4.2 Properties of Visible Light

Visible light is a mixture of all the colours of the rainbow. A prism refracts light, separating the colours. A second prism can recombine the colours to form white light. Different colours of light are carried by light waves that have different wavelengths. An object looks blue in sunlight because it reflects blue and absorbs colours other than blue from the sunlight.

Key Terms

light
reflection
refraction
spectrum
visible light
wave model of light

After a rainstorm you might step outside to a dazzling display of colour in the sky (see Figure 4.9). There might be a huge arc of colours curving through the sky in front of you.

Figure 4.9 When the sunlight is behind you and the air is full of water droplets, you may be lucky enough to see a spectacular rainbow.

4-5 Rainbows of Light

Find Out ACTIVITY

The ability to see colour depends on the cells in your eyes that are sensitive to different wavelengths of light. In this activity, you will observe the colours of the light produced by a flashlight.

Materials

- flashlight
- glass prism
- water
- dishwashing liquid

What to Do

1. In a darkened room, shine a flashlight through a glass prism. Project the resulting colours onto a white wall or ceiling. What colours do you see?
2. In a darkened room, shine a flashlight over the surface of water with dishwashing liquid bubbles in it. What do you see?
3. Clean up and put away the equipment you have used.

What Did You Find Out?

1. How did your observations in each case differ? Explain where you think the colours came from.

Wave Model of Light

Scientists have developed a model of light by looking at how light behaves, and then trying to explain what they see. As you learned in earlier science studies, a *model* is a way of representing something in order to understand it better and to make predictions. One explanation of light behaviour is the **wave model of light,** which pictures light travelling as a wave. In this model, **light** is a type of wave that travels through empty space and transfers energy from one place to another, such as from the Sun to Earth. In the simplest terms, **visible light** is a wave that you can see.

Refraction of Light

What occurs when a light wave passes from one material to another—from air into water for example? If the light wave is travelling at an angle and the speed that light travels is different in the two materials, the wave will be bent, or refracted. **Refraction** is the bending or changing direction of a wave as it passes from one material to another.

White light, such as sunlight, is made up of waves having different wavelengths and frequencies. If a light wave is refracted, such as by passing through a prism (see Figure 4.10), the different wavelengths bend by different amounts. Because the longer wavelengths are refracted less than the shorter wavelengths, different colours are separated when they emerge from the prism.

Did You Know?

The fastest known form of energy in our universe is a light wave travelling through space. The speed of light is approximately 300 000 km/s. The distance 300 000 km is equal to about seven times the distance around Earth.

Figure 4.10 A prism refracts light into different colours.

Colours of the Rainbow

Does the light leaving the prism in Figure 4.10 remind you of a rainbow? Like prisms, water droplets also refract light (see Figure 4.11). In a rainbow, the human eye can distinguish a range of colours that are often described as falling into seven broad categories. In order of decreasing wavelength, and increasing frequency, these colours are red, orange, yellow, green, blue, indigo, and violet. This range of colours or frequencies of visible light is called the visible **spectrum** (see Figure 4.12). The seven colours most easily seen in a rainbow are sometimes abbreviated in the form of a person's name: ROY G BIV (**R**ed, **O**range, **Y**ellow, **G**reen, **B**lue, **I**ndigo, **V**iolet).

Word Connect

The word "spectrum" comes from Latin and means spectre, which is another word for ghost. The plural of spectrum is spectra.

