THE BIG IDEA

The colors of the objects depend on the color of the light that illuminates them.

Color is in the eye of the beholder and is provoked by the frequencies of light emitted or reflected by things. We see red in a rose when light of certain frequencies reaches our eyes. Many organisms, including people with defective color vision, see no red in a rose.

28.1 The Color Spectrum

By passing a narrow beam of sunlight through a triangular-shaped glass prism, Newton showed that sunlight is composed of a mixture of all the colors of the rainbow.

28.1 The Color Spectrum

Isaac Newton was the first to make a systematic study of color.

Passing sunlight through a glass prism, Newton showed that sunlight is composed of a mixture of all the colors of the rainbow.

Newton called this spread of colors a **spectrum,** and noted that the colors were formed in the order red, orange, yellow, green, blue, and violet.

28.1 The Color Spectrum

Sunlight is an example of what is called white light. **White light** is a combination of all the colors.

Under white light, white objects appear white and colored objects appear in their individual colors.

28.1 The Color Spectrum

Newton showed that the colors in the *spectrum* were a property not of the prism but of white light itself.

He recombined the colors with a second prism to produce white light again.

In other words, all the colors, one atop the other, combine to produce white light.

White is not a color but a combination of all colors.

28.1 The Color Spectrum

When sunlight passes through a prism, it separates into a spectrum of all the colors of the rainbow.

28.1 The Color Spectrum

Black is similarly not a color, but is the absence of light. Objects appear black when they absorb light of all visible frequencies.

Even a polished surface may look black under some conditions.

Highly polished razor blades stacked together and viewed end on appear black.

Light that gets between the closely spaced edges of the blades gets trapped and is absorbed after being reflected many times.

28.1 The Color Spectrum

Black objects that you can see do not absorb all light that falls on them, for there is always some reflection at the surface.

If not, you wouldn't be able to see them.

28.1 The Color Spectrum

CONCEPT CHECK

How did Isaac Newton show that sunlight is composed of a mixture of all colors of the rainbow?

28.2 Color by Reflection

The color of an opaque object is the color of the light it reflects.

28.2 Color by Reflection

The colors of most objects around you are due to the way the objects reflect light.

The color of an opaque object is the color of the light it reflects.

Light reflects from objects similar to the way sound “reflects” from a tuning fork when another sets it into vibration.

28.2 Color by Reflection

We can think of atoms and molecules as three-dimensional tuning forks.

Electrons behave as tiny oscillators in orbits around the nuclei.

Electrons can be forced temporarily into larger orbits by the vibrations of electromagnetic waves.

Like tuning forks, once excited to more vigorous motion, electrons send out their own energy waves in all directions.

28.2 Color by Reflection

Differences Among Materials

Different materials have different natural frequencies for absorbing and emitting radiation.

At the resonant frequencies where the amplitudes of oscillation are large, light is absorbed.

At frequencies below and above the resonant frequencies, light is reemitted.

28.2 Color by Reflection

If the material is transparent, the reemitted light passes through it.

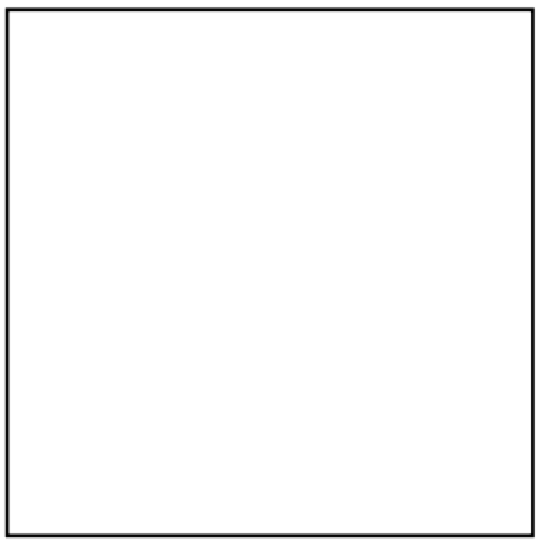
If the material is opaque, the light passes back into the medium from which it came. This is reflection.

Most materials absorb light of some frequencies and reflect the rest.

If a material absorbs light of most visible frequencies and reflects red, for example, the material appears red.

28.2 Color by Reflection

a. This square *reflects* all the colors illuminating it. In sunlight, it is white. When illuminated with blue light, it is blue.

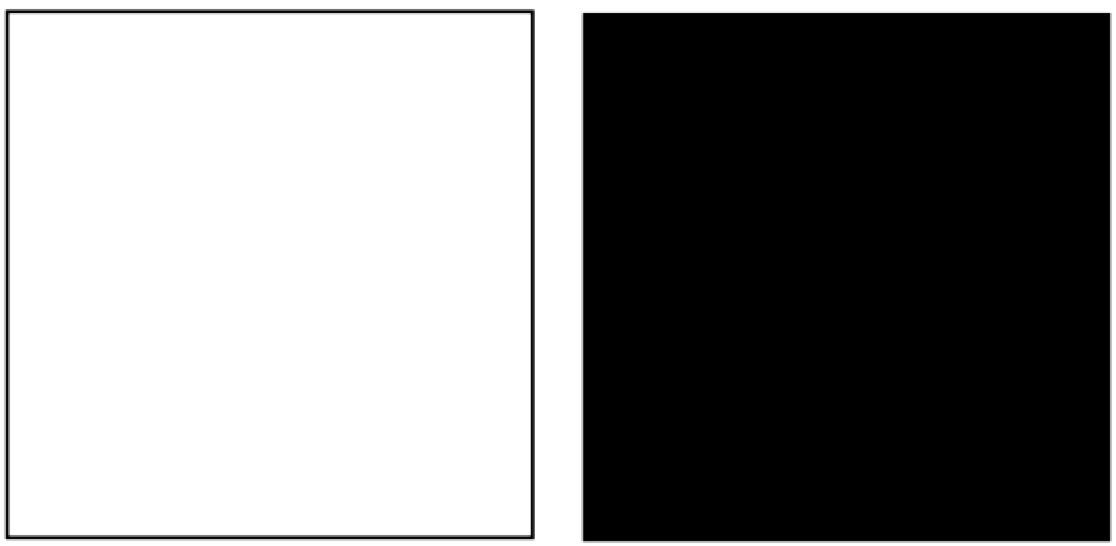


a

28.2 Color by Reflection

a. This square *reflects* all the colors illuminating it. In sunlight, it is white. When illuminated with blue light, it is blue.

b. This square *absorbs* all the colors illuminating it. In sunlight it is warmer than the white square.



a b

28.2 Color by Reflection

When white light falls on a flower, light of some frequencies is absorbed by the cells in the flower and some light is reflected.

Cells that contain chlorophyll absorb light of most frequencies and reflect the green part, so they appear green.

The petals of a red rose, on the other hand, reflect primarily red light, with a lesser amount of blue.

28.2 Color by Reflection

Petals of most yellow flowers, such as daffodils, reflect red and green as well as yellow.

Yellow daffodils reflect light of a broad band of frequencies.

The reflected colors of most objects are not pure single-frequency colors, but a spread of frequencies.

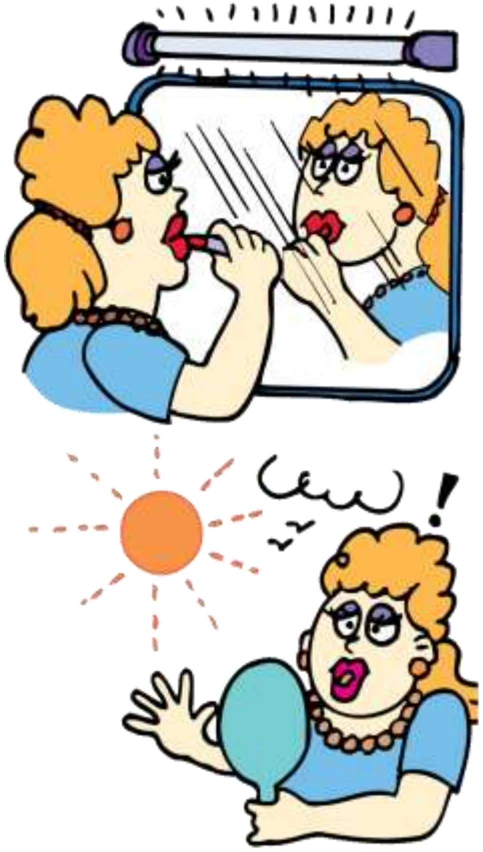
So something yellow, for example, may simply be a mixture of colors without blue and violet—or it can be red and green together.

28.2 Color by Reflection

Light Sources

The color of an object depends on the kind of light used.

- A candle flame is deficient in higher frequencies; it emits a yellowish light. Things look yellowish in candlelight.
- An incandescent lamp emits light of all the visible frequencies, but is richer toward the lower frequencies, enhancing the reds.
- A fluorescent lamp is richer in the higher frequencies, so blues are enhanced when illuminated with fluorescent lamps.



28.2 Color by Reflection

think!

When red light shines on a red rose, why do the leaves become warmer than the petals?

28.2 Color by Reflection

think!

When red light shines on a red rose, why do the leaves become warmer than the petals?

Answer:

The leaves absorb rather than reflect red light, so the leaves become warmer.

28.2 Color by Reflection

think!

When green light shines on a red rose, why do the petals look black?

28.2 Color by Reflection

think!

When green light shines on a red rose, why do the petals look black?

