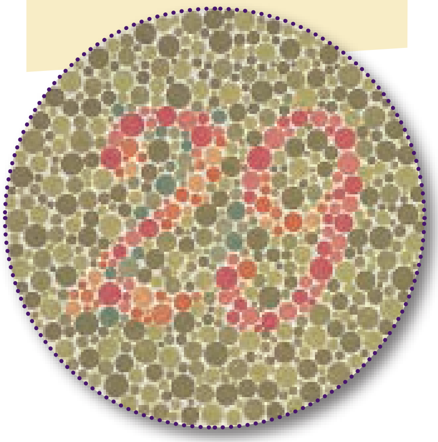
Scifile

When the nerve cells in the retina do not respond normally to colour, we say that a person is colour blind. There are many different types of colour blindness, but the most common is confusion between shades of red and green. An Ishihara test card contains many spots of different colours and intensities. A person with normal vision will see a particular number clearly, while someone with colour blindness will see nothing except random coloured dots. While being very rare in females, about 8% of males have problems with colour vision. Can you see a number in the dots? (Note that the colours in this book might not be accurate enough to assess your colour vision.)



Combinations of coloured spotlights can be used to add colours, and filters may be used to subtract colour from other combinations. An object can appear quite different under varied lighting conditions.

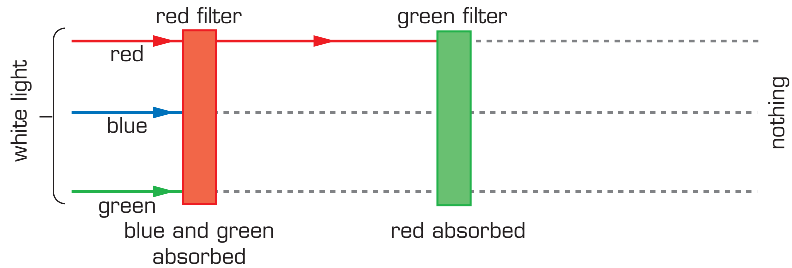


Figure 4.43
The red filter absorbs everything but red and the green filter absorbs the red, so nothing gets through the filters.

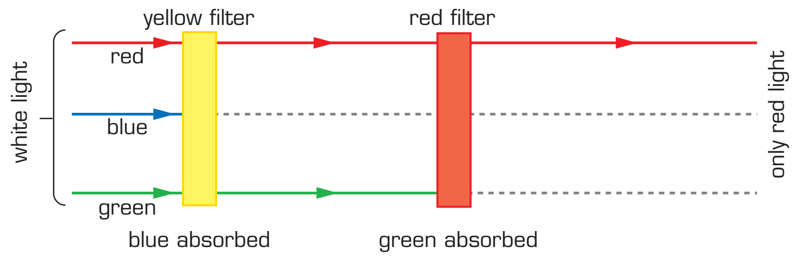


Figure 4.44
The yellow filter passes the red and green, but the red filter absorbs just the green, allowing only the red light through.

SCIENCE @ work

EXPERIMENT 4.7

Light up my life!

Aim

To investigate the addition of coloured light and explore the behaviour of coloured filters.

Materials

- spectroscope
- power supply
- coloured cards
- ray box
- coloured filters
- white paper

Method

1. Look at a light source through a spectroscope. Make a sketch and describe what you see.
2. Connect the ray box to a power supply and place it on a sheet of white paper. Place the three primary filters (red, green and blue) in each of the three separate sections in the light box. Adjust the mirror flaps so that the colours can overlap. Change the position of the filters to complete Table 4.2. Record what you see where all three colours overlap.

3. Replace the primary filters with the secondary filters (yellow, cyan and magenta) and change their positions to complete Table 4.3.
4. Switch the ray box off and remove the filters. Select a red, green, blue and yellow card from the ray box kit. With one eye (close the other), look at each of the cards through each primary filter. Record the colours you see in Table 4.4.

Table 4.2

Addition of primary colours	Colour produced
red + green	
red + blue	
green + blue	
red + green + blue	

Table 4.3

Addition of secondary colours	Colour produced
yellow + cyan	
yellow + magenta	
cyan + magenta	

Table 4.4

Colour of card	Colour card appears when viewed through these filters		
	Red	Green	Blue
Red			
Green			
Blue			
Yellow			

Results and Discussion

1. Sketch and describe what you could see through the spectroscope.
2. Can you explain where the colours came from?

Evaluation

1. Were the conditions in your laboratory such that you were successful in your experiment?
2. Is there any other colour combination that you would like to test or did you discover any results that surprised you?
3. Prepare a SWOT analysis of this experiment.

science

in action

BLUE SKIES AND RAINBOWS

Imagine waking up on a summer morning to a bright green sky. Sounding unlikely? Why is the sky blue?

