Topic 4.3

How can you mix colours to make different colours?

Key Concepts

- Colours of light can be added together to form a variety of colours.
- Pigments can subtract colours from light.

Key Skills

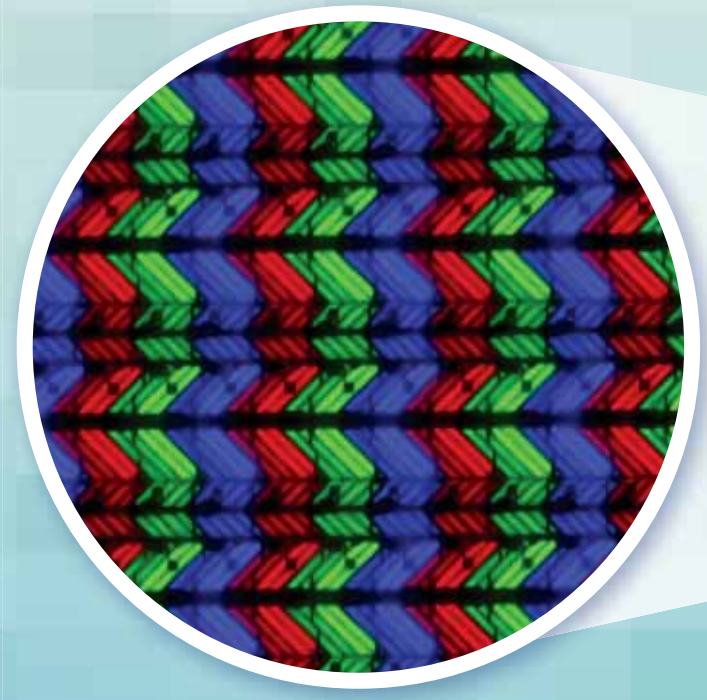
Inquiry

Key Terms

primary colours
secondary colours
complementary colours
tertiary colours

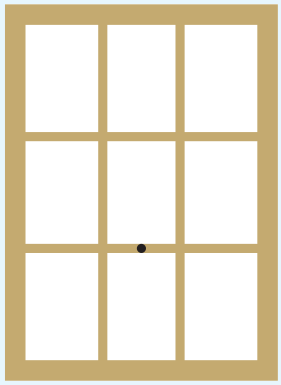
Did you know that the millions of colours on a computer monitor or TV screen are produced with only *three* colours? That's okay, because your eyes have only three types of colour-receiving cone cells that respond to colours of light. How do three different colours on a screen or monitor and three different types of cone cells in your eyes generate millions of colours?

A TV screen or monitor is made up of thousands of pixels, each of which produces a unique spot of light. Each pixel has three parts. One part can produce red, the second part can produce green, and the third part can produce blue. At any one moment, the strength of each colour in each pixel produces an overall colour. These colours stimulate different combinations of the three types of cone cells in your eyes. Your brain does the rest. That is, your brain interprets the different combinations of stimulated cone cells as all of the colours that you "see." (Why is the word "see" in quotation marks? The Starting Point Activity and the text on the page afterward will help to explain.)



Starting Point Activity

1. Stare at the black dot on the green cat for a count of 30 s.
2. Next stare at the black dot on the window frame for several seconds.
3. What do you see in the window after a few seconds have passed?
4. What colour does the image appear to be? Is the image actually there? What are you seeing?



Colours of light can be added together to form a variety of colours.

In nature, there are thousands of different compounds, called pigments, that absorb different colours (wavelengths) of light. But your eyes have only three types of cells that are sensitive to colour. Each of these cells responds to a group of wavelengths, though, and your brain combines the information to "see" the correct colour. As a result, you can see many colours.