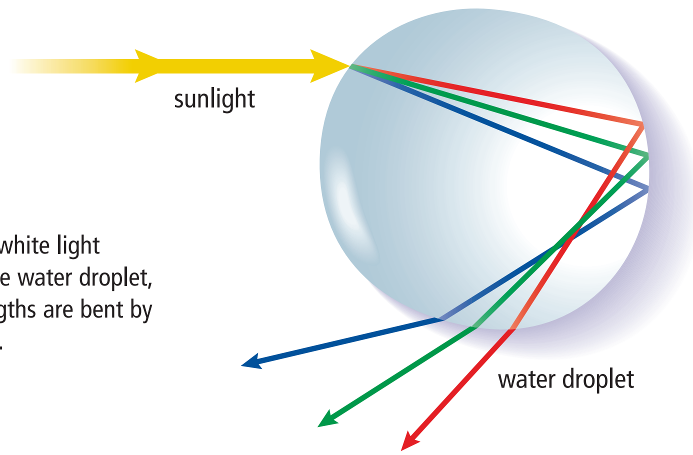
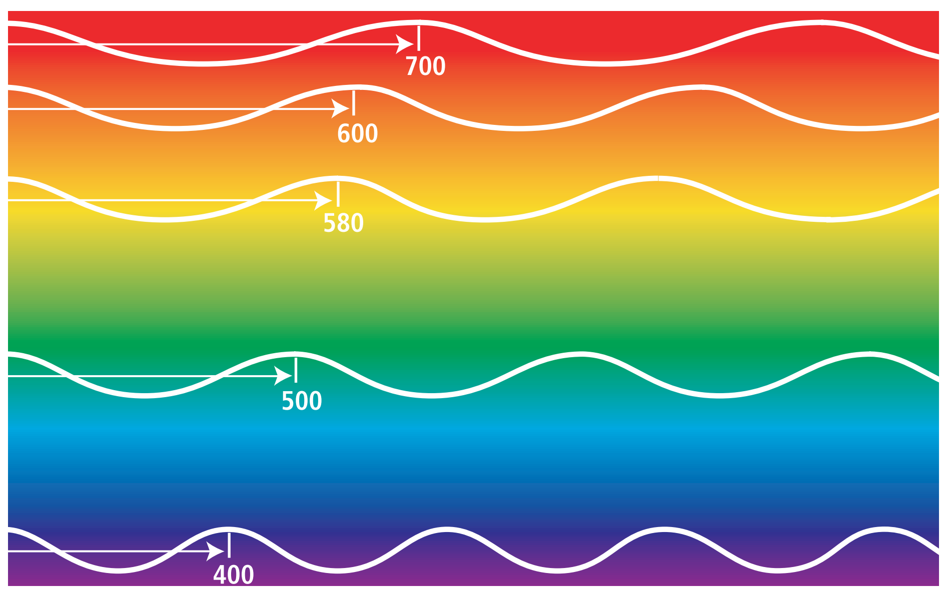


Figure 4.11 As white light passes through the water droplet, different wavelengths are bent by different amounts.

Figure 4.12 The visible spectrum is made up of different colours, each having its own wavelength. Red has the longest wavelength, about 700 nanometres (nm), while violet has the shortest, about 400 nm.



Reading Check

1. How does a prism separate light into different colours?
2. Which colour has the longest wavelength?
3. Which colour has the shortest wavelength?
4. Which colour has the highest frequency?
5. Which colour has the lowest frequency?