Light is scattered by billions of tiny particles in the atmosphere. All colours of light are scattered, but shorter wavelengths of light scatter more easily. Blue light is scattered about ten times more often than red light, explaining why our eyes see the sky as reflected blue light. You may wonder what happens at dawn and dusk. At these times, the Sun appears low in the sky. Light travels to us through a thicker layer of atmosphere than in the middle of the day. As a result, the blue wavelengths of light have already scattered away, and we see longer wavelength red light.

A blue sky may be one thing, but a rainbow is something else! Can you explain it? It is a complex process involving refraction, total internal reflection, and the dispersion of sunlight within water droplets!

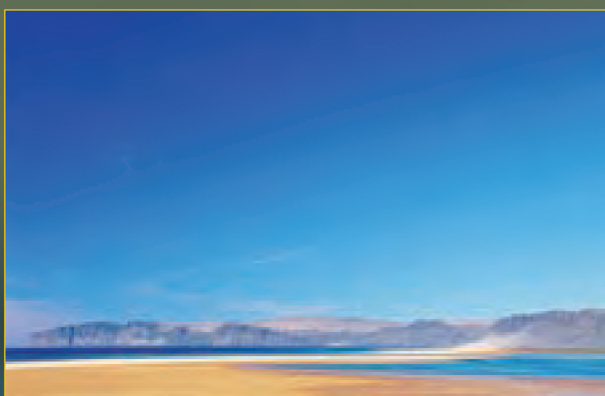


Figure 4.45
Why is the sky blue?

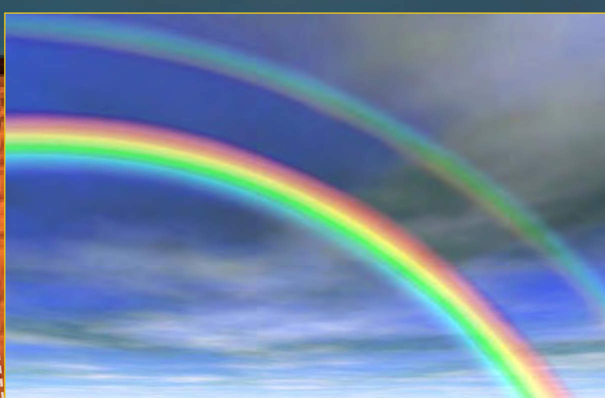


Figure 4.46
A rainbow is a spectacular example of natural dispersion.

A rainbow can only be seen under specific conditions, such as having the Sun behind us, usually low in the sky and water droplets from rain, in front. White light bends when it passes through a rain droplet. Because each wavelength of light will be bent slightly different amounts, this white light is split into all of the colours that make it up. This light is then totally internally reflected back out of the water droplet, as shown in Figure 4.47. Red light reflects back at an angle of about 42° to the incoming ray, whereas violet reflects back about 40°. This means that we always see the red part of the the sky than the violet part. The other colours lying between spectrum are reflected back at angles between these two value

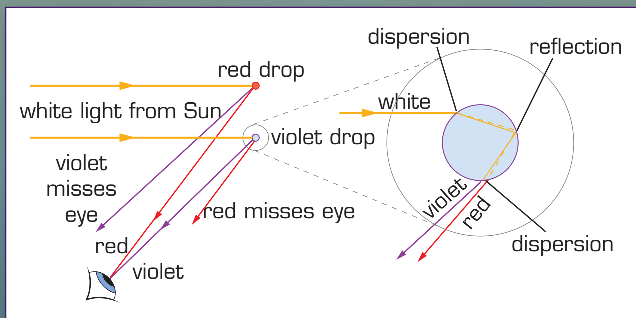


Figure 4.47
Light is splits into the colours of the spectrum as it is enters a water droplet. This light is totally internally reflected at the back surface of the droplet and is refracted once again as it leaves the droplet.

On some occasions, light is reflected twice within the droplets of water to produce a second rainbow, like a mirror image above the first. No two people ever see exactly the same rainbow, because the rainbow that you see is formed by a particular set of droplets that direct rays of the particular colour towards your eyes. The droplets that form the orange part of your rainbow may produce the blue section of the rainbow seen by a friend standing next to you. So next time you see a rainbow, you can know that it is unique!