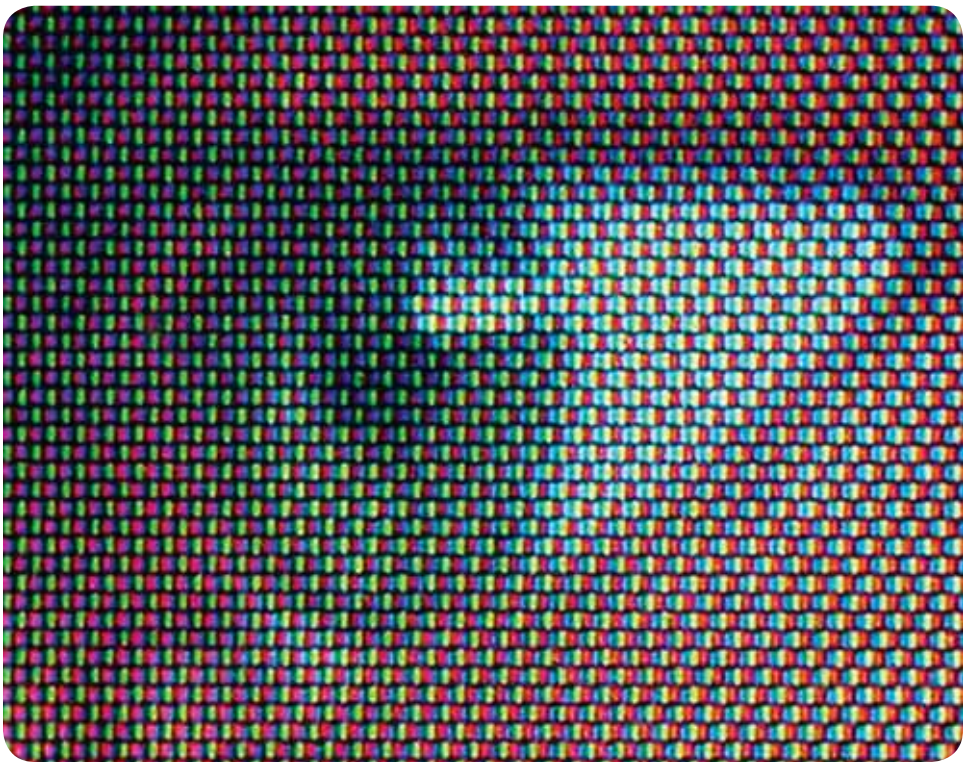
Mixing Colours

primary colours: three colours which, when combined in different amounts, can generate any other colour

Look very closely at the photograph in Figure 4.13. Notice that some of the pixels have brighter colours than others. Some pixels even have colours that are nearly black.

Now move the picture away from you and look at it from a distance. What do you see? As the picture gets farther away, your eyes "mix" the colours in the pixels. You see an image.

Figure 4.13 shows how a system of three primary colours can create the effect of many different colours. The **primary colours** are three colours that can be combined to generate any other colour. Primary colours can be *additive* or *subtractive*. The additive primary colours are discussed on the next page, and the subtractive primary colours follow on the page afterward.



▶ **Figure 4.13** This is an enlarged image of an LCD (liquid crystal display) that lets you see individual pixels.

ACTIVITY LINK

Activity 4.4, on page 300

Additive Primary Colours

To add colours, you need sources of coloured lights that can reach an observer's eyes. The light might go straight to the observer's eyes like the pixels on a TV screen or monitor. The light can also shine on a screen that reflects all colours. **Figure 4.14** shows what happens if you shine the additive primary colours—red, green, and blue—on a reflective screen.

Look at the centre of **Figure 4.14**. When you overlap the three primary colours, red, green, and blue, they "add up" to form white. When you add (overlap) any two of the three primary colours, they generate three new colours. These new colours are called **secondary colours**. The additive secondary colours are cyan, magenta, and yellow. The colours that are directly across from each other are called **complementary colours**. The colours generated by combining the additive primary colours are summarized in the following box.

secondary colours: the colours generated by combining two primary colours

complementary colours: a primary colour and the secondary colour created by mixing the other two primary colours

Combining Additive Primary Colours

red + green + blue = white

R + G + B = W

red + green = yellow

R + G = Y

red + blue = magenta

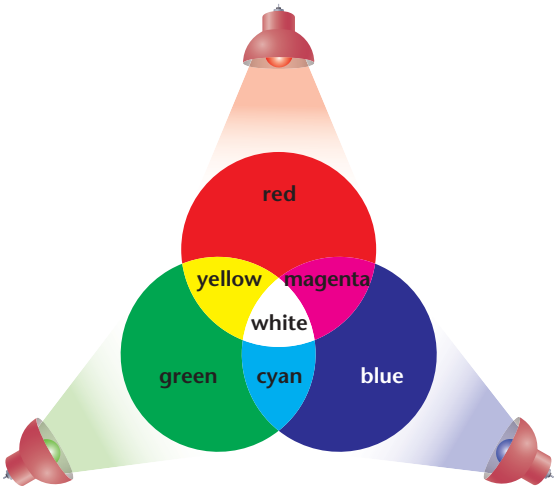
R + B = M

green + blue = cyan

G + B = C

Complementary Colours

red—cyan green—magenta blue—yellow



◀ **Figure 4.14** When you combine the additive primary colours, red and green add to yellow; green and blue add to cyan; and red and blue add to magenta.

