Topic 4.3
How can you mix colours to make different colours?

Specific Expectations

- **E1.1** analyze how additive and/or subtractive colour theory are applied in technologies used in everyday life
- **E2.1** use appropriate terminology related to light and optics, including, but not limited to: *angle of incidence, angle of reflection, angle of refraction, centre of curvature, focal length, luminescence, magnification, principal axis, radius of curvature,* and *vertex*
- **E3.5** use additive colour theory to predict the results of combining primary and secondary light colours
- **E3.6** use subtractive colour theory to describe the effect of colour filters on white light
- **E3.7** explain how the colour of an object is determined by reflection, absorption, and transmission of colour

Skills

- conduct inquiries to collect observations and data
- record observations using appropriate formats
- analyze and interpret information
- draw conclusions

Materials

Please see the teaching notes for each activity for a list of the materials required. Please see pages TR-50 to TR-52 for a summary of the materials required in this topic.

Overview

In this topic, students will apply additive and subtractive colour theory to explain optical phenomena and technology. Students will explain how the additive primary colours of light add to form complimentary colours. Students will investigate and use subtractive colour theory to explain colours of pigments and objects.

Common Misconceptions

- **Additive colour theory and subtractive colour theory are not well understood by most students (or adults).** The confusion often results from mixing up the two theories, primarily because it is easy to mix colours of pigments, but difficult to mix colours of light. Provide several experiences of mixing colours of light and of mixing colours of pigment. Work with students to explain clearly what is happening each time. Create a display similar to Figure 4.14 on page 297 and Figure 4.15 on page 298 and refer to it often. Be explicit about the limitations of each theory.
- **Students can be misled by colour filters, which often transmit more than the observed colour of light.** This contamination can affect results. Be aware of it and be able to explain this flaw to students.
- **Students may become confused when others describe observations differently than their own perception.** Our perception of colour is influenced by past experiences. As well, the absorption of light by material substances is different than the perception of light by the human eye. Make extensive use of colour ray diagrams to represent observed phenomena.

Background Knowledge

Colour theory is an expanding area of research as digital imaging and new technologies extend our ability to represent colours. For the purposes of this course, it is recommended that you confine discussions to the simplified versions of colour theory presented below. It is wise to acknowledge that colour can be a matter of opinion and is also clearly influenced by the brightness of the illuminating light and the observed surface.

The additive primary colours of light are red, green, and blue. When combined, these produce white light. Red and green light combine to produce yellow light. Red and blue light combine to produce magenta light. Green and blue light combine to produce cyan light. Magenta, yellow, and cyan are known as the subtractive primary colours.

By subtracting (or absorbing) light from the subtractive primary colours, the additive primary colours can be restored. When cyan pigment (absorbing red) and magenta pigment (absorbing green) are mixed, the combination absorbs red and green and only blue light is reflected. The combined effect of mixing pigments of the subtractive primary colours is the absorption of all light, which is perceived as black.

It is important to realize and to remind students that pigments remove or subtract colour. As they learned in the last topic, a red object, for example, appears red because it has absorbed (or subtracted) all other colours of light except the red light that it reflects. A true cyan filter, as another example, will subtract or absorb all colours of light except blue and green, which are transmitted.

The theory behind colour wheels and complimentary colours is based on Newton's work and involves mixing different colours of pigments. External influences such as the intensity of the illuminating light and the texture of the surface illuminated play a large role in the perception of the resulting colours. Theories about complimentary colours have little connection to additive or subtractive colour theory. Therefore, it is recommended that little time be spent on complimentary colours.

Literacy Strategies

Before Reading

- ELL English language learners would benefit from participating in activities designed to extend understanding of the concepts in the text, before reading the text. This sequence ensures students can focus on the concepts as well as the key vocabulary. As activities are debriefed, the text can be introduced to support what they have learned and the reading of that text becomes less onerous, since the English language learners will be able to draw on first-hand experience to make sense of what they read.
- Work with students to create a concept map about colours, showing what they already know. Encourage students to refer to their experiences of colour at home, in their room, in movies and television, as examples of what they know. This will help students make connections that they can build on as they read. It will also help point out any misconceptions or gaps that you can address in the topic.
- Introduce a process known as collaborative annotation. This strategy engages students in a process of co-constructing their interpretations of the text through collaboration. For each spread, encourage students to work together to share their interpretations of what they read, and record their discussions in point form as a group. They can practise this strategy with the topic opener on pages 294 and 295.