BLUE SKIES AND RAINBOWS questions

1. (a) Why does white light separate into the spectrum of colours when forming a rainbow? Include a diagram in your answer.
   (b) Why is red always seen at the top of the rainbow?
2. (a) Why does a rainbow only form when the Sun is at a particular angle?
   (b) What would happen at other times?
3. Try making your own blue sky and red sunset. Pour yourself a glass of water and then darken the room you are in. Now add some powdered milk to your water. Shine a torch on the mixture from side-on.
   (a) Can you see light being reflected from the particles of powdered milk?
   (b) What colour is this light?
   (c) Explain what you would expect to see with respect our blue skies.
   (d) Can you think of a way you could model what happens at sunset? Try to work this ou equipment and write a report on your discoveries.
   (e) How well did your new model work? What changes did you need to make?

SCIENCE @ work

ACTIVITY 4.8

Lighten up

You are to produce a play for your school. Some of the scenes are set in bright sunshine, others inside a dark, cold, creepy dungeon, and another at midnight on a moonlit night. Write a set of instructions for the lighting technician telling her which coloured lights to use to make the stage look most effective. If you have the facilities, work in a group to perform a scene from a dramatic production and design a plan for the most effective lighting. Different groups of students could design lighting for the same scene, and classmates could give feedback to each group about which techniques and combinations were the most effective.

1. Write a report, in a format of your choice, outlining the principles of colour that you employed in your scene and anything you learnt through completing this task.
2. How effective was your presentation? Did the audience understand how the lighting worked?
3. Complete an evaluation of the performance of your group.

questions 4.3

1. Explain to the person next to you the meaning of dispersion and then together write a list of at least five places where you could notice this effect.
2. Copy and complete Table 4.5.

Table 4.5

Object	Colours reflected	Colours absorbed
Red convertible		
Yellow banana		
Blue jeans		
Black bowling ball		
White dove		
White light		

3. Many people who live in hot climates wear white clothing. Explain why this would be an advantage in such an environment.
4. (a) What colour would a green frog look under yellow light?
   (b) Would any type of light make it appear black? Explain.
5. (a) If red light passes through a magenta filter, what colour emerges?
   (b) If a green filter is placed behind the magenta filter, what will the result be?
6. (a) Create a rhyme or jingle to help students remember the colours of the spectrum.
   (b) If light of all of these colours was shone together, what would you see?
7. (a) Have you ever noticed that lighting effects can be used to make a product seem more appealing? Conduct some research about the type of lighting that is used in a supermarket's meat department. Investigate the colour of lights used and if possible, compare how this product would appear under white fluorescent lighting. Write a summary of your findings.
   (b) In addition to lighting effects, some butchers or supermarkets actually add a colouring to make minced meat appear pinker and fresher. What are your thoughts on this process? Conduct your own investigation to research this further and present your answer as an issues map.
8. Gina and Clare decide to wear their new clothes to the night club. Gina looks stunning in her red top, blue pants and black shoes, and Clare is resplendent in her white top, yellow skirt and black shoes. The lighting inside the night club is nearly all red and blue. What would Gina's and Clare's clothes now look like?
9. Huong and Callum are relaxing on a beach. Huong is wearing red-tinted glasses and Callum is sporting a yellow pair. A toddler named Emily runs past them in a wobbly fashion, wearing a white T-shirt, green shorts and magenta cap. Describe how each boy will see Emily. You could use coloured pencils to draw your answer if you are feeling artistic.

10. Pigments are chemicals that absorb some colours of light and reflect others. The colour of the reflected light determines the colour of the object containing the pigment.
    Pigment X reflects mostly orange light with a little red and yellow, but absorbs all green, blue, indigo and violet light. Pigment Y reflects mostly green light, with some blue and yellow, but absorbs all other colours. If you dye a pair of your favourite socks in a mixture of X and Y, what colour will they become?
11. Working in a small group, allocate each group member a primary colour. Plan a short dramatic presentation that you could perform to teach younger students the principles of additive mixing of light.
    (a) At the end of the presentation ask the students what they learnt about light. Record their answers in a table.
    (b) From their answers, how well do you think the students understood your presentation?
    (c) How could you improve your performance?
    (d) Complete an evaluation of your group's performance.
12. Multilevel half-tone printing is a more advanced technique of colour printing than the method utilising subtractive colour mixing that was mentioned earlier in the SciFile on page 105. Research more about this process and how it operates. Present your results in a format of your choice.