Producing the Visible Spectrum

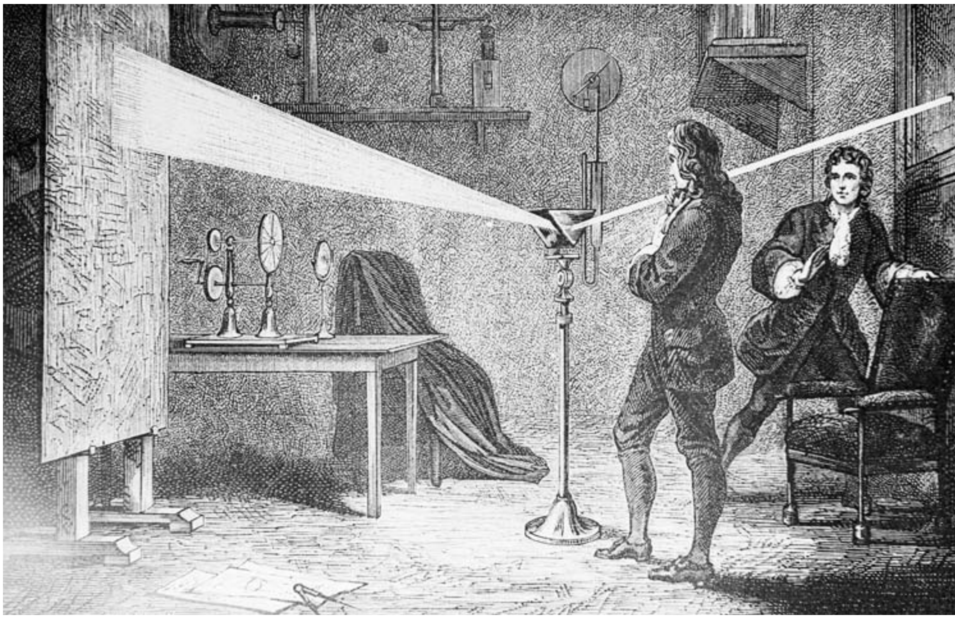


Figure 4.13 Sir Isaac Newton

At one time, people believed that colour was something added to light. When white light struck a green leaf, people believed that the leaf was adding green to the light. Is colour picked up when light strikes a coloured object? Or does light itself contain colour? In the 17th century, English scientist Sir Isaac Newton (see Figure 4.13) conducted a famous experiment in search of the answer to these questions.

Newton placed a prism so that a thin beam of white light could pass through it. When white light travelled through the prism, he saw bands of colour emerge. He observed that each band of colour was refracted at a different angle. Newton concluded that the prism was not the source of the colours. The different colours must have been present already in the white light.

Next, Newton passed these colours through more prisms. This time, only white light emerged, as shown in Figure 4.14. In this way, Newton showed that colour was a property of visible light. He proposed that white light such as sunlight is the result of mixing together all the different colours of light. Figure 4.15 shows what happens to the recombined light if one colour is removed from the spectrum.

Did You Know?

The Sun's maximum output is in the red to yellow part of the visible spectrum. Plants have evolved to make maximum use of these wavelengths. Various kinds of chlorophyll, the pigments that capture sunlight during photosynthesis, absorb red and yellow pigments especially well.

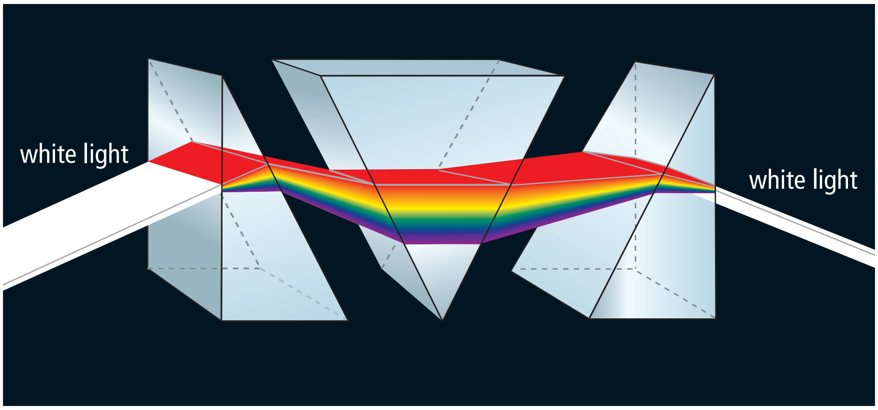


Figure 4.14 A prism causes white light to split into a spectrum. Two more prisms can recombine the colours, producing white light again.

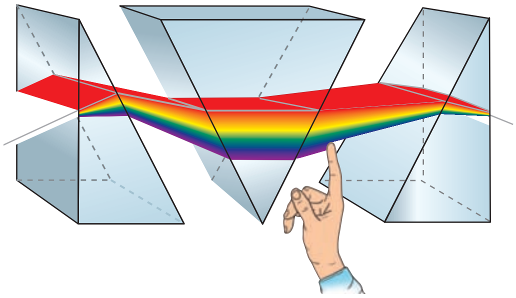


Figure 4.15 If one colour is removed from the spectrum, the recombined light is no longer white.