During Reading

- Before collaborating with their group, encourage students to use a two-column note-taking strategy. In the right column, they take notes to synthesize essential ideas and information from the text. In the left column, they interact with the content in any way they choose. This can include making personal connections to colour, pasting illustrations from magazines that represent colour theory, and so on.
- As students take notes, encourage them to build connections with their everyday experiences. For example, the additive primary colours red, blue, and green are referenced in RGB cables used to connect audio equipment.

After Reading

- Discuss advantages students saw in the two-column note-taking strategy. Encourage students to continue to use a two-column note-taking strategy. In the right column, they take notes to synthesize essential ideas. In the left-hand column, they interact with the content in a variety of ways that are meaningful to them.

Assessment FOR Learning

Tool	Evidence of Learning	Supporting Learners
Learning Check, page 297	Students create and use a graphic organizer to demonstrate adding colours of light together to obtain other colours.	• Demonstrate the results of adding the primary colours in combinations shown in Figure 4.14 using a white screen and high intensity flashlights with colour filters. • Remind students to use Figure 4.14 to help them. After students have written their answers, allow them to check their predictions. • Create sentence starters for students to complete. For example, "When you add red light and green light, you get _____." • Make **BLM G-39 Cause-and-Effect Map** to **BLM G-49 Venn Diagram** available for students to use to create their graphic organizers.
Learning Check, page 299 Activity 4.7, page 302	Students explain in words or pictures that adding pigment subtracts colour from light and changes the colour of light we see.	• Make liberal use of colour ray diagrams drawn with different colours of chalk on the chalkboard or use the illustrative and interactive capabilities of an interactive whiteboard. • Review students' results to Activity 4.5 and Activity 4.6 before they complete Activity 4.7.

Topic 4.3 (Student textbook pages 294–303)

Using the Topic Opener

- Read the text aloud to students, and then ask for personal experiences about colour in television, movies, and computer screens.
- Ask why our individual perception of colour is different. Ask: "We all have the same types of cells in our eyes so what role might our brains play in seeing colour?"
- Engage students by getting them to describe to a classmate their favourite movie and the part that colour plays in our perception of quality television programs and movies.

Starting Point Activity (Student textbook page 295)

Pedagogical Purpose

Afterimages are interesting phenomena that are explained by the biological processes enabling us to see. In this activity, students will experience an afterimage and realize that our perception of colour vision is a complex process.

Planning	
Time	5 min in class

Activity Notes and Troubleshooting

- To experience an afterimage, students must stare at the dot on page 295 for at least 30s, so the room must be quiet and focused. Time 30 s for the class as they look at the dot, or have students count silently as they look.
- This type of afterimage is caused when the cone cells adapt to over stimulation and lose sensitivity. Other afterimage experiences include the familiar glow in the eyes experienced after looking at a bright object.
- Encourage students to share their experiences with one another and the class.

Additional Support

- ELL Explain the instructions orally, and discuss the results together to help English language learners understand the activity.
- Students with colour-blindness may not experience the same white afterimage. A class discussion after the activity will be helpful to them.
- As you discuss students' results, ask whether students of different genders had different experiences. Since colour blindness is more prominent in males than females, this may be an issue.

Starting Point Activity Answers

3. Most students will see a white image of a cat in the window.

4. White. The image is not actually there. The cells that allow us to see green become fatigued after looking at the green cat for 30 s. They cannot process the green in the beige screen behind the window, so white is perceived instead.

Instructional Strategies for Topic 4.3

Student textbook pages 296–297

- Link the images on page 296 to students' personal experience with television and computer images and technology. Have students work in pairs with one student holding the textbook while the other views Figure 4.13 from close up and far away.
- Use red, yellow, and green light to demonstrate the effect of adding colours of light. Let students try their own ad hoc demonstrations of mixing different colours of light. Have students predict the results of combining two colours of light, then check their predictions.

- Create a graphic similar to Figure 1.14, or have a student create one, and display it in the classroom.
- Activity 4.4 on page 300 can be used to reinforce the material on these pages. Make explicit reference to the link between Activity 4.4 and Figure 4.14.