Answer:

The petals absorb rather than reflect the green light. So, the rose appears to have no color at all—black.

28.2 Color by Reflection

CONCEPT CHECK

What determines the color of an opaque object?

28.3 Color by Transmission

The color of a transparent object is the color of the light it transmits.

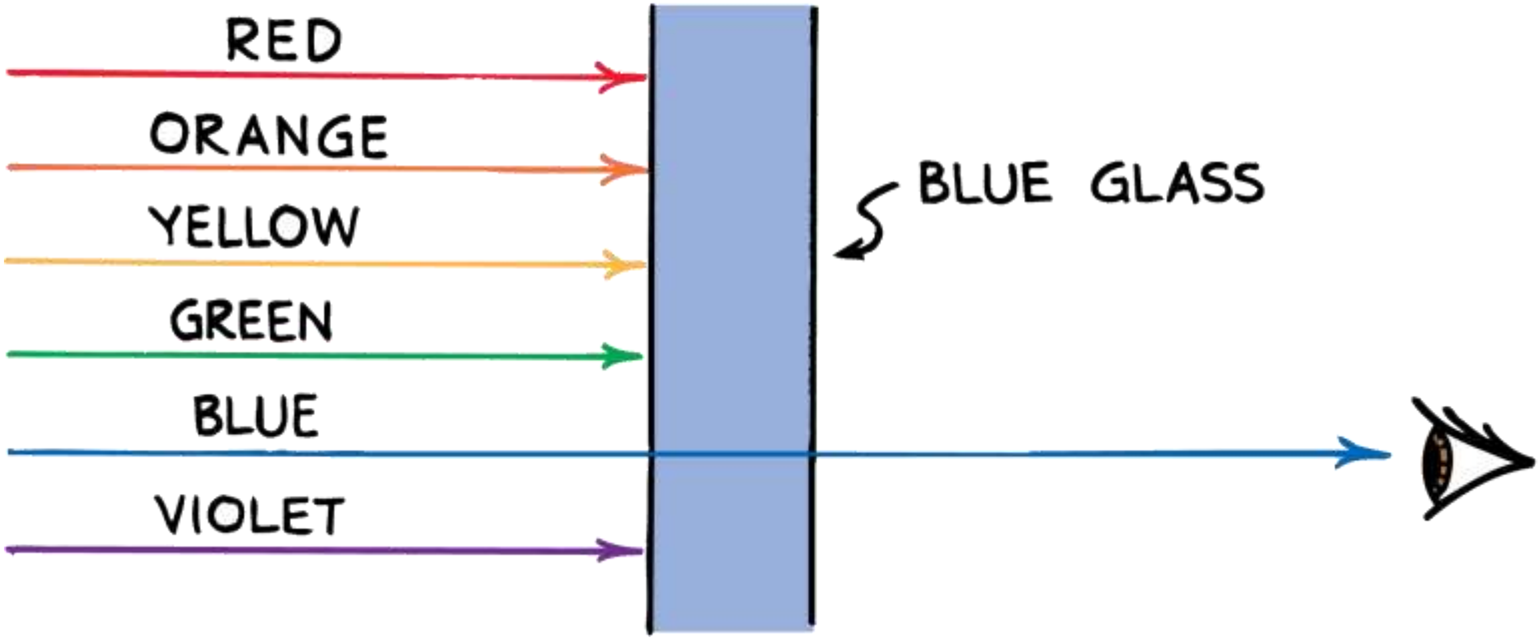
28.3 Color by Transmission

A red piece of glass appears red because it absorbs all the colors that compose white light, except red, which it transmits.

A blue piece of glass appears blue because it transmits primarily blue and absorbs the other colors that illuminate it.

28.3 Color by Transmission

Blue glass transmits only energy of the frequency of blue light; energy of the other frequencies is absorbed and warms the glass.



28.3 Color by Transmission

The material in the glass that selectively absorbs colored light is known as a **pigment.**

Electrons in the pigment atoms selectively absorb light of certain frequencies in the illuminating light.

Other frequencies are reemitted from atom to atom in the glass.

Ordinary window glass is colorless because it transmits light of all visible frequencies equally well.

28.3 Color by Transmission

CONCEPT CHECK

What determines the color of a transparent object?

28.4 Sunlight

Yellow-green light is the brightest part of sunlight.

28.4 Sunlight

White light from the sun is a composite of all the visible frequencies. The brightness of solar frequencies is uneven.

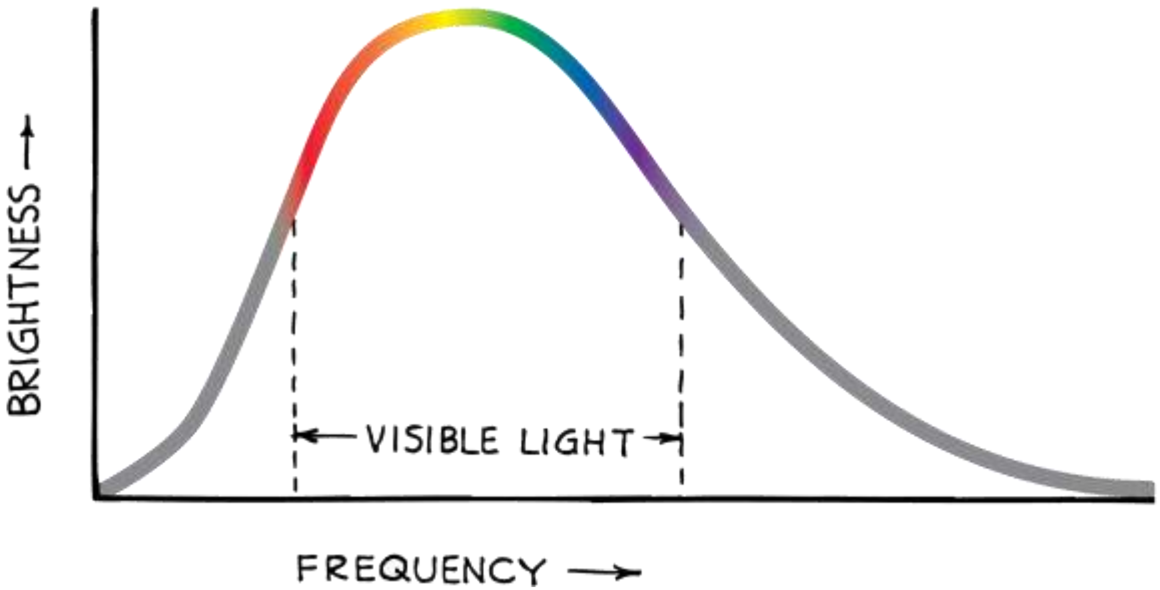
The lowest frequencies of sunlight, in the red region, are not as bright as those in the middle-range yellow and green region.

Humans evolved in the presence of sunlight and we are most sensitive to yellow-green.

The blue portion of sunlight is not as bright, and the violet portion is even less bright.

28.4 Sunlight

The radiation curve of sunlight is a graph of brightness versus frequency. Sunlight is brightest in the yellow-green region.



28.4 Sunlight

CONCEPT CHECK

Which visible frequencies make up the brightest part of sunlight?

28.5 Mixing Colored Light

You can make almost any color at all by overlapping red, green, and blue light and adjusting the brightness of each color of light.

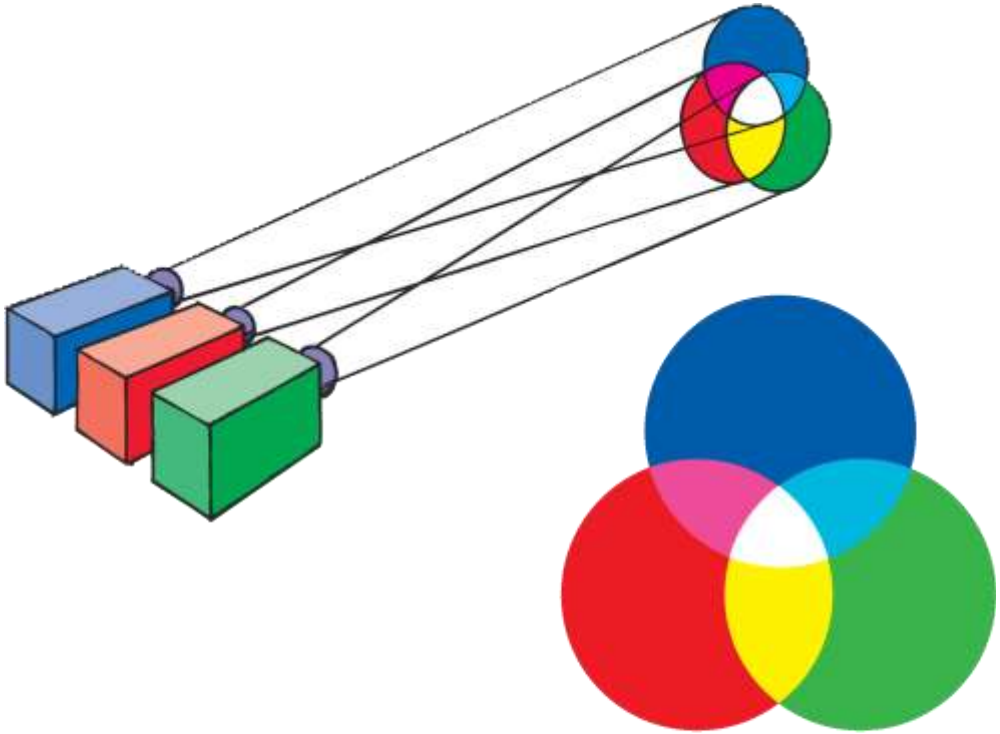
28.5 Mixing Colored Light

Light of all the visible frequencies mixed together produces white.