LEARNING CHECK

1. Use a flowchart or other graphic organizer to summarize the main points about primary colours, secondary colours, and complementary colours.
2. Predict the colour you would get by adding the following combinations of primary colours.
   a) red and blue **b)** blue and green **c)** green and red

ACTIVITY LINK
Activity 4.5 on page 300

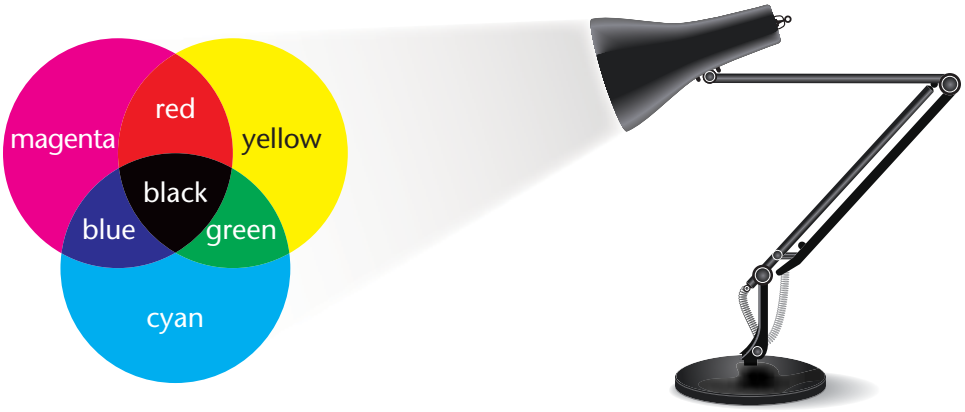
Pigments can subtract colours from light.

When an object absorbs a colour, it removes it from the beam of light. Therefore, you can say that the absorbed colour is "subtracted" from the light. The colours of most of the objects that you observe every day are the result of subtracting colours.

Subtractive Primary Colours

▲ **Figure 4.15** Most printers use only three pigment colours as well as black.

Similar to the case of additive colours, there are three primary subtractive colours. A variety of combinations of these three colours—cyan, magenta, and yellow—can subtract light from white light to produce nearly any colour. You have probably seen these three colours in the form of ink for printers, as shown in **Figure 4.15**. If you overlap films of equal strength of these colours and place them under a white light, you will see the pattern shown in **Figure 4.16**. The colours produced by subtracting equal amounts of two of the three subtractive primary colours are called secondary colours. Notice that the secondary subtractive colours are the same as the three additive primary colours. The box at the bottom of this page summarizes the information about subtractive colours. Notice that "K" is used for black to avoid confusion with B for blue.



▲ **Figure 4.16** Magenta, cyan, and yellow films are subtracting colours from white light.

