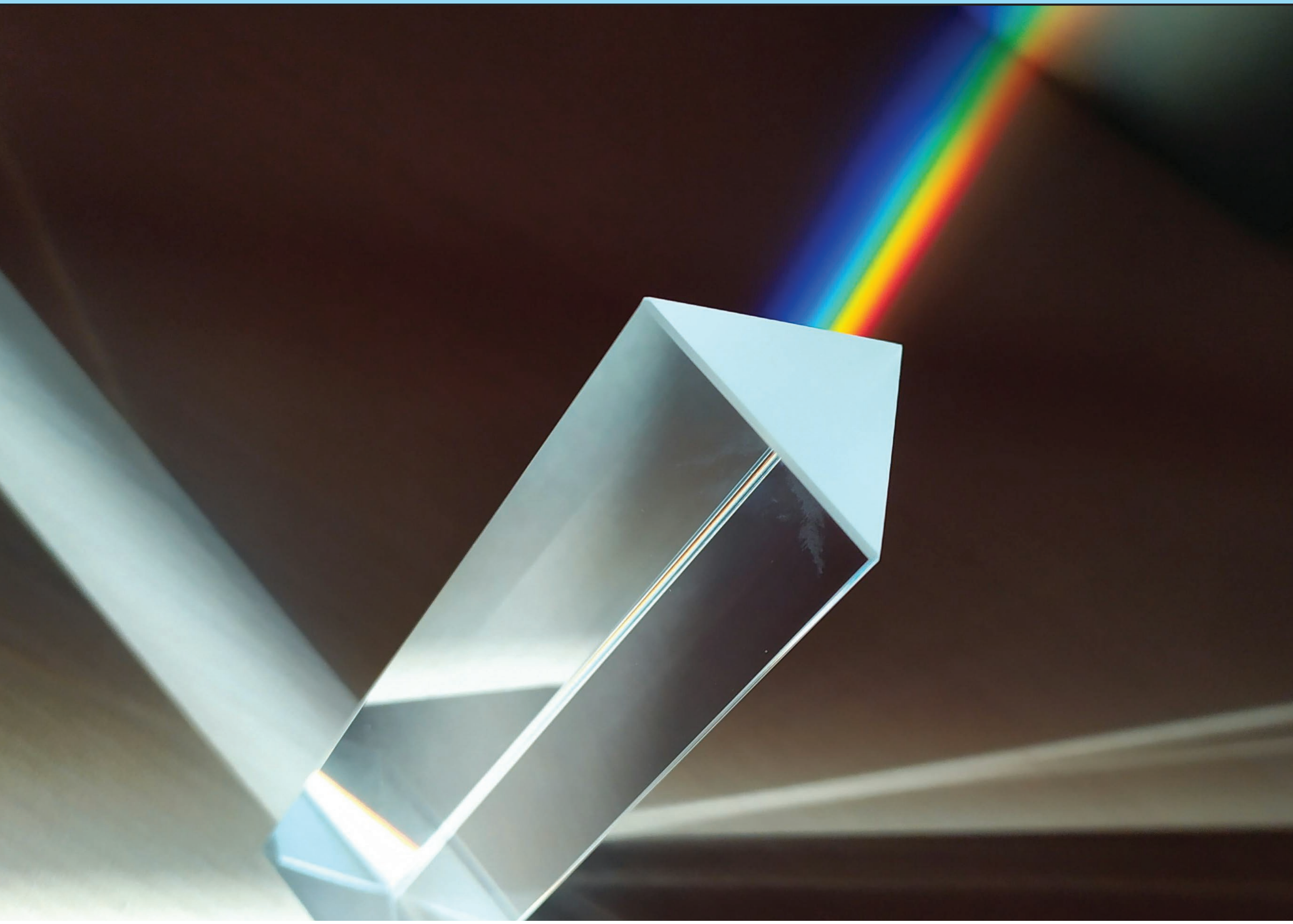
# LIGHT & OPTICS

## THE COSMIC FOUNDATIONS SERIES



À LA DÉCOUVERTE DE L'UNIVERS
DISCOVER THE UNIVERSE

Dunlap Institute for Astronomy & Astrophysics
UNIVERSITY OF TORONTO

# LIGHT & OPTICS

THE COSMIC FOUNDATIONS SERIES

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DISCOVER THE UNIVERSE

## DEVELOPMENT TEAM


**Discover the Universe**
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## ILLUSTRATIONS & DESIGN

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## DRAWING INSPIRATION FROM...

Oak Ridge National Laboratory Science Club (Light and Colour activity)
Girls in STEM (Light and Optics workbook, developed by CJ Woodford)
Purdue University Infrared Nanostructured Devices research group (Diffraction grating experiments)

## COVER PICTURE CREDITS

**Magnetism:** Visualization built by Greg Shirah and Tom Bridgman, NASA/Goddard Space Flight Center Scientific Visualization Studio. Caption by Mike Carlowicz

**Light & Optics:** Dobromir-Hristov

**Beyond Foundations:** NASA/NOAA


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Dunlap Institute for Astronomy & Astrophysics
UNIVERSITY OF TORONTO

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# Safety Guidelines for Light & Optics Activities

**For the safety of both you and your students, please follow these precautions whenever conducting activities involving lasers, prisms, diffraction gratings, or student eyeglasses:**

## LASER POINTER SAFETY

Always review laser safety before use. Remind students that laser pointers are not toys.

Use with care. Laser pointers should only be handled by individuals –students or teachers– with steady, reliable motor control.

Never aim lasers at or near the eyes: any laser beam, whether directed or deviated, can cause eye damage. Always use the laser in a box to avoid stray rays.

## PRISM SAFETY

Handle with care. While optical prisms are generally durable, they can chip, crack, or shatter if dropped or mishandled.

