a medium
   d. The reflection of light off a mirror in the same direction as the incoming light

4. White is the scattering of
   a. all colors in the visible light spectrum.
   b. outgoing infrared radiation from Earth's surface.
   c. all wavelengths of energy.
   d. none of the above

5. What factor changes a blue sky to red during sunset?
   a. The wavelength of incoming light from the sun
   b. The number of clouds in the sky
   c. The distance the incoming light travels through the atmosphere
   d. The temperature at which the sun is emitting light

6. Light travels faster in water than air. T F

7. Longwave energy carries more energy than shortwave energy. T F

8. The colors in a secondary rainbow are opposite of a primary rainbow. T F

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9. Describe the process in which sunlight interacts with cloud particles to make clouds appear white. Be sure to include details on what type of energy is emitted from the sun, the shape of cloud droplets, and the type of scattering that occurs.

10. Visible light ranges in wavelength from 0.38×10^{-6} to 0.70×10^{-6} meters. Convert these wavelengths from scientific notation.

    a. 0.000038 and 0.00007 meters
    b. 0.00000038 and 0.0000007 meters
    c. 380 and 700 meters
    d. 380,000 and 700,000 meters

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Common Core State Standards (CCSS) Initiative

To learn more, visit http://www.corestandards.org

Next Generation Science Standards (NGSS)

To learn more, visit http://www.nextgenscience.org

The following standards are met in this learning module:

1. **NGSS.MS-PS4-2**

MS-PS4-2. Waves and Electromagnetic Radiation
Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
Lecture: Electromagnetic Spectrum, Properties of Energy, Why the Sky is Blue, Red Sunsets, Clouds, Rainbows & Double Rainbows; Pre-Class Activity; In-Class Activity: Parts 2 & 3; Take Home Assignment: Parts 1 & 2; Student Evaluation

2. **NGSS.MS-PS4-1**

MS-PS4-1. Waves and Electromagnetic Radiation
Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.
Lecture: Electromagnetic Spectrum & Visible Light; In-Class Activity: Part 1; Student Evaluation

3. **CCSS.MATH.CONTENT.8.EE.A.4**

Grade 8. Expressions & Equations
Perform operations with numbers expressed in scientific notation, including problems where both decimal and scientific notation are used. Use scientific notation and choose appropriate size for measurements of very large or very small quantities. Interpret scientific notation that has been generated by technology.
Lecture: Electromagnetic Spectrum; Student Evaluation

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4. **[CCSS.ELA-LITERACY.RST.6-8.8]**

Grade 8: Science and Technical Subjects
Distinguish among facts, reasoned judgment based on research findings, and speculation in a text.
In-Class Activity: Part 2; Student Evaluation

5. **[CCSS.ELA-LITERACY.RST.6-8.4]**

Grade 6-8: Science and Technical Subjects
Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific science or technical context relevant to grades 6-8 texts and topics.
Lectures: Bolded text; Pre-Class Activity; In-Class Activity: Part 3; Student Evaluation

6. **[CCSS.ELA-LITERACY.RST.6-8.7]**

Grade 6-8: Science and Technical Subjects
Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table).
Video lectures

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