4.4 Using light

Polarisation

Light travels as a **transverse wave**. This type of wave vibrates at right angles to its direction of motion as was shown in Figure 4.3. Imagine a cork bobbing up and down in the sea as an ocean wave travels at right angles to this vertical movement, leaving the cork behind as the energy of the wave travels ahead. To better understand the wavelike motion of light, have a friend hold one end of a piece of rope, and quickly move the other end up and down. You have produced what is called a **polarised** transverse wave. This is a wave that vibrates in a single plane. If you move your hand quickly back and forth horizontally, you can create another wave that is polarised at right angles to the first. Can you make a wave that is not polarised in one direction?

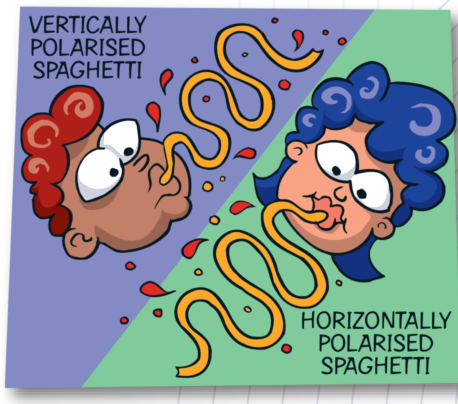


Figure 4.48
The Polarised Wave Fan Club at lunchtime.

Figure 4.49
When light reflects from certain very smooth surfaces, suc… partially polarised. It … can see the direction … which assists them i… of the Sun, even on …

Figure 4.50
Polaroid sunglasses filter polarised light.

Light can be polarised by a polaroid filter. This filter can be thought to have long molecules within it that align themselves in a particular direction. Only light waves that vibrate in the same direction as this alignment are allowed through the filter, the waves vibrating in other directions being absorbed. Filters like these are used in the polarising lenses of sunglasses. They absorb much of the light energy, but allow enough light through for us to still see clearly.

SCIENCE @ work

ACTIVITY 4.9

Cool shades!

If you have two polarising filters, you can see how they work in cutting out vibrating planes of light. First, hold up one of the filters and look at a well-lit object through it. Slowly turn the filter. Do you observe any changes? Now, hold a second filter over the first as you look at the object. If you slowly turn one filter, what happens? Record any changes that you notice as you turn one filter through 360°. Try to explain what is happening, and how these processes are used in sunglasses.

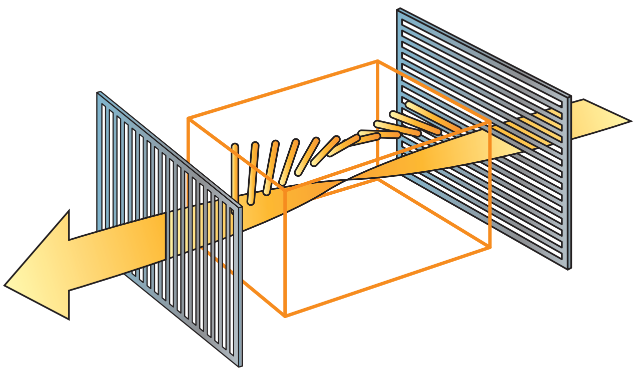


Figure 4.51
The liquid crystal in a laptop screen lies between two glass plates. One plate has a series of horizontal grooves, while the other consists of a series of vertical grooves. The liquid crystal trapped inside likes to align itself with these grooves. This means that its orientation gradually changes from being vertical, where closest to the vertical grooves, spiralling to a horizontal orientation closest to the horizontal grooves. This is called a twisted cell of liquid crystal and allows a calculator or computer screen to rotate the plane of polarised light. This light is used to illuminate pixels on the laptop screen.

Scifile

Light reflected from calm water could make it difficult for birds to see clearly. However, it is polarised in a horizontal direction. Sunglasses work because they block these horizontal rays. Scientists believe that a pelican's eyes work like a pair of sunglasses, with a polarising filter to cut out this reflected glare.

Scifile

In the field of light scattering, ellipsometry, the pattern in which polarised light scatters from a surface, is studied. This can provide valuable information about the roughness of the scattering surface or any defects present, for example in the manufacture of CDs or semiconductors. The surface of various types of paper used for printing, such as those with a glossy or matt finish can be compared using this technology to create the better quality print.

Looking in 3D

Have you ever used 3D glasses, or perhaps seen a movie that is 'in 3D?' In order to see in three dimensions, our brain must receive two images of the one thing, but these images must be taken from a slightly different point of view. This happens naturally with your eyes, because they are spaced 6 or 7 cm apart, which means that the view from each eye is slightly different. In the case of a 3D film, a scene that has been filmed from two similar (but different) angles is projected onto the screen in two colours, which are usually red and blue. By putting on your 3D glasses, with one red and one blue filter, each eye then sees one version of how it was recorded. Your brain is able to interpret this information of the two scenes to create a 3D reconstruction.