Stop use if damaged. If a prism shows any signs of breakage, stop using it immediately. Dispose of broken pieces safely –as you would with shattered glass– to avoid injury from sharp edges.

## DIFFRACTION GRATINGS & PRISMS: SOLAR WARNING

Never look directly at the Sun through a diffraction grating or a prism. These materials are not designed for solar viewing.

Serious risk of eye damage. Looking at the Sun this way can cause severe injury, including retinal burns, vision loss, or permanent blindness.

## EYEGLASS CAUTION

If students are using their own eyeglasses for any activity, remind them to treat their glasses with care –they may be expensive or difficult to replace.

# LIGHT & OPTICS

**This guide includes five hands-on activities exploring optics through coloured filters, prisms, and diffraction gratings.** Students will investigate how light behaves when it passes through a prism, how different wavelengths affect light, and key concepts such as transmission, absorption, reflection, refraction, image formation, focal point, and focal length. These activities connect to curriculum areas such as general science, physics, and even art.

The table below uses a ○ to indicate activities that are best presented as a demonstration or class discussion; a ✪ for activities designed to meet targeted learning goals; and ● indicates the activity is possibly already familiar but may be used as a review; blank for unsuitable.

| | Grade K | Grade 1 | Grade 2 | Grade 3 | Grade 4 | Grade 5 | Grade 6 | Grade 7-8 | Grade 9-10 | Grade 11-12 |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 Learning About Colour<br>30 mins | ✪ | ✪ | ✪ | ✪ | ✪ | ✪ | ✪ | ● | ● | ● |
| 2 Reflection and Refraction<br>30 mins | ○ | ○ | ○ | ○ | ✪ | ✪ | ✪ | ✪ | ✪ | ● |
| 3 Concave and Convex Prims<br>30-45 mins | ○ | ○ | ○ | ○ | ✪ | ✪ | ✪ | ✪ | ✪ | ● |
| 4 Eyeballs<br>30-60 mins | | | ○ | ○ | ✪ | ✪ | ✪ | ✪ | ✪ | ● |
| 5 Diffraction<br>30-45 mins | ✪ | ✪ | ✪ | ✪ | ✪ | ✪ | ✪ | ✪ | ✪ | ✪ |