Combining Subtractive Primary Colours

white – (cyan + magenta + yellow) = black

W – (C + M + Y) = K

white – (cyan + magenta) = blue

W – (C + M) = B

white – (cyan + yellow) = green

W – (C + Y) = G

white – (magenta + yellow) = red

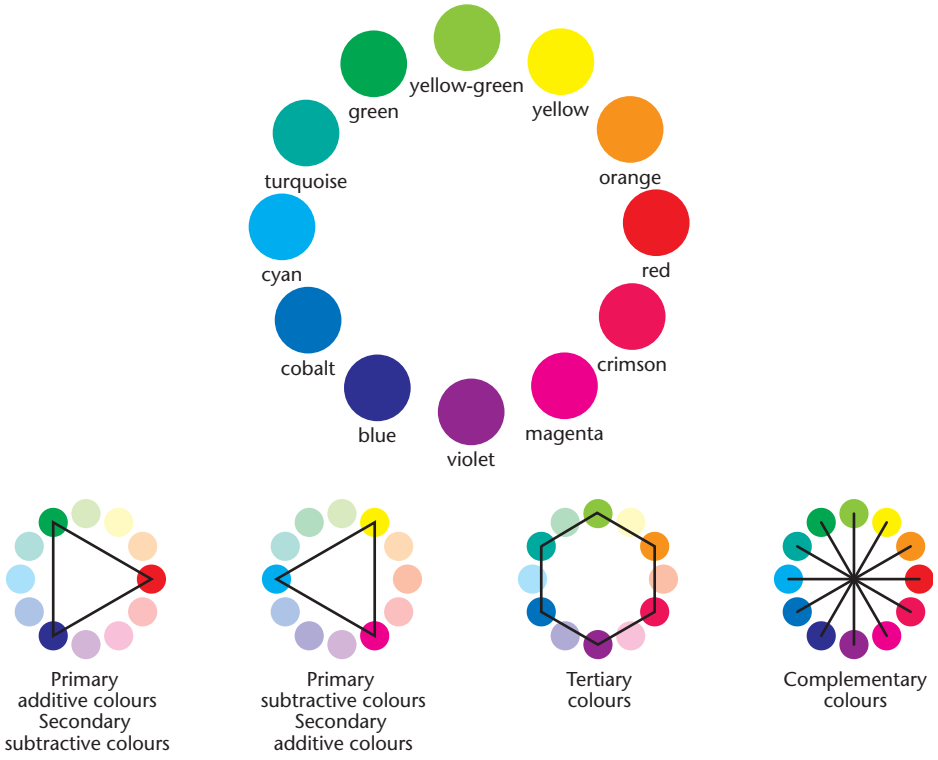
W – (M + Y) = R

Colour Wheel

A colour wheel like the one shown in **Figure 4.17** summarizes all that you have learned about the additive and subtractive primary colours, the secondary colours, and the complementary colours. The colour wheel also includes another category of colours called tertiary colours. A **tertiary colour** is the colour that you get by mixing the secondary colours. The following list summarizes the relationships among the colours.

tertiary colours: colours formed by mixing the secondary colours

- The primary subtractive colours are the secondary additive colours.
- The primary additive colours are the secondary subtractive colours.
- The colours that are directly across from each other are complementary colours.
- When you add complementary colours, you get white.
- When you subtract complementary colours, you get black.



▲ **Figure 4.17** Use this colour wheel to help you remember all of the relationships among the groups of colours. Notice that the smaller circles below the colour wheel point to the primary, secondary, tertiary, and complementary colours.

LEARNING CHECK

1. How can you "subtract" a colour from light?
2. What is the relationship between primary subtractive colours and secondary additive colours?
3. Explain how you can find complementary colours on a colour wheel.

ACTIVITY LINK

Activity 4.6, on page 301

Activity 4.7, on page 302

Inquiry Focus

Activity 4.4

TRICKING THE EYE

What does it really mean to "see" a certain colour? If a red light is shining on a screen, do you see red? That depends on what other colours are also shining on the screen. In this activity, you will add colours and decide what colour you "see."

What You Need

- 3 ray boxes (no slits)
- 1 red filter
- 1 green filter
- 1 blue filter
- 1 white piece of paper to act as a screen

What To Do

1. Place a single colour filter in front of each ray box.
2. Predict what colour will appear on the screen when you shine all three colours—red, green, and blue—onto the same spot on the screen.
3. Plug in the ray boxes and shine all three toward the same spot on the screen.
4. Experiment with the positions of the ray boxes to produce white and as many other colours as you can. Record the combinations of ray-box colours that produce white and other colours.

Inquiry Focus

Activity 4.5

MIXING MORE COLOURS

Cyan, magenta, and yellow colours are created by adding two specific primary colours. Now find out what happens when you mix cyan, magenta, and yellow transparencies on white paper.

What You Need

- bright lamp
- white paper
- cyan film (transparency)
- yellow film (transparency)
- magenta film (transparency)

What To Do

1. Direct the lamp on the white paper.
2. Place the cyan film and the yellow film on the white paper so they overlap. Observe and record the colour where the films are overlapped.
3. Place the cyan film and the magenta film on the white paper so they overlap. Observe and record the colour where the films are overlapped.
4. Place the magenta film and the yellow film on the white paper so they overlap. Observe and record the colour where the films are overlapped.
5. Place all three coloured films on the white paper so they overlap. Observe and record the colour where the films are overlapped.

What Did You Find Out?