- White also results from the combination of only red, green, and blue light.
- Red and green light alone overlap to form yellow.
- Red and blue light alone produce the bluish-red color called *magenta.*
- Green and blue light alone produce the greenish-blue color called *cyan.*

28.5 Mixing Colored Light

When red light, green light, and blue light of equal brightness are projected on a white screen, the overlapping areas appear different colors.



28.5 Mixing Colored Light

The frequencies of white light can be divided into three regions:

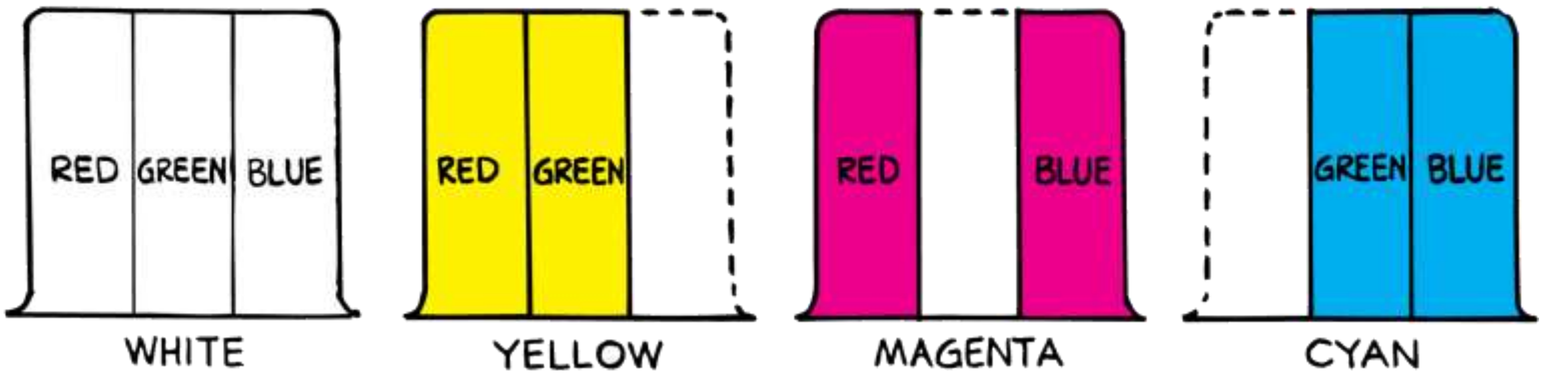
- the lower-frequency red end
- the middle-frequency green part
- the higher-frequency blue end

Low and middle frequencies combine to form yellow to the human eye. The middle and high frequencies appear greenish blue (cyan). The low and high frequencies appear bluish red (magenta).

28.5 Mixing Colored Light

The low-frequency, middle-frequency, and high-frequency parts of white light appear *red, green,* and *blue.*

To the human eye, red + green = yellow; red + blue = magenta; green + blue = cyan.

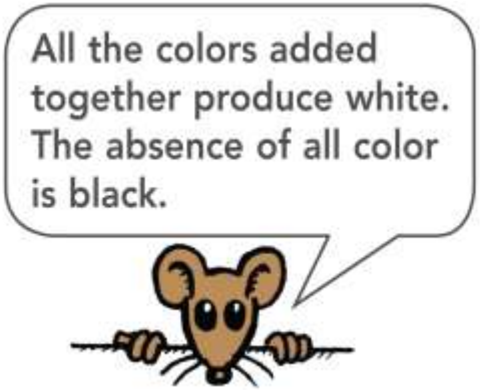


28.5 Mixing Colored Light

This amazing phenomenon is due to the way the human eye works.

The three colors do not have to be red, green, and blue, although those three produce the highest number of different colors.

For this reason, red, green, and blue are called the **additive primary colors.**



28.5 Mixing Colored Light

Color television is based on the ability of the human eye to see combinations of three colors as a variety of different colors.

The picture is made up of tiny spots, each less than a millimeter across.

When the screen is lit, some of the spots are red, some green, and some blue.

At a distance the mixtures of these colors provide a complete range of colors, plus white.

28.5 Mixing Colored Light

think!

What color does red light plus blue light make?

28.5 Mixing Colored Light

think!

What color does red light plus blue light make?

Answer:

Magenta

28.5 Mixing Colored Light

CONCEPT CHECK

Which three visible frequencies combine to form almost any color?

28.6 Complementary Colors

Every color has some complementary color that when added to it will produce white.

28.6 Complementary Colors

When two of the three additive primary colors are combined:

- red + green = yellow
- red + blue = magenta
- blue + green = cyan

When we add in the third color, we get white:

- yellow + blue = white
- magenta + green = white
- cyan + red = white

28.6 Complementary Colors

When two colors are added together to produce white, they are called **complementary colors.**

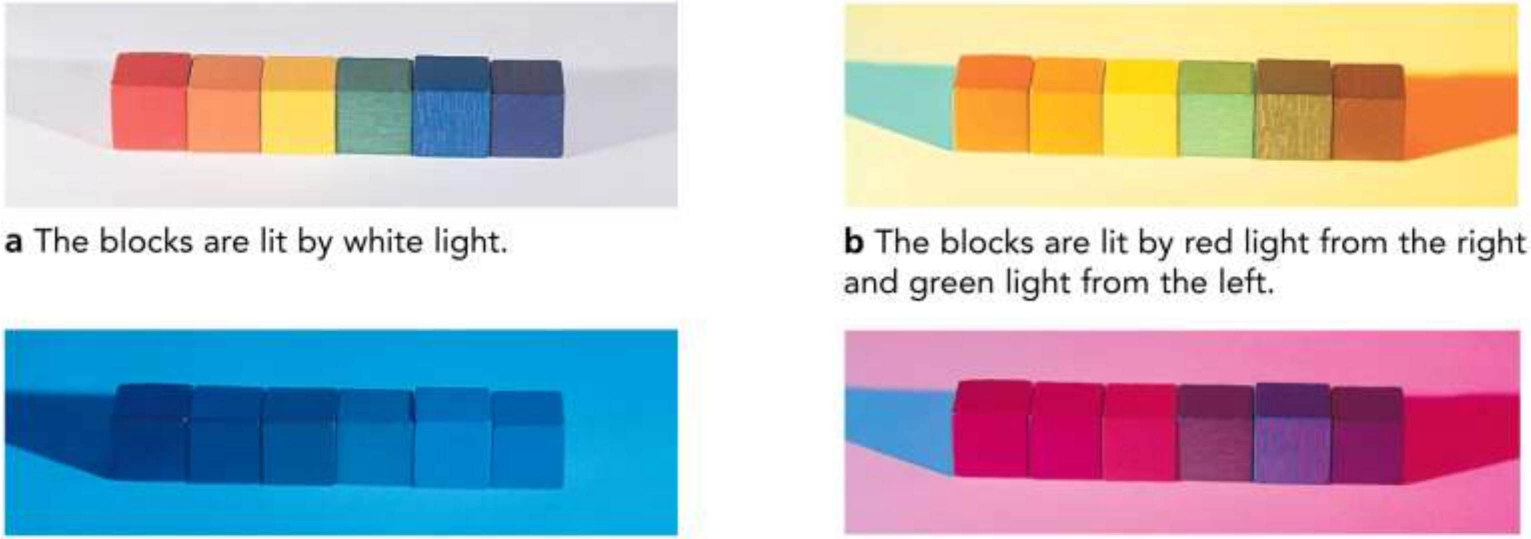
Yellow and blue are complementary because yellow is the combination of red and green.

Red, green, and blue light together appear white.

By similar reasoning we see that magenta and green are complementary colors, as are cyan and red.

28.6 Complementary Colors

Six blocks and their shadows appear as different colors depending on the color of light that illuminates them.



a The blocks are lit by white light.

b The blocks are lit by red light from the right and green light from the left.

c The blocks are lit by blue light.

d The blocks are lit by blue light from the left and red light from the right.

28.6 Complementary Colors

Begin with white light and *subtract* some color from it. The resulting color appears to be the complement of the one subtracted.