Polarisers can also be used to generate 3D imag Figure 4.52b. In this system, one eye views a pictu polarising filter and the other sees a slightly differ horizontally polarising filter. In the same way as p your brain combines these to create a 3D image.

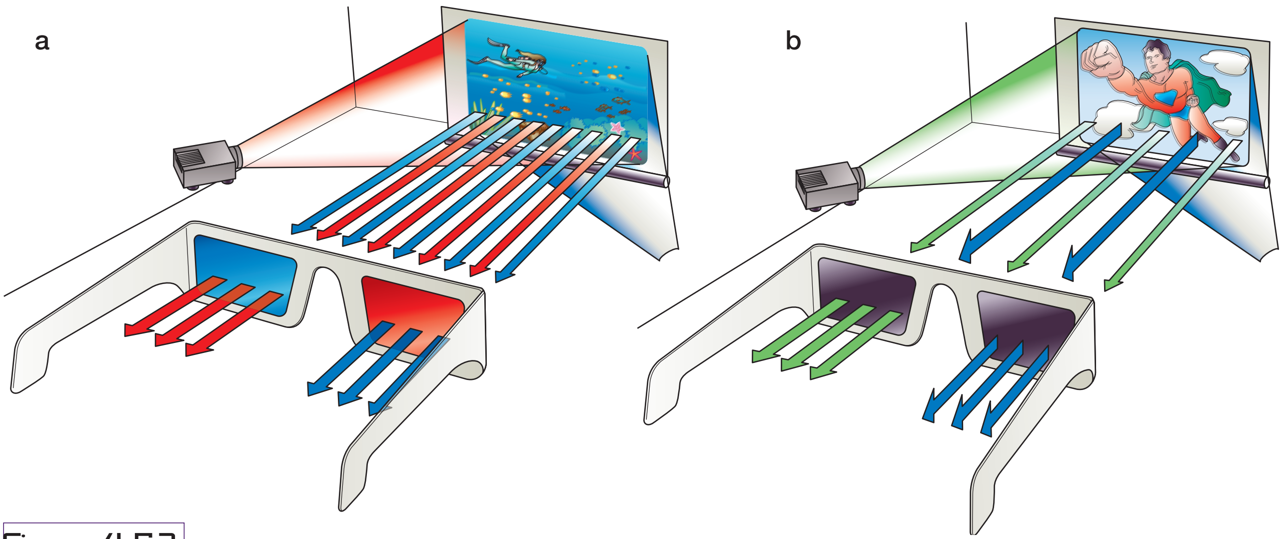


Figure 4.52
Look out, it's heading straight for you! **a** 3D glasses. **b** Polarising glasses.

Lasers

We rely upon lasers to scan items at the shops, to borrow a book at the library or to play a CD or DVD. What is so special about laser light?

The word laser stands for **l**ight **a**mplification by **s**timulated **e**mission of **r**adiation. To understand what this means, consider an electric light bulb. When it is turned on, the light emitted from it is made up of a mixture of different frequencies, which are distributed at random. The waves producing this light are not in step with each other. That is, the crest of one wave would not be lined up with the crest of all of the other waves. This light is chaotic, and is said to be incoherent. In contrast, all of the light waves emitted from a laser beam have the same frequency (so the same colour). It is said to be monochromatic, and has light beams that are in phase, or all in step with each other.

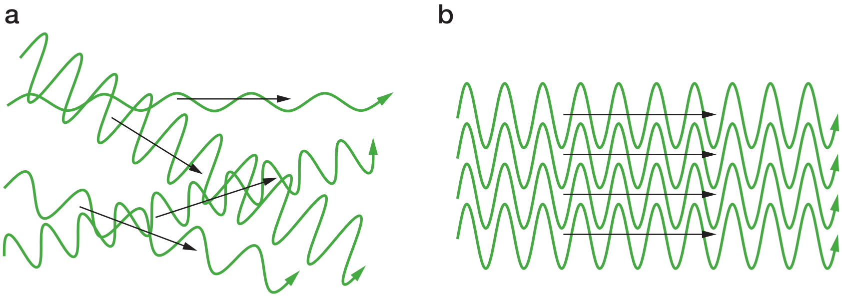


Figure 4.53
a Waves of light from an ordinary (non-laser) light bulb are incoherent, **b** whereas a laser produces a concentrated beam of light that is coherent.