Student textbook pages 298–299

- Explain that pigments and filters remove light by reflecting or allowing only certain colours to pass through or reflect.
- DI Students may need several demonstrations, using different media, to understand this. Demonstrate in as many different ways as possible, and encourage students to do the same, explaining for each demonstration the colour that is subtracted by each pigment, and the resulting colour. Refer to Figure 4.16. Filters, paint, food colouring, chalk, and modelling clay are all possible media to use.
- Use coloured chalk on the chalkboard, or other means to make colour ray diagrams that show how different colours are produced by subtraction.
- Activity 4.5 on page 300 can be used to reinforce the material on these pages.

Learning Check Answers (Student textbook page 297)

1. Graphic organizers should show the following points.

- The primary colours are red, green, and blue.
- These primary colours can be combined in pairs to produce yellow, cyan, and magenta.
- Complimentary colours are created by mixing a primary colour and the secondary colour produced by mixing the other two primary colours.

2. Predictions may vary.

a) magenta

b) cyan

c) yellow

Learning Check Answers (Student textbook page 299)

1. Filters or pigments can subtract colours from light.

2. Primary subtractive colours are the same as the secondary additive colours.

3. Complimentary colours are opposite each other on a colour wheel.

Activity 4.4 Tricking the Eye (Student textbook page 300)

Pedagogical Purpose

Students will experience how different colours of light can be added to produce new colours in a predictable fashion.

Planning	
Materials	Per group: 3 ray boxes 3 filters (red, blue, and green) white paper coloured pencils (optional)
Time	15 min in class 15 min preparation
Safety	Remind students not to shine light in their eyes or their classmates' eyes. Some ray boxes get hot. Caution students not to touch the metal parts with their hands.

Skills Focus

- make predictions
- organize and record observations

Activity Notes and Troubleshooting

- This activity can be conducted as a demonstration. Or students can work in small groups. Student should record their observations individually.
- Consider asking a senior student to assist as needed if this activity is done by groups of students.
- It is important that the room be very dark to help students see the different colours of light.
- Encourage students to try different combinations of light as described and record their results using colour ray diagrams and coloured pencils.

Additional Support

- ELL Place English language learners in groups with at least one student who has strong English and interpersonal skills to facilitate understanding and participation.
- Student groups could be based on gender. If you do this, ask students to consider whether students of different genders perceive colour differently.
- Students exhibiting colour blindness will not be able to complete this task on their own. Watch for students, particularly males, experiencing difficulty, and encourage them to work with a classmate to share observations, and to use coloured pencils with visible colour labels.

Activity 4.4 Answers

What To Do

4. Red and blue light produce magenta.
Blue and green light produce cyan.
Green and red light produce yellow.
Red, blue, and green light produce white light.

Activity 4.5 Mixing More Colours (Student textbook page 300)

Pedagogical Purpose

Students will experience the effect of subtracting colours of light. This activity could be considered the opposite of the previous activity.

Planning	
Materials	Per group: bright lamp (this could be an overhead projector) white paper 3 colour transparencies (cyan, yellow, magenta) coloured pencils (optional)
Time	15 min in class 15 min preparation
Safety	Remind students not to look directly into the lamps.

Background

The subtractive primary colours—cyan, magenta, and yellow—should remove all light if combined. A cyan filter permits green and blue light to pass through. When combined with a magenta filter, which transmits red and blue light, only blue should be visible. Similarly, when cyan and yellow filters are combined, only green should pass through. When magenta and yellow filters are combined, only red should pass through.

Skills Focus

- make predictions
- organize and record observations

Activity Notes and Troubleshooting

- Before class, test the filters to be sure that they produce the stated colours of light. See **www.scienceontario.ca** for a source of filters that produce light very close to the colours cyan, yellow, and magenta.
- You may wish to perform this activity this as a demonstration. Students should record their observations individually.
- Consider asking a senior student to help as necessary if groups of students conduct this activity.
- It is important that the room be very dark to help students perceive the different colours of light.
- Encourage students to try different combinations of filters as described and record their results using colour ray diagrams and coloured pencils.

Additional Support

- ELL Place English language learners in groups with at least one student who has strong English and interpersonal skills to facilitate understanding and participation.
- Student groups could be based on gender. If you do this, ask students to consider whether students of different genders perceive colour differently.
- Students exhibiting colour blindness will not be able to complete this task on their own. Watch for students, particularly males, experiencing difficulty, and encourage them to work with a classmate to share observations, and to use coloured pencils with visible colour labels.