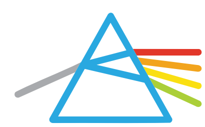
## MATERIALS

**May be found in the Science Kit:**

- Measuring tapes (5)
- Laser pointer / flashlight (5)
- Prisms (1 box of 7)
- Coloured paddles (18, 3 sets of 6)
- Diffraction gratings (5)
- Eyeglass lenses (5)

**Must be provided by teacher:**

- Writing utensils (e.g. pencils, pens, etc.)
- Writing and drawing paper
- Shoe box or other similarly sized box
  **the Science Kit box could work!*



**Before using the laser pointer for the first time:** unscrew the top and remove the small piece of paper that prevents the battery from making contact. Once removed, screw the top back on securely before handing it out to students.

## VIDEOS & HANDOUTS

Videos have been created for each activity in this guide to help explain concepts and activities. You can use these in the classroom! Links to YouTube are provided through the guide. Handouts have also been created to be given to your students to help concretize their lessons, you'll find these at the back of the guide.

# THE FOUNDATIONS OF LIGHT & OPTICS

**Begin by watching the Introduction to Light & Optics video with your class!**

After watching the introduction video, and before diving into the activities in this section, you might want to start with a few big-picture questions for your students: Why is learning about light important? What is light? What is optics?

Encourage discussion and see if there are points of agreement or disagreement. Invite students to explore *why* they might see things differently —this can open the door to deeper curiosity and learning.

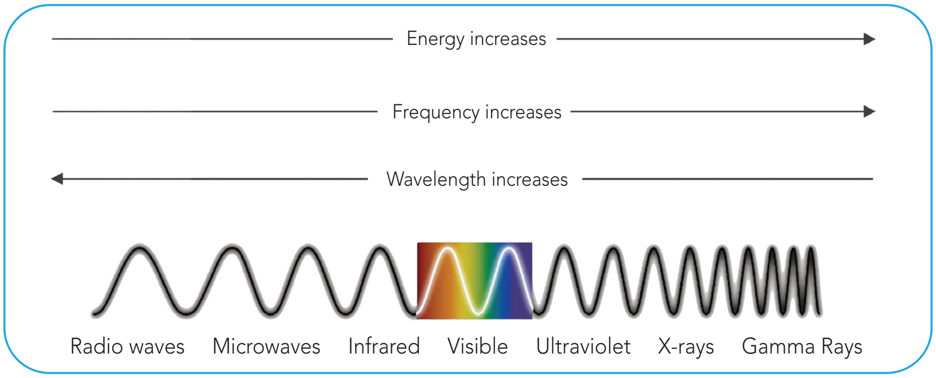
**Light is a form of energy** that stimulates our eyes and allows us to see the world around us. We're most familiar with *visible light:* the portion of the spectrum that our eyes can detect. But there are many types of light we can't see, such as infrared and ultraviolet light.

Each type of light is defined by how much energy it carries. We often describe this using a spectrum, from low-energy to high-energy light, which also corresponds to the wavelength of the light. Light is often represented as a wave, with a wavelength measured from one peak (or trough) to the next. *See figure below.*

**Optics is the study of how light behaves and how it interacts with matter**; understanding those interactions can help us better observe the world and universe around us.

Light and optics are at the heart of astronomy. They help us build tools like cameras and filters, determine what stars and galaxies are made of, and understand how galaxies move. In fact, almost everything we know about the universe comes from studying the light emitted or reflected by celestial objects.

We'll explore these ideas more through the activities below, with specific research connections highlighted throughout.



# ACTIVITY 1

## LEARNING ABOUT COLOUR

Kick off the activity with this video!