This light is said to be coherent. It produces a very powerful beam that can assist us in many applications, and can even burn through steel if focused correctly.

Lasers can be developed that have a range of energies for a variety of uses. A laser beam has been bounced off a mirror placed on the Moon and returned to Earth to enable us to calculate the distance to the Moon. Lasers also have applications in forensics. Lasers, together with mirrors, are very useful in tracing the trajectory of bullets in forensic cases. An argon-ion laser can also be used to detect weak fingerprints that have not responded to standard techniques.

Scifile

Professor Keigo Iizula, from Toronto, has been pioneering a system that utilises the fact that light from a laptop screen is already polarised. He has shown that it is possible to use a sheet of ordinary cellophane to rotate the plane of these polarised waves by 90°. He has demonstrated that, by combining two images that have been polarised differently onto a laptop screen, and then looking at the screen with polarising glasses, the viewer will see a 3D image. Iizula's relatively simple idea has generated a lot of interest, for its commercial possibilities for advertising and gaming machine markets keen to have 3D graphics to enhance their products.

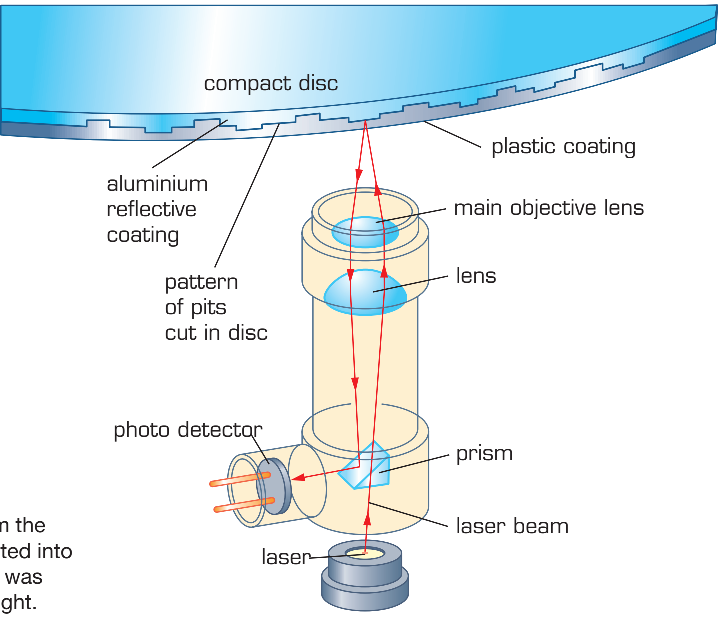


Figure 4.54
Laser light is detected as it reflects off tiny pits that form the surface of a CD. This pattern of reflected light is converted into a digital signal and is used to reproduce the sound that was originally used to burn the pits into the CD using laser light.

questions 4.4

1. Describe how a polarised wave vibrates.
2. If you were to look at a light source through two polarising lenses, with one held at 90° to the other, explain what you would see. Include diagrams to help with your explanation.
3. In a transverse wave, do the particles vibrate at right angles to the direction of motion or in the same direction? Give an example of a transverse wave.
4. Imagine you are at the movies with a pair of 3D glasses, watching a movie in 3D.
   (a) Describe how such a movie would have been filmed.
   (b) Why do your glasses have a red filter and a blue filter?
   (c) If you had lost vision in one eye, do you think you could see in three dimensions? Explain your answer.
5. With a group of students, create a role-play to demonstrate how a polarising filter works to cut much of an incoming light beam from passing through.
6. Why would a pelican benefit from having eyes that work like sunglasses? Present you findings as a cartoon or poster.
7. Investigate how anti-glare sunglasses are manufactured. Prepare a short report with diagrams that explains the process.
8. Pelicans are unlikely to be the only animals that benefit from polarisation of light. With your friends, brainstorm a list of animals that could do this. Choose one animal each and investigate how and why it polarises light. Report back to the class with a presentation of your choice.
9. Using wire, string or another material of your choice, build a model to demonstrate the difference between coherent and non-coherent light.
10. (a) What happens when you 'burn' a CD?
    (b) How does a CD player convert the surface features of the CD into sound?
11. Investigate one application of lasers, such as in manufacturing, medicine, reading barcodes or measuring distance and present your findings to your class in a format of your choice. Make any appropriate changes to your presentation based on feedback from class members.
12. A hologram is an example of an optically variable device (OVD). OVD holograms are added to banknotes, passports, credit cards, coins and licences to protect them against counterfeiting. Carry out some research to find out where different types of OVDs may be used in the future.