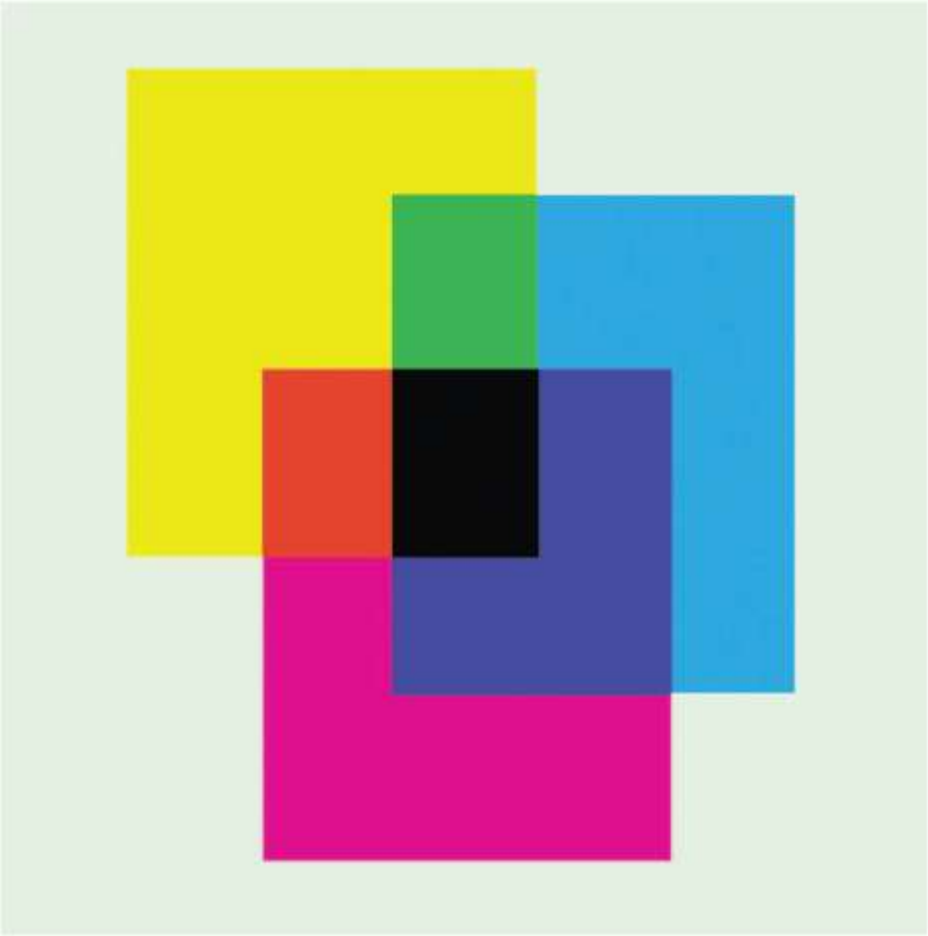
Some of the light incident upon an object is absorbed. The part that is absorbed is in effect subtracted from the incident light.

For example, if white light falls on a pigment that absorbs red light, the light reflected appears cyan.

Subtract a color from white light and you have the complementary color.

28.6 Complementary Colors

When white light passes through all three transparencies, light of all frequencies is blocked (subtracted) and we have black.



28.6 Complementary Colors

think!

What color does white light minus yellow light appear?

28.6 Complementary Colors

think!

What color does white light minus yellow light appear?

Answer:

Blue

28.6 Complementary Colors

think!

What color does white light minus green light appear?

28.6 Complementary Colors

think!

What color does white light minus green light appear?

Answer:

Magenta

28.6 Complementary Colors

CONCEPT CHECK

What happens when you combine any color with its complementary color?

28.7 Mixing Colored Pigments

When paints or dyes are mixed, the mixture absorbs all the frequencies each paint or dye absorbs.

28.7 Mixing Colored Pigments

Red and green paint do not combine to form yellow as red and green light do.

The mixing of paints and dyes is an entirely different process from the mixing of colored light.

Paints and dyes contain particles of pigment that produce colors by absorbing light of certain frequencies and reflecting others.

28.7 Mixing Colored Pigments

When paints or dyes are mixed, the mixture absorbs all the frequencies each paint or dye absorbs.

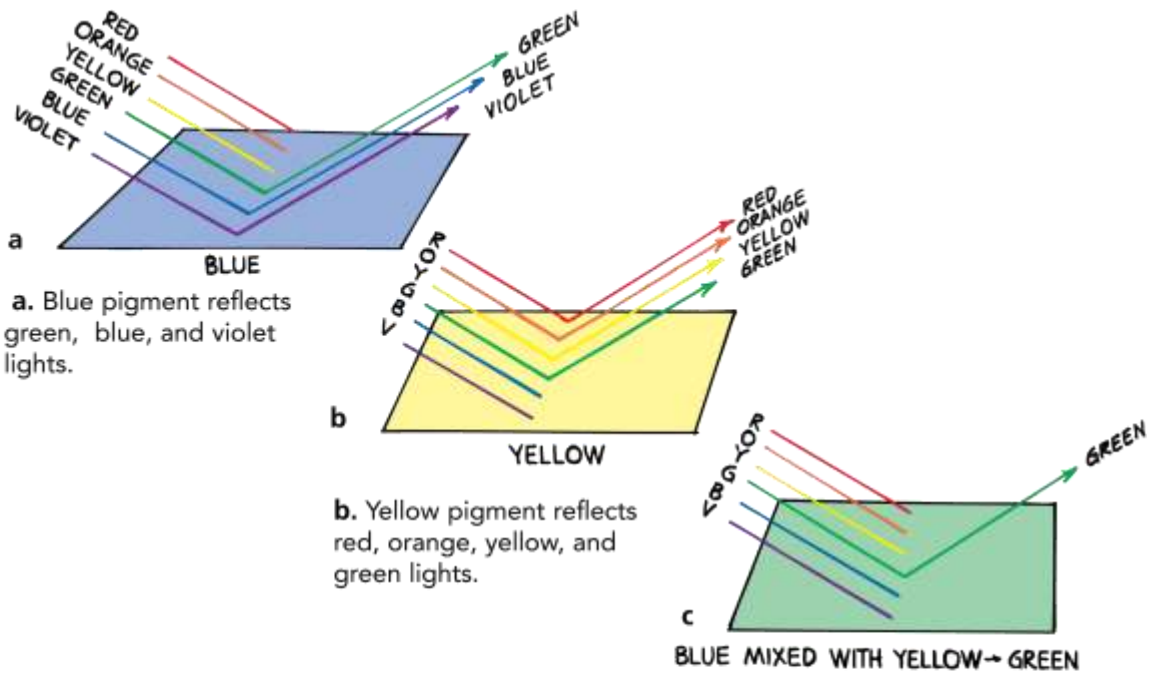
Blue paint, for example, reflects mostly blue light, but also violet and green; it absorbs red, orange, and yellow light.

Yellow paint reflects mostly yellow light, but also red, orange, and green; it absorbs blue and violet light.

28.7 Mixing Colored Pigments

When blue and yellow paints are mixed, then between them they absorb all the colors except green.

This process is called *color mixing by subtraction.*



a. Blue pigment reflects green, blue, and violet lights.

b. Yellow pigment reflects red, orange, yellow, and green lights.

c. When blue and yellow pigments are mixed, the only common color reflected is green.

28.7 Mixing Colored Pigments

Mixing colored light is called *color mixing by addition.*

When you cast lights on a stage, you use the rules of color addition, but when you mix paint, you use the rules of color subtraction.

28.7 Mixing Colored Pigments

The three colors most useful in color mixing by subtraction are:

- magenta (bluish red)
- yellow
- cyan (greenish blue)

Magenta, yellow, and cyan are the **subtractive primary colors,** used in printing illustrations in full color.

28.7 Mixing Colored Pigments

Table 28.1 Color Subtractions

Pigment	Absorbs	Reflects
red	blue, green	red
green	blue, red	green
blue	red, green	blue
yellow	blue	red, green
cyan	red	green, blue
magenta	green	red, blue

28.7 Mixing Colored Pigments

Color printing is done on a press that prints each page with four differently colored inks (magenta, yellow, cyan, and black).

- Each color of ink comes from a different plate, which transfers the ink to the paper.
- The ink deposits are regulated on different parts of the plate by tiny dots.
- The overlapping dots of three colors plus black give the appearance of many colors.

28.7 Mixing Colored Pigments

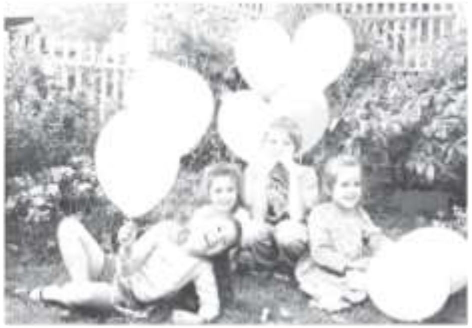
Only four colors of ink are used to print color illustrations and photographs—magenta, yellow, cyan, and black.

a. magenta

b. yellow

c. cyan

d. magenta + yellow + cyan



e. black

f. magenta + yellow + cyan + black

28.7 Mixing Colored Pigments

CONCEPT CHECK

Which visible frequencies are absorbed by a mixture of paints or dyes?

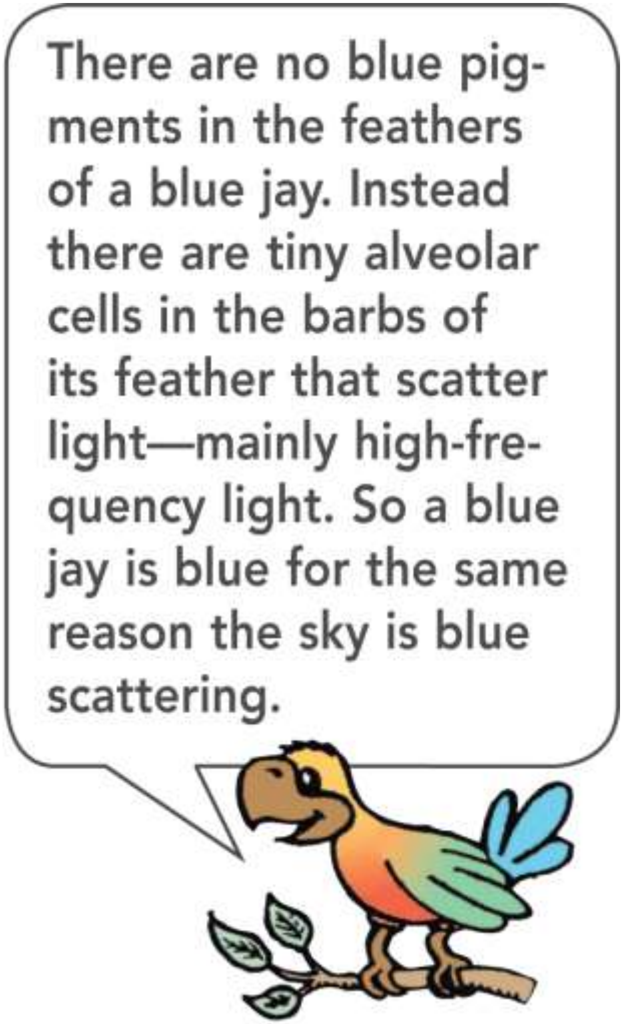
28.8 Why the Sky Is Blue

The sky is blue because its component particles scatter high-frequency light.