### Background and Context

In this first activity, students explore the properties of colour using coloured paddles, a variety of light sources, and differently coloured objects. It's a hands-on, flexible activity that can be adapted for a wide range of ages. For younger learners, the focus is on discovery, while older students can be guided toward deeper understanding and connections to curriculum content in art, general science, and physics.

For students in **Kindergarten through Grade 5**, this activity is primarily exploratory. Students will discover primary and secondary colours, and experiment with additive and subtractive colour mixing.

Starting in **Grade 4**, you may want to introduce more detail about how additive and subtractive colour mixing works. Light is an *additive* medium, meaning that when coloured lights are combined, they move toward white light which contains all colours. This contrasts with mixing paints or pigments, a *subtractive* process, where combining colours (especially in equal amounts) tends to move toward black, the absence of colour.

For students in **Grade 7 and up**, you can take the activity further by asking students to form hypotheses, explore cause and effect, and make real-world connections. Encourage them to come up with their own explanations, then use guiding prompts like these to deepen the discussion:

**Why does an object appear a certain colour?**
For example, a blue chair looks blue because it reflects blue light and absorbs all the other colours.

**What is radiant energy, and how does it relate to heat?**
Radiant energy is the energy carried by light. When an object absorbs a lot of light, it gets warmer. That same blue chair absorbs every colour except blue —so it will warm up under bright light. A white chair, on the other hand, reflects all colours and will absorb less radiant energy, staying cooler.

**How does colour relate to light waves?**
Light is a form of energy that can be represented as waves. We describe different colours by their wavelengths: longer wavelengths (like red and orange) carry less energy, and shorter wavelengths (like blue and violet) carry more. This can challenge students' assumptions —warm colours like red actually have lower energy, while cool colours like blue have higher energy!

## Learning Objectives

For students in **Kindergarten through Grade 3**, by the end of this activity students will be able to:

- Identify different colours
- Classify colours as "warm" or "cool" according to colour theory
- Compare objects of the same colour and of different colours
- Investigate combinations of colours

For students in **Grade 4 through Grade 12**, by the end of this activity students will be able to:

- Demonstrate and identify combinations of colours
- Examine and investigate all possible colour combinations
- Infer from observations that the colour of an object is the colour of light being reflected

## Grades and Timing

This activity is expected to take 30 minutes or less.

## Preparation

Estimated preparation time: 5-15 minutes

- Gather all required materials.
- If you haven't already, open the battery compartment of the laser pointer and remove the small piece of white paper so the battery can connect properly.
- Take a moment to read through the activity steps, teacher hints, student activity sheets, and the background information provided.

## Materials

- Colour paddles
- Laser pointer (doubles as light source) or another light source (e.g. flashlight, overhead light, Sun)
- White or light coloured blank paper

## RUNNING THE ACTIVITY

**Begin: Watch the explanation video with your students.**
Divide students into groups so that each group has either one full set of six coloured paddles (one of each colour) or at *least* three paddles. Each group should also have a blank sheet of white paper to work with.

If you're including a laser pointer in the activity, make sure each group has one. Before getting started, **review proper laser safety with your students** to ensure everyone uses it responsibly.

**Step 1: *5 min***
Consider an opening discussion using the following prompts:

- What is colour?
- What does it mean for an object to be "blue" or "red" or another colour?
- How do we know what colour an object is?
- Are colours of light different from colours of other media, like paint or ink?

**Step 2: *5–10 min***
Encourage students to identify the colour of each paddle and observe the colours created by combining them (i.e. holding two paddles together). Have them hold a paddle up to the light or over a well-lit white sheet of paper to see how the light changes.

Next, guide students to combine primary coloured paddles to create secondary colours, name the results, and describe which ones they think are warm or cool colours. As an added challenge, ask students to combine primary and secondary colours and see if the resulting colour matches any other paddle in the set. During the investigation, either in small groups or as a class, consider asking: *Which combinations surprised you? Which colours did you consider "warm" or "cool"? Why?*

HINT!