Activity 4.5 Answers

What Did You Find Out?

1. **a)** green
   b) blue
   c) red
   d) black
2. The colours cyan, magenta, and yellow are each combinations of two of red, green, and blue light. Each filter absorbs one of the colours red, green, and blue and transmits the other two. Two filters combined will absorb two of red, green, and blue, and will only transmit one. Three filters combined will absorb all three of red, green, and blue, and transmit no light at all.

Activity 4.6 Subtracting Colour with Films and with Your Eyes

(Student textbook page 301)

Pedagogical Purpose

Students have an opportunity to consolidate what they have learned about additive and subtractive colour mixing.

Planning	
Materials	Per student: three colour films or transparencies (cyan, magenta, and yellow) **BLM 4-6 Activity 4.6** (optional)
Time	20 min in class

Background

In What To Do steps 1 to 5, students are experimenting with subtractive colour mixing. They are using a coloured filter to subtract, or absorb, particular colours from light. In steps 6 and 7, students perform an experiment similar to the Starting Point Activity. They fatigue the cone cells in their eyes that see a particular colour, then experience the ability to perceive that colour for a while afterward.

Skills Focus

- gather, organize, and record data
- draw conclusions
- communicate using appropriate language

Activity Notes and Troubleshooting

- Before class, test the filters to be sure that they produce the stated colours of light. See **www.scienceontario.ca** for a source of filters that produce light very close to the colours cyan, yellow, and magenta.
- After students have recorded their observations for steps 2 to 4, they can compare their observations with a classmate, and repeat the tests if necessary.
- Encourage volunteers to share their thoughts about why they saw what they did in step 7 with the class, and encourage other students to add to the explanation or ask questions.
- Students could work in pairs for step 7, with one student timing the activity and the other student viewing the image.

Additional Support

- Students who require support organizing and recording their observations can use **BLM 4-6 Activity 4.6.**
- ELL Place English language learners in groups with at least one student who has strong English and interpersonal skills to facilitate understanding and participation.
- Students exhibiting colour blindness will not be able to complete this task on their own. Watch for students, particularly males, experiencing difficulty, and encourage them to work with a classmate to share observations.

Activity 4.6 Answers

What Did You Find Out?

1. A cyan filter should produce a black spot on red. These are complimentary colours. A magenta filter should produce a black spot on green. These are complimentary colours. A yellow filter should produce a black spot on blue. These are complimentary colours.
2. With a cyan filter, you should not see the cyan spot. The filter allows the cyan light through, but only allows the cyan part of the white light surrounding the cyan spot through. So the cyan spot blends in with its background.
   With a magenta filter, you should not see the magenta spot. The filter allows the magenta light through, but only allows the magenta part of the white light surrounding the magenta spot through. So the magenta spot blends in with its background.
   With a yellow filter, you should not see the yellow spot. The filter allows the yellow light through, but only allows the yellow part of the white light surrounding the yellow spot through. So the yellow spot blends in with its background.
3. You should see a Canadian flag in its normal colours. Your green- and blue-registering cone cells will be fatigued by looking at the cyan flag so your eyes will only see the red light reflected from the white paper. Cyan and red are complimentary colours.
4. You might see a light fish with dark blue bars on it. The cone cells that register blue become fatigued by staring at the dark blue fish so you cannot see the blue in the cyan water. The cone cells that register yellow also become fatigued and cannot see the yellow in the cyan water, so you see only blue in its place.

Activity 4.7 Using Diagrams to Illustrate Subtracting Colours

(Student textbook page 302)

Pedagogical Purpose

Students will use colour ray diagrams to explain the effect of subtracting colours when white light is shone on different coloured surfaces.