28.8 Why the Sky Is Blue

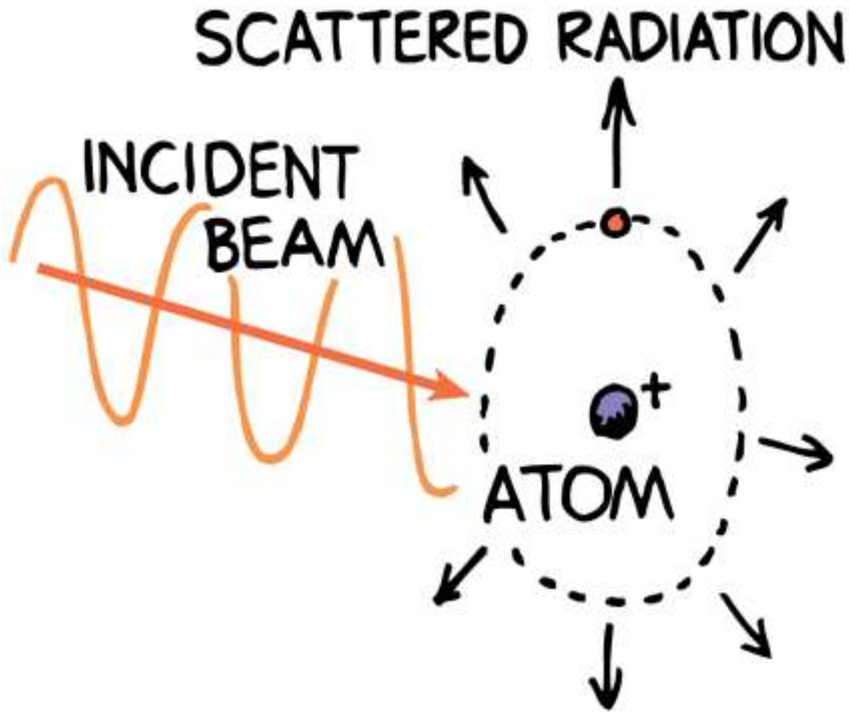
Scattering is a process in which sound or light is absorbed and reemitted in all directions.

Light is scattered by molecules and larger specks of matter that are far apart from one another in the atmosphere.



28.8 Why the Sky Is Blue

A beam of light falls on an atom and causes the electrons in the atom to move temporarily in larger orbits. The more vigorously oscillating electrons reemit light in various directions.



28.8 Why the Sky Is Blue

The Sky

Atoms and molecules reemit light waves. Very tiny particles do the same.

The nitrogen and oxygen molecules and the tiny particles that make up the atmosphere are like tiny bells that “ring” with high frequencies when energized by sunlight.

Like the sound from bells, the light is sent in all directions.

28.8 Why the Sky Is Blue

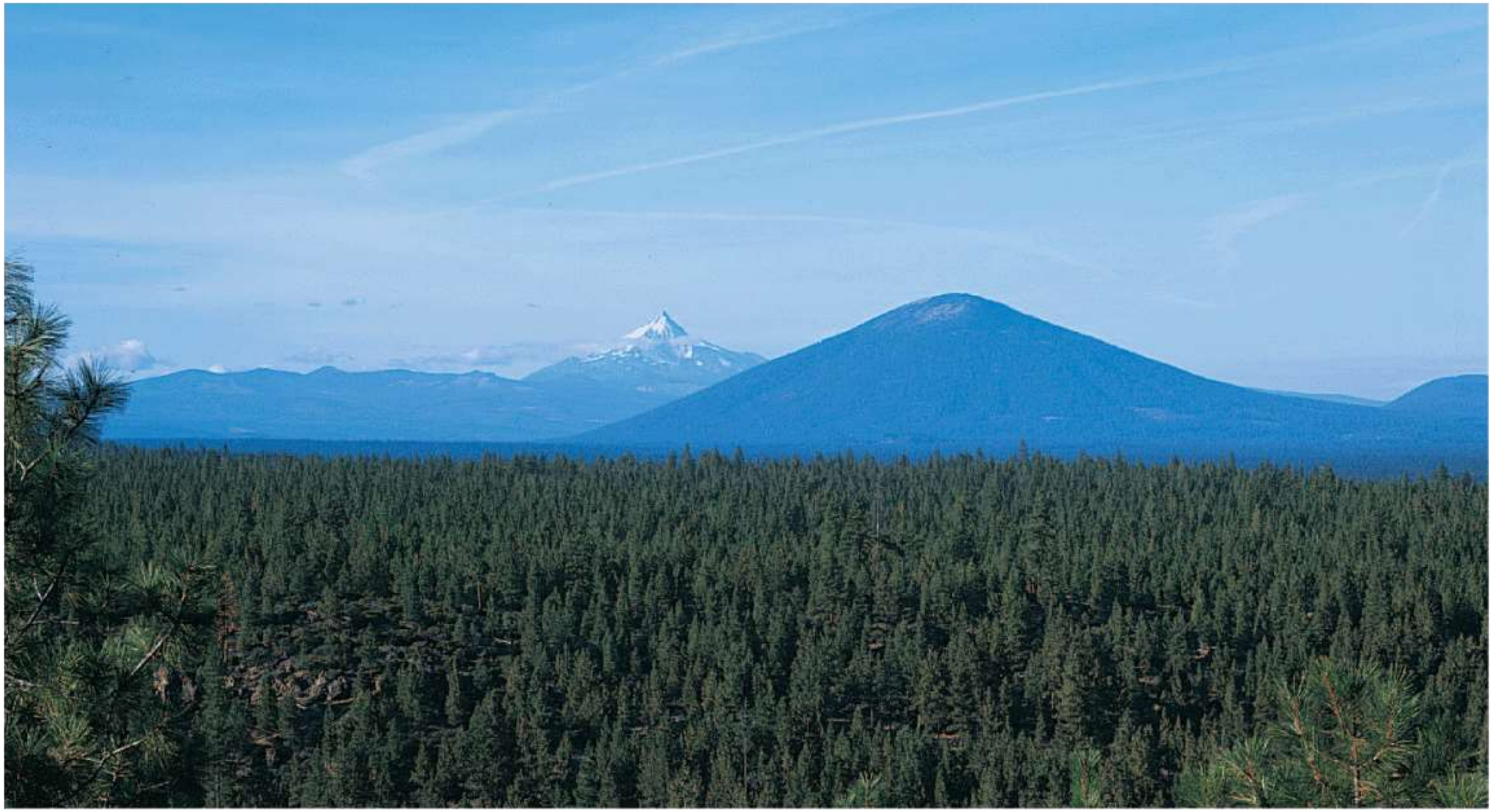
Most ultraviolet light is absorbed by a layer of ozone gas in the upper atmosphere. The rest is scattered by atmospheric particles and molecules.

28.8 Why the Sky Is Blue

Of the visible frequencies, violet light is scattered the most, followed by blue, green, yellow, orange, and red, in that order.

- Violet light is scattered more than blue but our eyes are not very sensitive to violet light.
- Our eyes are more sensitive to blue, so we see a blue sky.

28.8 Why the Sky Is Blue



28.8 Why the Sky Is Blue

The blue of the sky varies under different conditions.

Where there are a lot of particles larger than oxygen and nitrogen molecules, the lower frequencies of light are scattered more.

This makes the sky less blue, and it takes on a whitish appearance.

After a heavy rainstorm, when the particles have been washed away, the sky becomes a deeper blue.

28.8 Why the Sky Is Blue

The higher that one goes into the atmosphere, the fewer molecules there are in the air to scatter light.

The sky appears darker.

When there are no molecules, as on the moon, for example, the “sky” is black.

28.8 Why the Sky Is Blue

The Clouds

Water droplets in a variety of sizes—some of them microscopic—make up clouds.

The different-size droplets result in a variety of frequencies for scattered light: low frequencies from larger droplets and high frequencies from tinier droplets of water molecules.

The overall result is a white cloud.

28.8 Why the Sky Is Blue

CONCEPT CHECK

Why is the sky blue?

28.9 Why Sunsets Are Red

By the time a beam of light gets to the ground at sunset, all of the high-frequency light has already been scattered. Only the lower frequencies remain, resulting in a red sunset.

28.9 Why Sunsets Are Red

The lower frequencies of light are scattered the least by nitrogen and oxygen molecules.

Red, orange, and yellow light are transmitted through the atmosphere more readily than violet and blue.

Red light, which is scattered the least, passes through more atmosphere without interacting than light of any other color.

At dawn and at sunset, sunlight reaches us through a longer path through the atmosphere than at noon.