*Primary colours are red, blue, and yellow: These combine to form secondary colours: orange, green, and purple. Warm colours are typically red, orange, and yellow. While cool colours are generally green, blue, and purple.*

*Note: While in colour-theory we talk about warm- and cool-toned colours, in physics it's the opposite: blue is hotter and red represents cooler temperatures. For example, "cooler" stars are red, while the hottest stars are blue!*

**Step 3: *5 min***
Students are encouraged to look around the room or outside through the paddles and describe what they see. You may consider asking students to share verbally or to write their observations and compare with their groupmates.

### Step 4: *5 min*

Have students choose an object that is a different colour from the paddle they're using. Ask them to describe how the object looks when viewed through the paddle. You might prompt students with questions like:

- Were you surprised by how any of the objects looked through the paddle?
- Did you notice any patterns? If so, can you test your idea using a different paddle?

**HINT!** *Objects may appear tinted through the paddle, or if the object's colour is opposite the paddle's colour on the colour wheel it might appear black, like with: Red + Green, Blue + Orange, Yellow + Purple*

### Step 5: *5 min*

Next, have students choose an object that is the same colour as the paddle they're using. Ask them to observe and describe how it looks through the paddle.

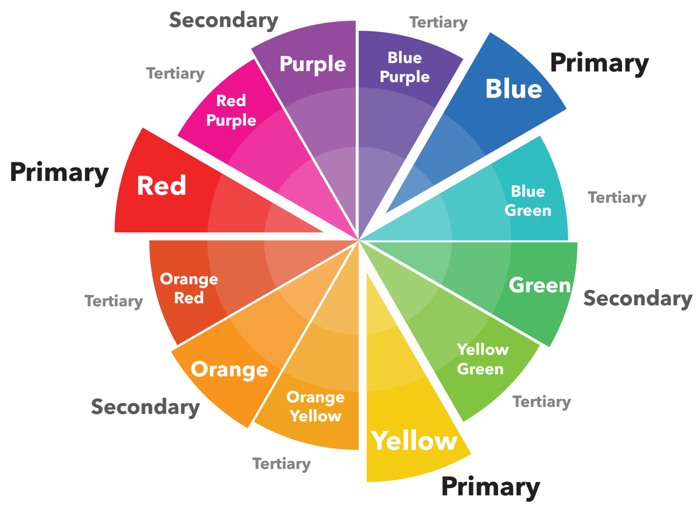
**HINT!** *The object should appear more intensely coloured. For example, a green object viewed through a green paddle will look even greener.*

### Step 6: *5 min* ⚠

For students in Grade 4 and up, challenge them to use the laser pointer by shining the beam through the paddle that matches its colour (typically red) onto a white paper. Ask students to observe carefully and describe what they see.

Once each group has completed this step, consider having a class discussion to share and compare observations. Prompt students to suggest possible explanations for what they noticed.

*A Colour Wheel*



# ACTIVITIES 2 - 4

## REFLECTION, REFRACTION, AND EYEBALLS

### Background and Context for Activities 2-4

In the next three activities, students explore the related concepts of reflection and refraction through observation and hands-on experimentation with prisms. These activities are recommended for students in Kindergarten and up, with opportunities to introduce more steps and challenge questions for older students –particularly around ray diagrams, focal points, and focal lengths. These lessons connect directly with general science and physics curricula.

For students in **Kindergarten to Grade 6**, these activities are exploratory. Students will investigate how light behaves as it passes through prisms held in different orientations, and they'll be encouraged to connect their observations to real-world experiences based on the patterns they notice.

For students in **Grades 6 to 9**, take the learning a step further by having them represent their observations using ray diagrams and analyse what they see to better understand specific phenomena. For example, they might determine the focal point of a prism and compare it to everyday tools like magnifying glasses or eyeglasses.