1. What colour was the overlap between a) the cyan and yellow film? b) the cyan and magenta film? c) the magenta and yellow film? d) all three films?
2. Recall the colours that are produced by adding pairs of the primary colours (red, green, and blue). Based on this information, suggest possible explanations for the colours that you observed in this activity.

Inquiry Focus

Activity 4.6

SUBTRACTING COLOUR WITH FILMS AND WITH YOUR EYES

First, you will make some observations about complementary colours. You will use what you learned to try to explain what happens in your eyes when you stare at coloured images.

What You Need

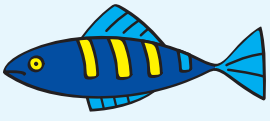
- 3 colour films or transparencies (cyan, magenta, and yellow)
- colour wheel on page 299

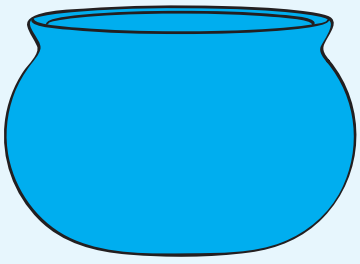
What To Do

1. Make a list of all of the primary additive and subtractive colours in the wheel.
2. Place the cyan film over the colour wheel.
3. Beside each colour on your list, write the colour that it appears to be after the cyan film was placed over it.
4. Repeat steps 2 and 3 with the magenta film.
5. Repeat steps 2 and 3 with the yellow film.
6. Stare at the dot in the centre of the maple leaf on the Canadian flag for at least 20 s. Quickly look at a sheet of white paper and stare at it for several seconds. Describe what you see.
7. Stare at the centre stripe of the fish for at least 20 s. Quickly move your eyes to the fish bowl and stare at the centre of it. Describe what you see.

What Did You Find Out?

1. Did you see any black spots when you placed the cyan, magenta, and yellow films over the colour wheel? If so, what was the relationship between the colour of the film and the original colour of the spot?
2. Were there any colours that you could no longer see when you placed the cyan, magenta, and yellow films over the colour wheel? Suggest an explanation for these results.
3. After you stared at the Canadian flag then stared at white paper, what did you see? The image that you saw is called an "after image." What is the relationship between the original colour and the colour of the "after image?"
4. After you stared at the fish and then stared at the fish bowl, what did you see? Explain how this observation might be related to subtractive colours.