28.9 Why Sunsets Are Red

At noon sunlight travels through the least amount of atmosphere, so a relatively small amount of light is scattered.

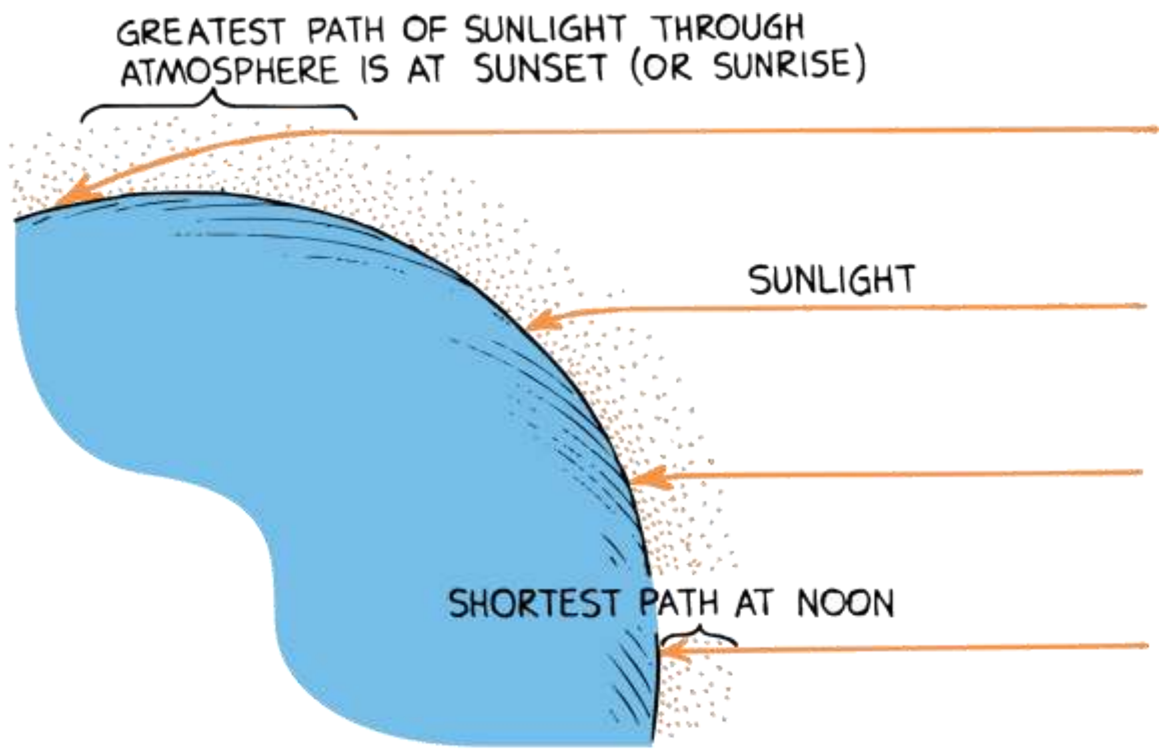
As the sun is lower in the sky, the path through the atmosphere is longer, and more blue is scattered from the sunlight.

Less and less blue remains in the sunlight that reaches Earth.

The sun appears progressively redder, going from yellow to orange, and finally, red.

28.9 Why Sunsets Are Red

By the time a beam of sunlight gets to the ground at sunset, only the lower frequencies survive, producing a red sunset.

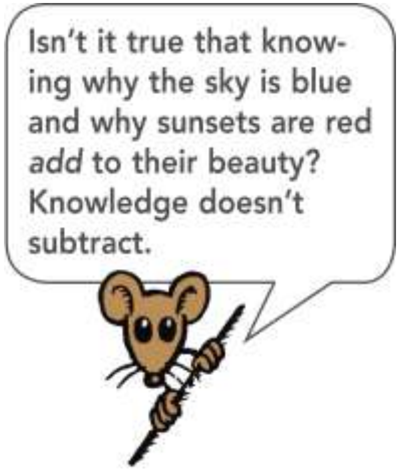


28.9 Why Sunsets Are Red

The colors of the sun and sky are consistent with our rules for color mixing.

- When blue is subtracted, the complementary color that is left is yellow.
- The subtraction of violet leaves orange.
- When green is subtracted, magenta is left.

The relative amounts of scattering depend on atmospheric conditions, changing from day to day for a variety of sunsets.



28.9 Why Sunsets Are Red

28.9 Why Sunsets Are Red

The sunset sky is red because of the absence of high-frequency light.

You see the scattered blue when the background is dark, but not when the background is bright because the scattered blue is faint.

When you look from Earth's surface at the atmosphere against the darkness of space, the atmosphere is sky blue.

When astronauts look down through the same atmosphere to the bright surface of Earth, they do not see the same blueness.

28.9 Why Sunsets Are Red

think!

If molecules in the sky scattered low-frequency light more than high-frequency light, how would the colors of the sky and sunsets appear?

28.9 Why Sunsets Are Red

think!

If molecules in the sky scattered low-frequency light more than high-frequency light, how would the colors of the sky and sunsets appear?

Answer:

If low frequencies were scattered more, red light would be scattered out of the sunlight on its long path through the atmosphere at sunset, and the sunlight to reach your eye would be predominantly blue and violet.

28.9 Why Sunsets Are Red

think!

Distant dark mountains are bluish in color. What is the source of this blueness? (*Hint:* What is between you and the mountains you see?)

28.9 Why Sunsets Are Red

think!

Distant dark mountains are bluish in color. What is the source of this blueness? (*Hint:* What is between you and the mountains you see?)

Answer:

If you look at distant dark mountains, very little light from them reaches you, and the blueness of the atmosphere between you and the mountains predominates. The blueness is of the low-altitude “sky” between you and the mountains.

28.9 Why Sunsets Are Red

CONCEPT CHECK

Why are sunsets red?

28.10 Why Water Is Greenish Blue

Water is greenish blue because water molecules absorb red.

28.10 Why Water Is Greenish Blue

We often see a beautiful deep blue when we look at the surface of a lake or the ocean.

That is not the color of water. It is the reflected color of the sky.

The color of water itself, as you can see by looking at a piece of white material under water, is a pale greenish blue.

28.10 Why Water Is Greenish Blue

Ocean water is cyan because it absorbs red. The froth in the waves is white because its droplets of many sizes scatter many colors.

28.10 Why Water Is Greenish Blue

Water is transparent to nearly all the visible frequencies of light.

Water molecules absorb infrared waves because they resonate to the frequencies of infrared.

The energy of the infrared waves is transformed into kinetic energy of the water molecules.

Infrared is a strong component of the sunlight that warms water.

28.10 Why Water Is Greenish Blue

Water molecules resonate somewhat to the visible-red frequencies. This causes a gradual absorption of red light by water.

A 15-m layer of water reduces red light to a quarter of its initial brightness. There is very little red light in the sunlight that penetrates below 30 m of water.

The complementary color of red is cyan—a greenish-blue color. In seawater, everything at these depths looks greenish blue.

28.10 Why Water Is Greenish Blue

The sky is blue because blue from sunlight is reemitted in all directions by molecules in the atmosphere.

Water is greenish blue because water molecules absorb red.

The colors of things depend on what colors are reflected by molecules, and also by what colors are absorbed by molecules.

28.10 Why Water Is Greenish Blue

think!

Distant snow-covered mountains reflect a lot of light and are bright. But they sometimes look yellowish, depending on how far away they are. Why are they yellow? (*Hint:* What happens to the reflected white light as it travels from the mountain to you?)

28.10 Why Water Is Greenish Blue

think!

Distant snow-covered mountains reflect a lot of light and are bright. But they sometimes look yellowish, depending on how far away they are. Why are they yellow? (*Hint:* What happens to the reflected white light as it travels from the mountain to you?)

Answer:

Distant snow-covered mountains often appear a pale yellow because the blue in the white light from the snowy mountains is scattered on its way to you. The complementary color left is yellow.

28.10 Why Water Is Greenish Blue

CONCEPT CHECK

Why is water greenish blue?

28.11 The Atomic Color Code—Atomic Spectra

After an excited atom emits light, it returns to its normal state.

28.11 The Atomic Color Code—Atomic Spectra

Every element has its own characteristic color when it emits light.

The color is a blend of various frequencies of light. Light of each frequency is emitted when the electrons change energy states.

Electrons have well-defined energy levels—lower energy near the atomic nucleus and higher energy farther from the nucleus.

When an atom absorbs external energy, one or more of its electrons is boosted to a higher energy level.

28.11 The Atomic Color Code—Atomic Spectra

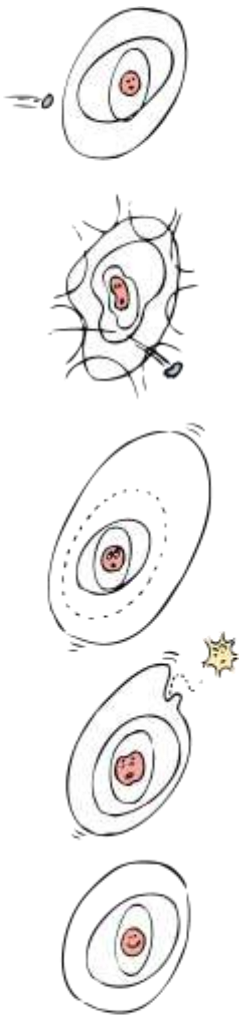
The energized atom is in an excited state. An **excited state** is a state with greater energy than the atom's lowest energy state.