Colour and Reflection

Reflection occurs when a light wave strikes an object and bounces off. When sunlight strikes coloured clothing, some colours are reflected while other colours are absorbed (Figure 4.16). Only the reflected colours can be seen.

Figure 4.16 Yellow cloth reflects yellow and absorbs other colours. Red cloth reflects red and absorbs other colours.

internet connect

Only three numbers are needed to specify every colour that can be produced on a computer screen. People who create web pages sometimes specify colours this way. For more information go to **www.bcscience8.ca**.

Why does a bright red shirt look black when it is placed in a dark room? The answer is that since a shirt does not produce its own light, but merely reflects the light in the room, the shirt appears to be black when there is no source of light.

Only three colours of light, such as red, green, and blue, are needed to produce all the colours of the rainbow. The colours red, green, and blue are sometimes called the additive primary colours. They are called additive colours because adding all three together in the proper amounts will make white light, as shown in Figure 4.17A. The light of two additive primary colours will produce a secondary colour. The three secondary colours are yellow, cyan, and magenta (see Figure 4.17B).

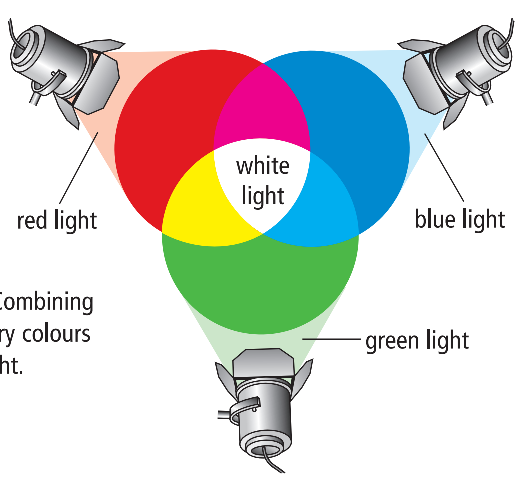


Figure 4.17(A) Combining the additive primary colours produces white light.

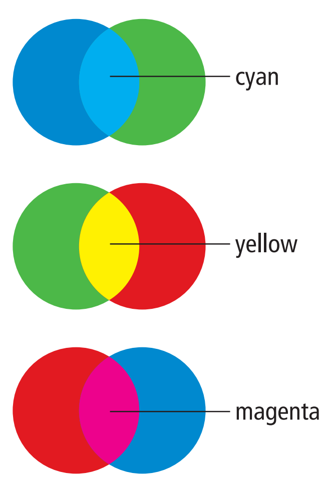


Figure 4.17(B) Each secondary colour is created by combining two of the primary additive colours.

Figure 4.18 When light waves reflect from the ridges on a CD, the light waves can add together to make some colours brighter. Light waves can also cancel each other, removing some colours.

Explore More

It takes three colours of light to produce white light, but they do not have to be the primary colours. For example, the secondary colours of yellow, magenta, and cyan, could do the same job. Red, green, and blue (RGB) are usually used in computer monitors, while cyan, magenta, yellow, and black (CMYK) are usually used in printers. Find out why these colour systems are used. Visit **www.bcscience8.ca.**

Reading Check

1. Why did Newton conclude that the prism was not the source of colours?
2. How could you use primary colours to produce secondary colours?
3. Why does a green shirt look green?
4. Why does a blue hat look black when it is in a dark room?

4-6 Colour Your Rainbow

Find Out ACTIVITY

In this activity, you will create a rainbow using a bright light source and a CD. Then you can "colour your rainbow" as you observe it through different coloured filters.

Materials

- CD
- coloured filters
- coloured pencils or felt pens
- white light source

What to Do

1. Hold a CD up to a light and adjust it until you can see a rainbow of colours. Keep in mind that different individuals see colours differently.
2. Select a red coloured filter. Hold it between your eye and the CD. Then try holding the filter between the CD and the light source. Use coloured pencils or felt pens to draw what you see in colour.
3. Repeat with several different coloured filters.

What Did You Find Out?