Planning	
Materials	Per student: 6 coloured pencils: red, blue, green, cyan, magenta, and yellow **BLM 4-7 Activity 4.7** (optional)
Time	30 min in class

Skills Focus

- use appropriate formats to communicate ideas

Activity Notes and Troubleshooting

- A peer helper could help maintain crowd control as students work through this activity.
- Discourage the use of pens or markers. The ink from these often bleeds, resulting in colour mixing.
- Instead of copying diagrams from the textbook, students could record their answers on **BLM 4-7 Activity 4.7.**

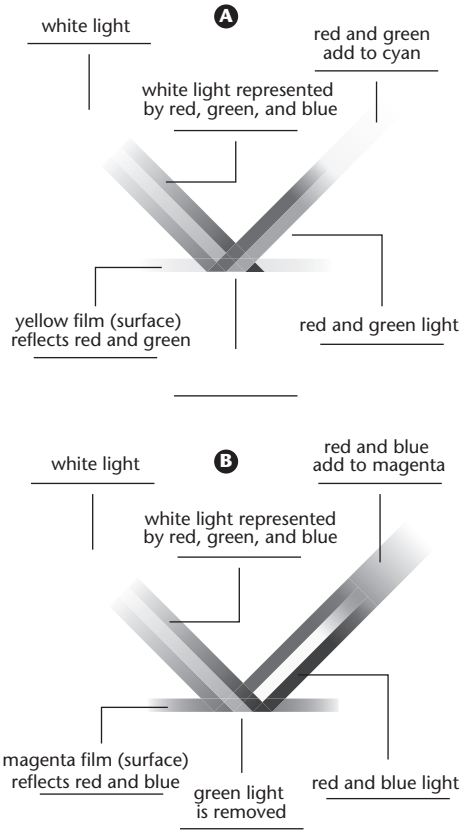
Additional Support

- Pair English language learners with students demonstrating strong English communication skills to help with understanding.
- DI Consider allowing students to work in groups of two or three for step 3 and discuss, or predict and test, their responses before recording them. Student should record their ideas individually. Student representations of natural phenomena are the most important way for students to examine their own thinking and for you to know what students are thinking.
- Students exhibiting colour blindness will not be able to complete this task without assistance. Watch for students, particularly males, experiencing difficulty and encourage them to work with a partner, and to use coloured pencils with visible colour labels.

Activity 4.7 Answers

What To Do

2.



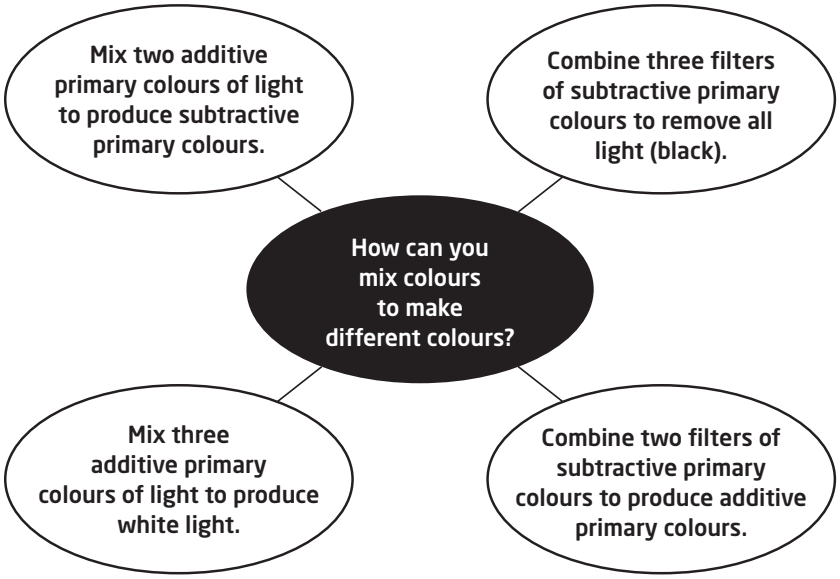
3. left: blue light will be reflected
centre: green light will be reflected
right: red light will be reflected

Topic 4.3 Review (Student textbook page 303)

Please see also **BLM 4-8 Topic 4.3 Review (Alternative Format)**.

Answers

1. Answers may vary. For example:



2. This is called adding colour. It produces magenta.

3. The processes are reflection of specific colours and subtraction of specific colours from white light.

4. Two additive primary colours together produce a subtractive primary colour. Two subtractive primary colours together absorb light and only transmit one of the additive primary colours.

5. a) yellow

b) cyan

c) no light (black)

d) white

6. Colour wheels show relationships between primary, secondary, and tertiary colours.

7. The aliens would see blues and greens as we do, but would not be able to see a secret message written in red ink.

8. **A** magenta, **B** cyan

9. **A** green, **B** red