The excited state is only momentary, for the electron is quickly drawn back to its original or a lower level.

When this electron transition occurs, the atom emits a pulse of light—a photon.

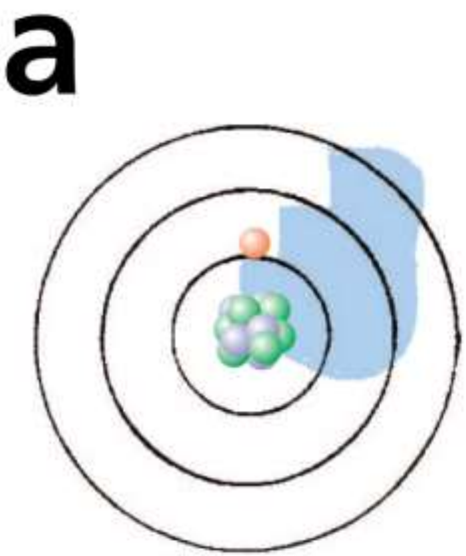
28.11 The Atomic Color Code—Atomic Spectra

Light is emitted by excited atoms.



28.11 The Atomic Color Code—Atomic Spectra

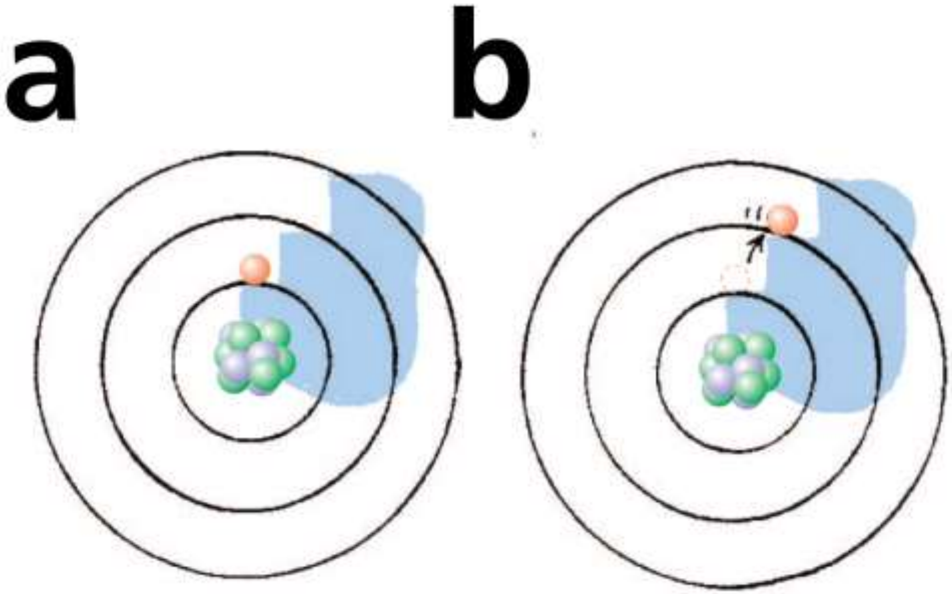
a. The different electron orbits in an atom are like steps in energy levels.



28.11 The Atomic Color Code—Atomic Spectra

a. The different electron orbits in an atom are like steps in energy levels.

b. When an electron is raised to a higher level, the atom is excited.

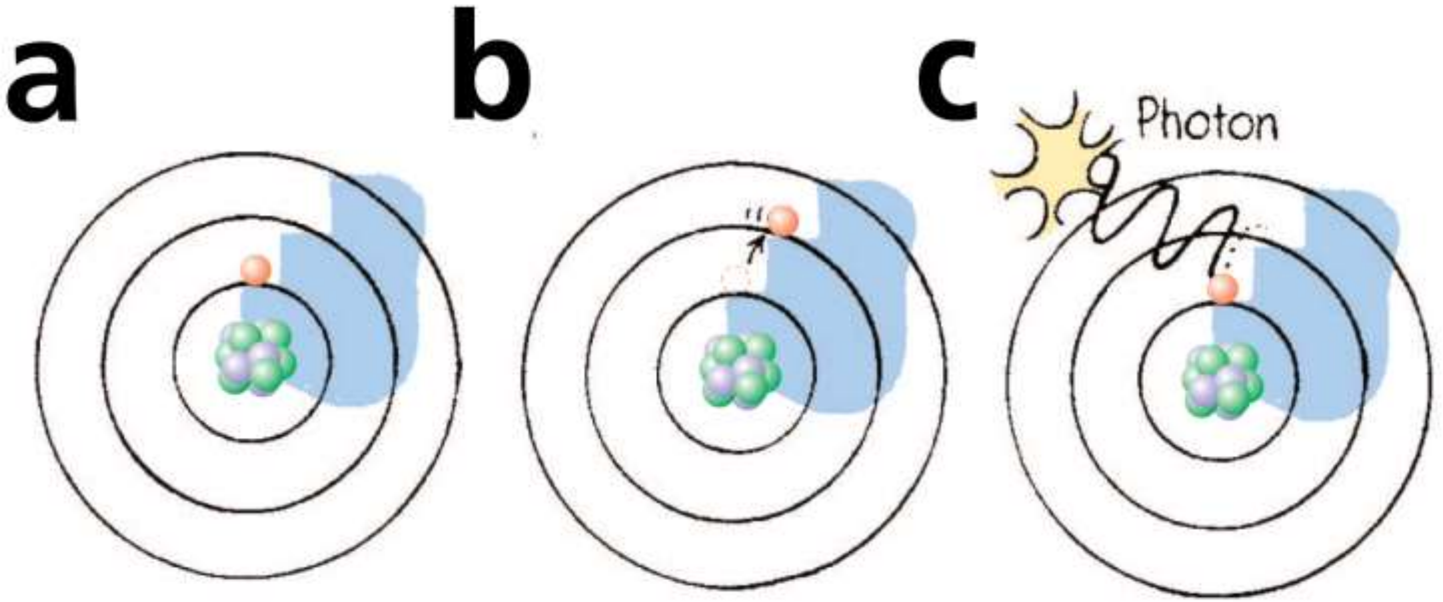


28.11 The Atomic Color Code—Atomic Spectra

a. The different electron orbits in an atom are like steps in energy levels.

b. When an electron is raised to a higher level, the atom is excited.

c. When the electron returns to its original level, it releases energy in the form of light.



28.11 The Atomic Color Code—Atomic Spectra

Relating Frequency and Energy

The frequency of the emitted photon, or its color, is directly proportional to the energy transition of the electron.

$$f \sim E$$

A photon carries an amount of energy that corresponds to its frequency. Red light from neon gas, for example, carries a certain amount of energy. A photon of twice the frequency has twice as much energy and is found in the ultraviolet part of the spectrum.

28.11 The Atomic Color Code—Atomic Spectra

When many atoms in a material are excited, many photons with many different frequencies are emitted.

They correspond to electron transitions between different levels.

Measuring the frequencies of light in a spectrum is also measuring the relative energy levels in the atom emitting that light.

The frequencies, or colors, of light emitted by elements are the “fingerprints” of the elements.

28.11 The Atomic Color Code—Atomic Spectra

Analyzing Light

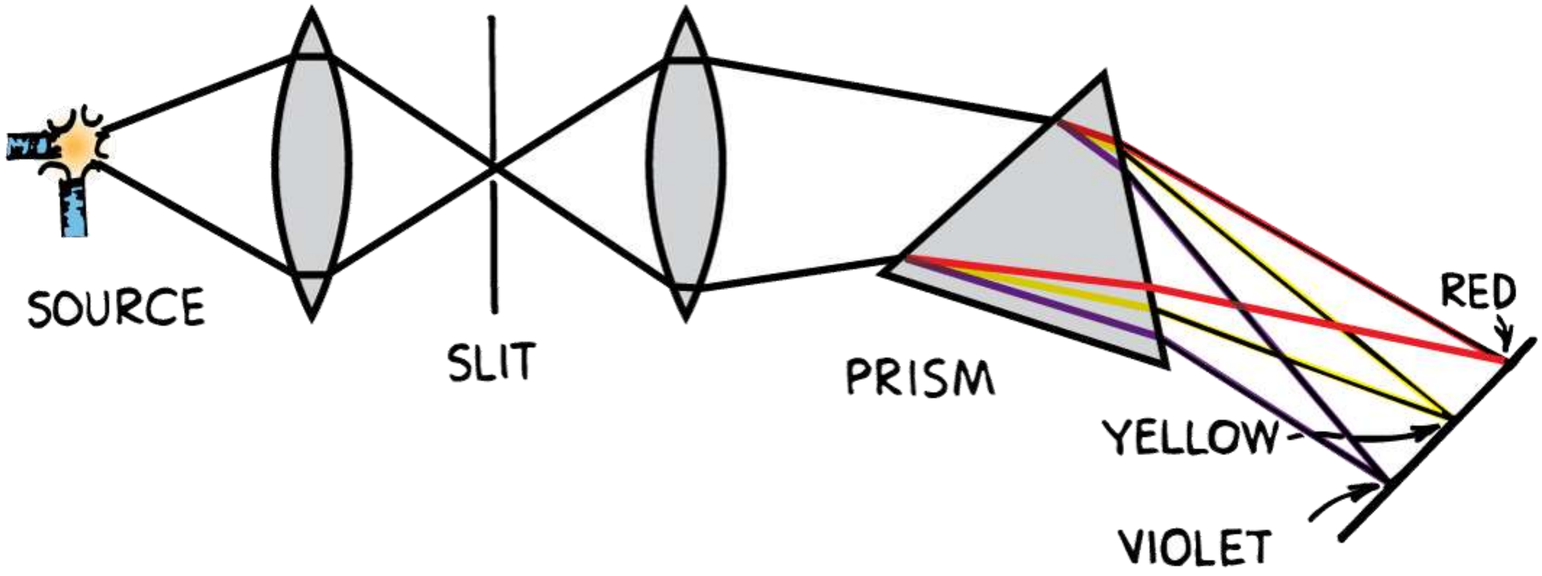
The light from glowing elements can be analyzed with an instrument called a **spectroscope.**

A spectroscope displays the spectra of the light from hot gases and other light sources. (*Spectra* is the plural of *spectrum*.)