1. Compare your findings with your classmates' findings.
2. Write a short paragraph that answers the following questions:
   (a) Which colours do you see when you look at the rainbow made from white light? (Remember, you might see more or fewer colours than a classmate.)
   (b) What is the effect on the appearance of the rainbow when a red filter is held in front of it?
   (c) Does it make any difference whether the filter is held between the CD and your eye or between the CD and the light source? Explain.
   (d) What does a coloured filter do to the light coming from the light source?

Career Connect

Concert Lighting Designer

Garry Waldie

It is pitch black when you hear the first notes of that hit song. Suddenly the lights come up and your favourite band is in the spotlight. Garry Waldie has designed, programmed, and run thousands of light shows at concerts. He has worked with Justin Timberlake, Metallica, John Mellencamp, Christina Aguilera, P. Diddy, and many more.

Q. How did you become a lighting designer?

A. As a kid, I was always going to the theatre. I managed to get on tour after working with some local acts. Then I got to do the lighting for the opening act. Eventually I worked up to lighting the main act, and today I do about 200 shows a year.

Q. Why is lighting important to a concert?

A. It sets the mood and enhances the whole show.

Q. How do you create a light show?

A. First I listen to the material and come up with a concept for each song. I pitch the concept to the band and find out what else will be happening at the same time, such as live feed video. Once the concept is firm, we videotape the band doing the songs. We work through the night programming the lights so they give the songs the right feel. We can usually program two to four songs per night. Today you need a lot of programming skills so you can use computer-aided design programs such as AutoCAD to design the light show. You also need to understand how the lights and lenses work.

Q. What do you need to know about lenses and prisms to be able to design a light show?

A. These days we usually use automated lights that have all the different lenses and prisms integrated into one unit. The lenses spread the beam size to make it cover a larger or smaller area. Prisms break up the patterns that we put in the lights. These "gobo patterns" can be anything from a simple spiral to the name of a band or hockey team.

An example of gobo patterns

Questions

1. How are the lights for a concert controlled?
2. Why does the designer need to understand different lenses and prisms?
3. Why would a computer-aided design program be good to learn if you wanted to become a lighting designer?

Check Your Understanding

Checking Concepts

1. You can understand some properties of light by using the wave model.
   (a) What is a model in science?
   (b) What is light, as described by the wave model?
2. Which has a longer wavelength, red light or green light?
3. Which colour refracts more in a prism, yellow or blue?
4. Explain how a prism is able to break sunlight up into its component colours.
5. Contrast refraction and reflection.
6. (a) What is the minimum number of coloured lights needed to produce all possible colours, including white?
   (b) List some colours that will work together to produce white light.
7. What do the letters B and V stand for in the acronym ROY G BIV?

Understanding Key Ideas

8. A light beam that is composed of red and green light is passed through a red-coloured filter.
   (a) What is the colour of light that passes through the filter?
   (b) What colour is absorbed by the filter?
9. Explain how a shirt can look green even though the light falling on it contains red, blue, and green.
10. Describe a way to use two prisms to remove the colour yellow from a beam of sunlight.
11. Make a concept map that links wavelength, frequency, amplitude, brightness, and colour.
12. (a) A certain electromagnetic wave has a wavelength of 200 nm. Is this wave visible to humans? Explain your answer.
    (b) A micrometre (μm) is one millionth of a metre. State the wavelength of the wave
    (i) in micrometres
    (ii) in millimetres
    (iii) in metres
13. Suppose that a device is built that converts colour into sound. For example, if this device detects the colour yellow, it will produce the tone equivalent to middle C on the piano. If it detects blue, then it will produce the same tone one octave higher in pitch (C above middle C).
    (a) How will the sound for red light compare with the two tones mentioned above?
    (b) How will green, orange, and violet compare?

Pause and Reflect

Some green paints are green because the pigment is made out of green chemicals. Other green paints are made by blending two or more non-green pigments such as blue and yellow. Why do you think that many artists prefer to blend their own green paints rather than use ready-made green paints?