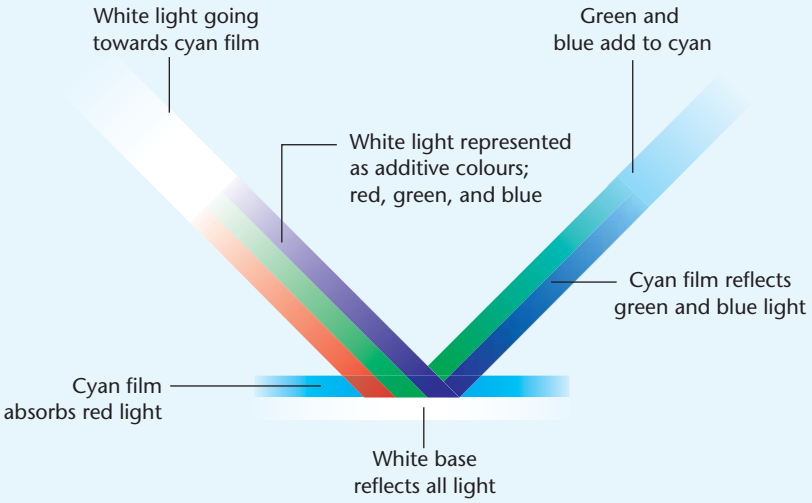


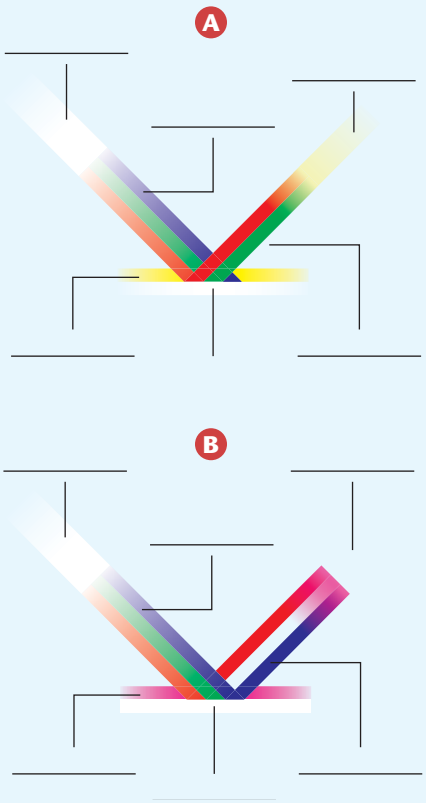
Inquiry Focus

Activity 4.7

USING DIAGRAMS TO ILLUSTRATE SUBTRACTING COLOURS

Study the diagrams shown here to learn a way to show what happens when colours are subtracted from white light. You will then make diagrams of your own to analyze several combinations of colours.



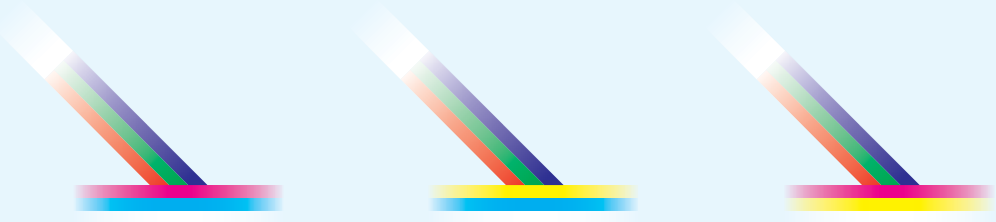


What You Need

- 6 coloured pencils or pens (red, green, blue, cyan, magenta, and yellow)
- paper or notebook

What To Do

1. The white incoming light is represented by the additive colours, red, green, and blue. When it reaches the coloured films, one or more of the primary additive colours is absorbed and the others are reflected.
2. Copy diagrams A and B on a piece of paper. Use the main diagram above as a guide to fill in all the labels.
3. Copy the diagrams below on a piece of paper. Complete the diagrams, showing what colours of light will be reflected.



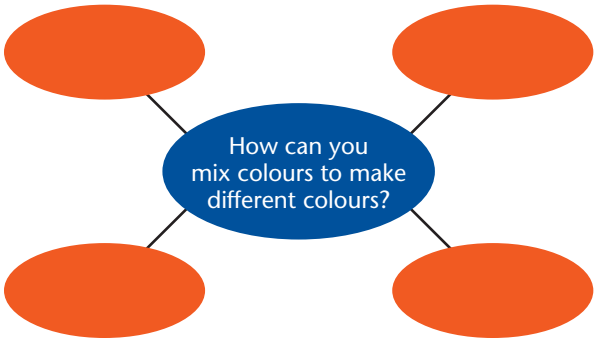
Topic 4.3 Review

Key Concept Summary

- Colours of light can be added together to form a variety of colours.
- Pigments can subtract colours light.

Review the Key Concepts

1. K/U Answer the question that is the title of this topic. Copy and complete the graphic organizer below in your notebook. Fill in four examples from the topic using key terms as well as your own words.



2. K/U When a red light and a blue light shine on the same spot on a white screen, what do you call the process? What colour will you see on the screen?

3. K/U When white light shines on a painting, what process allows you to see the colours? Give two different answers that are both correct.

4. C Explain how the additive and subtractive primary colours are related.

5. T/I In your notebook, complete the following "colour equations."

a) R + G = _____

b) G + B = _____

c) W − (Y + M) = _____

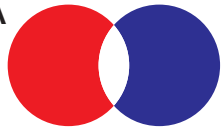
d) G + M = _____

6. C Describe three features of a colour wheel.

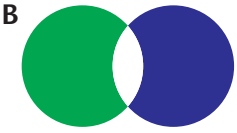
7. A Imagine that aliens have landed on Earth. You find out that their visual organs have only two types of colour-sensing cells: one for green and the other for blue and violet. Which colours would they see as we do? How could you write a secret message on paper in such a way that they would not notice the message?

8. A The following diagrams represent light from two coloured spotlights shining on a white background. What will be the colours of the overlapping sections?

A

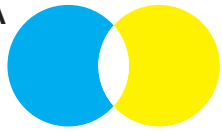


B



9. A The following diagrams represent coloured films with white light shining on them. What will be the colours of the overlapping sections?

A



B