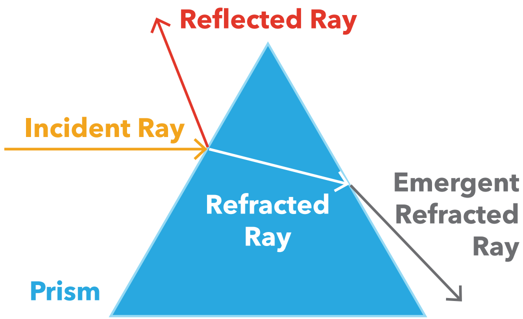
These activities offer an excellent opportunity to introduce or reinforce the concepts of reflection and refraction for students in Grade 6 and up.

Students in **Grade 9 and above** are encouraged to take their learning further by:

- Predicting outcomes in alternative experimental setups
- Critically evaluating their experimental process and methods
- Applying their understanding to real-world contexts, such as strong vs. weak eyeglass prescriptions

As students investigate, encourage them to come up with their own explanations for what they observe. It may be helpful to review the laws of reflection and refraction with students before or during the activity; for students in Grade 6 and up, you might guide the discussion using some of the key concepts on the next page.

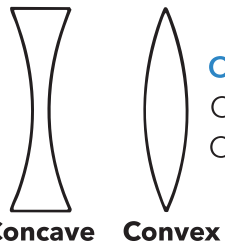
*Example of a simple ray diagram. In this illustration, the blue triangle represents a triangular prism, and the arrows show the light rays interacting with it. The incident ray (or incoming ray) enters from the left, where it is then reflected and refracted by the prism.*



# KEY CONCEPTS FOR DISCUSSION

### Prisms and Lenses

When a prism is very thin, we often call it a lens. One way to think about it is that a prism has four sides, while a lens typically has two. Even though their shapes are different, the same physical behaviours of light, like reflection and refraction, still occur. Lenses are simply more compact and often more practical for tools like cameras.




### Convex and Concave

Convex surfaces curve outward: narrower at the edges and wider in the middle. Concave surfaces curve inward: wider at the edges and narrower in the centre.

### Transmission and Absorption

Light is transmitted when it passes through a material. Light is absorbed when its energy is transferred into the material, often warming it up.

### Reflection and Refraction

Light is *reflected* when it bounces off a surface and changes direction. Light is *refracted* when it enters a material and its path bends due to the properties of that material.

### Refractive Index

This is a number that tells us how much a material slows down light. It's calculated as the ratio between the speed of light in air and the speed of light in the material.

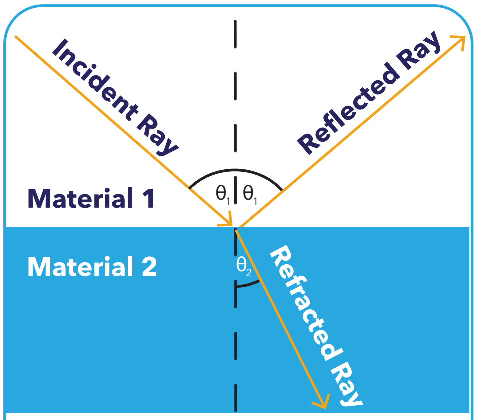
### Law of Reflection

The angle of incidence (incoming ray) is equal to the angle of reflection. In other words, light reflects symmetrically.