Web

Pathways

John Gilllam:

Research scientist

From a young age I knew that I wanted to do some sort of science, and in high school I decided that physics or maths would be the most enjoyable. I did an undergraduate physics degree at Melbourne University, and found parts of it were not at all what I had expected. The course was challenging and much of the earlier years seemed very dry.

In third year, after a course in quantum mechanics, and an extremely enjoyable series of practical experiments, I was much more inspired to continue in the field. My coursework in my honours year offered an insight into general relativity and some particle physics. This and the research section of the year were so enjoyable that I decided to try and become a research scientist in experimental physics.

After applying at Monash University, I was accepted as a candidate for a PhD. This has allowed me to conduct research in the application of new detector technology to medical imaging, as well as help conduct experiments on international synchrotron sources.

The experimental apparatus for my project is in Liverpool, England, and my job is to take data acquired overseas and reconstruct final images. On a day-to-day basis this involves a lot of computer programming; however, I have also been part of a number of experimental trips overseas, to SPring-8—the world's biggest synchrotron in Japan—and Daresbury Laboratories—a science centre in North England.

Figure 4.55
John Gillam.

Figure 4.56
SPring-8 is currently the world's biggest synchrotron located in Hyogo Prefecture, Japan.

Related careers
Physicist, engineer, astronomer

More information

- Australian Institute of Physics
- Job Guide for Victoria. Published annually by the Australian Government, Department of Education and Training
- VTAC Guide. Published annually by the Victorian Tertiary Admissions Centre

04 Chapter review

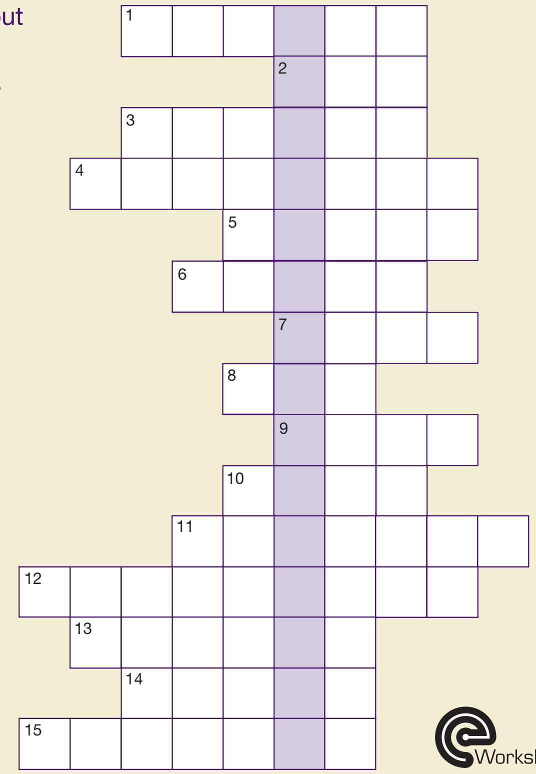
KEY TERMS

absorbs
accommodation
concave lens
converging
convex lens
critical angle
dispersion
diverging
filter
focal length
hypermetropia
lens
myopia
normal
optical fibre
polarised
primary colours
principal focus
real image
reflects
refracted
refraction
secondary colours
spectrum
total internal reflection
transverse wave
virtual image

key ideas

Copy the grid and then use the clues to find out what inspired this chapter.

1. This filter passes red and green but stops blue.
2. Our personal optical instrument!
3. Look through this to see only one colour.
4. The whole range of colours.
5. This light contains all colours.
6. Primary colour—artists might disagree!
7. Light travels in these straight lines.
8. This colour is refracted the least.
9. Another primary colour, perhaps sad!
10. This part of the eye lets you focus close and far objects.
11. There are seven in a rainbow.
12. These light waves vibrate in one plane.
13. Hot road surfaces let you see something that isn't really there!
14. This type of energy isn't heavy!
15. This secondary colour is a mixture of red and blue light.