The spectra of light sources are viewed through a magnifying eyepiece.

28.11 The Atomic Color Code—Atomic Spectra

A fairly pure spectrum is produced by passing white light through a thin slit, two lenses, and a prism.



28.11 The Atomic Color Code—Atomic Spectra

A spectroscope separates light into its constituent frequencies. Light illuminates the thin slit at the left, and then it is focused by lenses onto either a diffraction grating (shown) or a prism on the rotating table in the middle.

28.11 The Atomic Color Code—Atomic Spectra

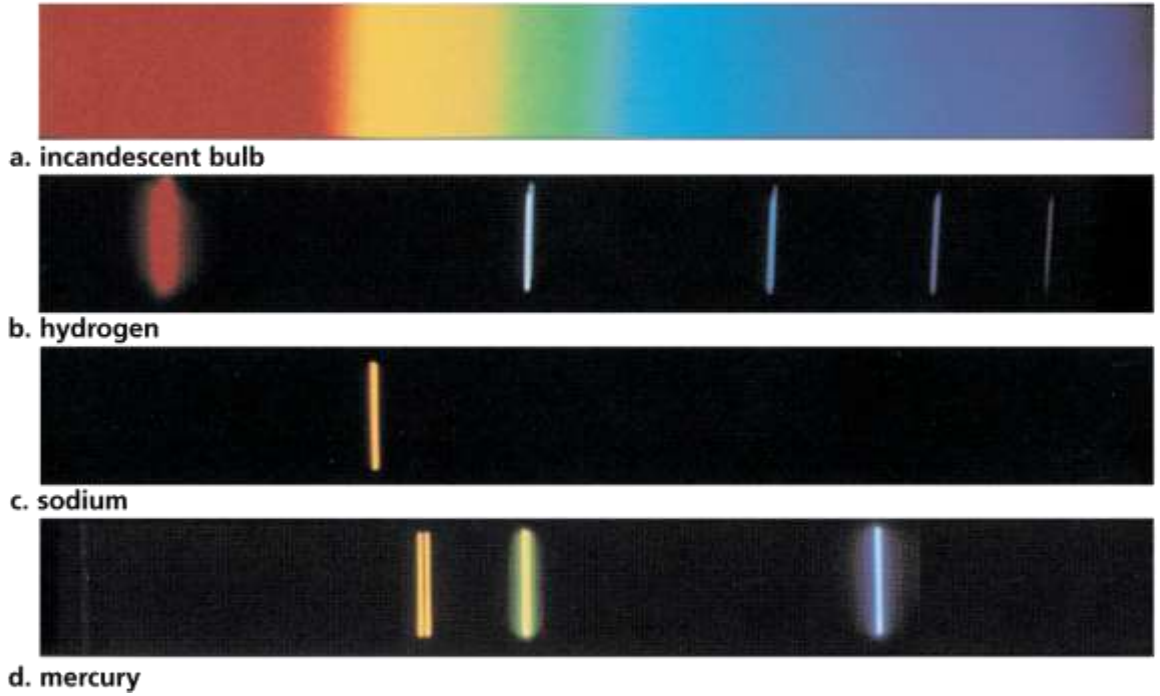
When light from a glowing element is analyzed through a spectroscope, the colors are the composite of a variety of different frequencies of light.

The spectrum of an element appears not as a continuous band of color but as a series of lines.

Each line corresponds to a distinct frequency of light in a **line spectrum.**

28.11 The Atomic Color Code—Atomic Spectra

An incandescent bulb has a continuous spectrum. Three elements: hydrogen, sodium, and mercury have different line spectra.

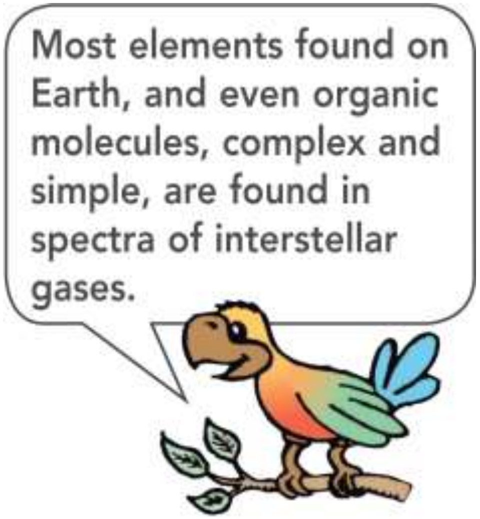


28.11 The Atomic Color Code—Atomic Spectra

Much of the information that physicists have about atomic structure is from the study of atomic spectra.

The atomic composition of common materials, the sun, and distant galaxies is revealed in the spectra of these sources.

The element helium, the second most common element in the universe, was discovered through its “fingerprint” in sunlight.



28.11 The Atomic Color Code—Atomic Spectra

CONCEPT CHECK

What happens to an excited atom after it emits light?

Assessment Questions

1. Black is
   a. a combination of all the colors of the spectrum.
   b. a combination of two or more appropriate colors.
   c. light when a prism is held upside down.
   d. the absence of light.

Assessment Questions

1. Black is
   a. a combination of all the colors of the spectrum.
   b. a combination of two or more appropriate colors.
   c. light when a prism is held upside down.
   d. the absence of light.

Answer: D

Assessment Questions

2. To say that rose petals are red is to say that they
   a. absorb red.
   b. reflect red.
   c. emit red.
   d. transmit red.

Assessment Questions

2. To say that rose petals are red is to say that they
   a. absorb red.
   b. reflect red.
   c. emit red.
   d. transmit red.

Answer: B

Assessment Questions

3. The color light that gets through a piece of transparent blue glass is
   a. blue.
   b. yellow, the opposite color of blue.
   c. actually green.
   d. red minus magenta.

Assessment Questions

3. The color light that gets through a piece of transparent blue glass is
   a. blue.
   b. yellow, the opposite color of blue.
   c. actually green.
   d. red minus magenta.

Answer: A

Assessment Questions

4. The solar radiation curve is
   a. the path the sun takes at nighttime.
   b. a plot of amplitude versus frequency for sunlight.
   c. a plot of brightness versus frequency of sunlight.
   d. a plot of wavelength versus frequency of sunlight.

Assessment Questions

4. The solar radiation curve is
   a. the path the sun takes at nighttime.
   b. a plot of amplitude versus frequency for sunlight.
   c. a plot of brightness versus frequency of sunlight.
   d. a plot of wavelength versus frequency of sunlight.

Answer: C

Assessment Questions

5. When red and blue light are overlapped, the color produced is
   a. magenta.
   b. yellow.
   c. cyan.
   d. white.

Assessment Questions

5. When red and blue light are overlapped, the color produced is
   a. magenta.
   b. yellow.
   c. cyan.
   d. white.

Answer: A

Assessment Questions

6. The complementary color of blue is
   a. magenta.
   b. yellow.
   c. cyan.
   d. white.

Assessment Questions

6. The complementary color of blue is
   a. magenta.
   b. yellow.
   c. cyan.
   d. white.

Answer: B

Assessment Questions

7. For mixing pigments or dyes, the primary colors are magenta, cyan, and
   a. red.
   b. green.
   c. yellow.
   d. blue.

Assessment Questions

7. For mixing pigments or dyes, the primary colors are magenta, cyan, and
   a. red.
   b. green.
   c. yellow.
   d. blue.

Answer: C

Assessment Questions

8. The blueness of the daytime sky is due mostly to light

   a. absorption.

   b. transmission.

   c. reflection.

   d. scattering.

Assessment Questions

8. The blueness of the daytime sky is due mostly to light
   a. absorption.
   b. transmission.
   c. reflection.
   d. scattering.

Answer: D

Assessment Questions

9. The redness of a sunrise or sunset is due mostly to light that has not been
   a. absorbed.
   b. transmitted.
   c. scattered.
   d. polarized.

Assessment Questions

9. The redness of a sunrise or sunset is due mostly to light that has not been
   a. absorbed.
   b. transmitted.
   c. scattered.
   d. polarized.

Answer: C

Assessment Questions

10. The greenish blue of ocean water is due mostly to the absorption of
    a. infrared light.
    b. ultraviolet light.
    c. polarized light.
    d. scattered light.

Assessment Questions

10. The greenish blue of ocean water is due mostly to the absorption of
    a. infrared light.
    b. ultraviolet light.
    c. polarized light.
    d. scattered light.

Answer: A

Assessment Questions

11. The frequency of an emitted photon is related to its
    a. amplitude.
    b. polarization.
    c. momentum.
    d. energy.

Assessment Questions

11. The frequency of an emitted photon is related to its
    a. amplitude.
    b. polarization.
    c. momentum.
    d. energy.

Answer: D