Worksheet

review questions

1. Copy Figure 4.57 and complete the ray diagrams.

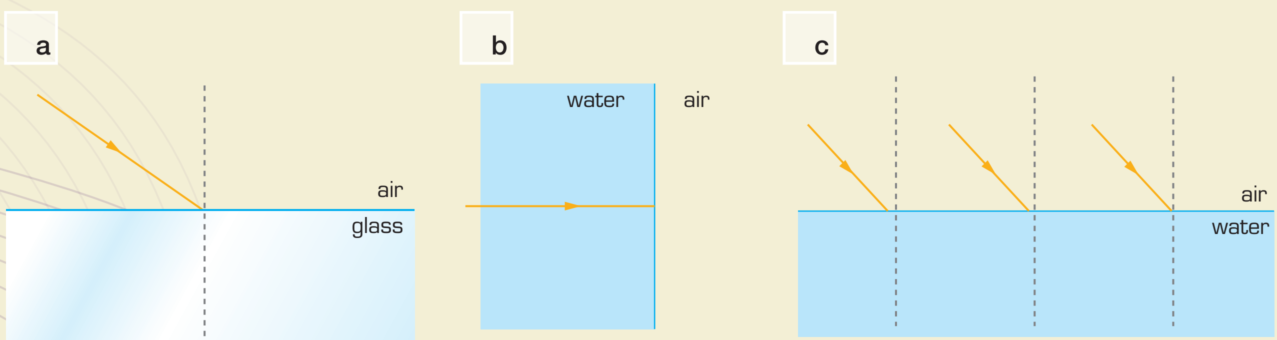


Figure 4.57

2. Draw a diagram on your page and describe why a cut diamond sparkles.

3. Copy Figure 4.58 and complete the ray diagrams for light passing through the lenses. Mark the focal length in each case.

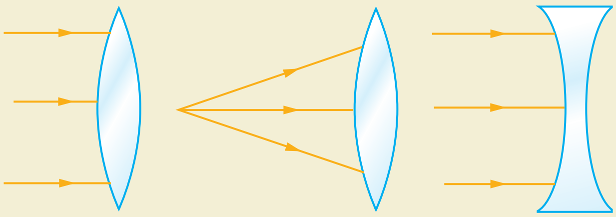


Figure 4.58

4. Explain how bottles left in dry grass can start fires. Create a poster or jingle warning of this danger.
5. Your middle-aged next-door neighbour is having trouble reading a birthday card that you have given her. What type of vision problem do you think she has, and which type of lens would an optometrist prescribe for her?
   Then she confesses that she also finds it hard to focus on distant cars while trying to cross the road. Can you suggest a further problem that your neighbour could have, and its most common treatment?
6. For each diagram in Figure 4.59, what colours would be reflected if the light shining on the objects was:
   (a) white?
   (b) blue?
7. (a) A yellow toy car is viewed under a red light. What colour does it appear?
   (b) The light source is now changed to cyan. What colour does the car now seem?
8. (a) Explain carefully what is meant by the term 'polarised wave'.
   (b) Explain how sunglasses use this property of light waves.
9. What is a 'twisted cell of polarised light'? Can you name two places where these are found?
10. In the near future, it may be possible to use 3D displays from a laptop computer. Suggest a few specific ways that such new technology may be used in advertising, or come up with your own idea for an ad that could run on a screen in 3D.
11. Create a T-chart to explain the difference between the nature of light that is emitted when you turn on your bedroom light, and that of a laser?

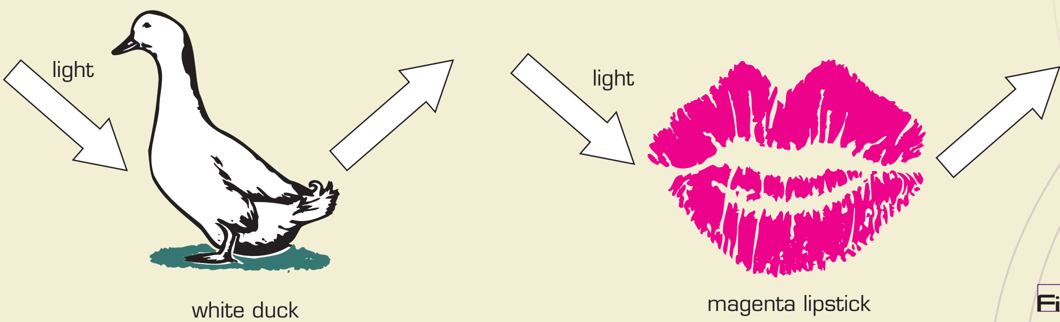


Figure 4.59

eTester

reflection light

complete KWLH

Return to the **Thinking about** at the beginning of the chapter. In the scenario, you first notice your brother's legs looking short in the pool, then see small rainbows across a table from a crystal key ring, and finally see a magazine clearly after putting on a pair of glasses.

Look at the explanations you and your partner made for each of these effects. Were they reasonable? List any adjustments you would now make to any of your responses.