### Law of Refraction

This law is written as: $n_1 \sin(\theta_1) = n_2 \sin(\theta_2)$

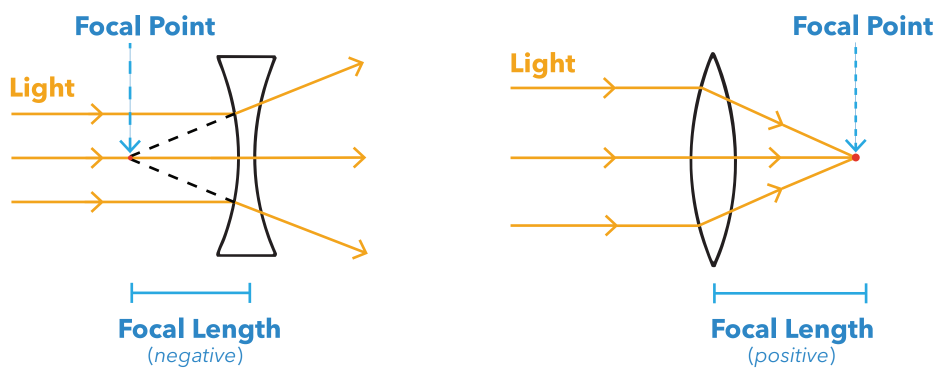
It means that when light passes between materials with different refractive indices (n), it bends. The greater the difference between the refractive indices, the more the light bends.




*A ray diagram representation of both the law of reflection and the law of refraction, for light interacting at the boundary between two materials with different refractive indices.*

### Focal Point
The point where incoming light rays passing through a prism or lens come together, or focus, is called the focal point.

### Focal Length
This is the distance from the centre of the lens or prism to its focal point. By definition, the focal length is positive when the light converges (convex prism) and negative when the light diverges (concave prism).




*Example ray diagrams that trace light rays diverging from a concave prism (left) and converging on a convex prism (right).*

### Magnifying Glasses, Eyes, and Telescopes
All three of these use convex lenses to bend and focus light, to form a clear image.

### Nearsightedness
People who are nearsighted can clearly see things close up, but have difficulty seeing objects that are far away.

### Farsightedness
People who are farsighted can clearly see things far away, but struggle to focus on objects that are close up.

## Research Connections

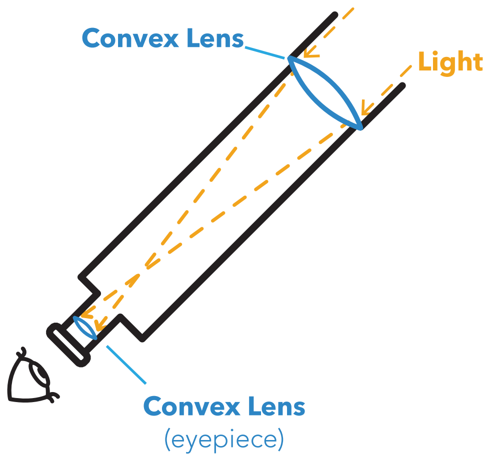
The concepts of reflection and refraction are central to astronomy, both in everyday skywatching and in advanced research!

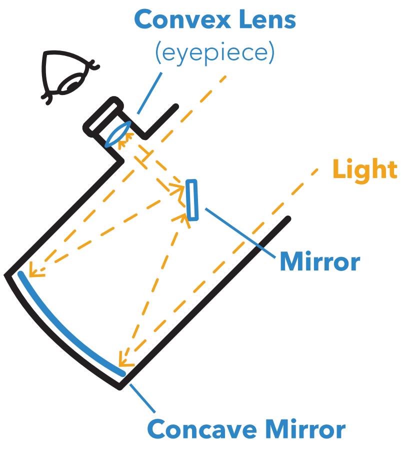
Everything we see in the night sky, whether with our eyes or through a telescope, is either **emitting light, reflecting light, or both**. For example, our Sun emits visible light that travels across the Solar System, illuminating objects like planets, moons, and asteroids. We're able to see these objects from Earth because they reflect the Sun's light.

Refraction also plays a role in what we see. As light passes through Earth's atmosphere, it bends –this is why the **Moon or Sun may appear distorted** near the horizon when setting. This bending affects our view of stars and other celestial objects, and can even tell us something about what's happening in the atmosphere itself.

Finally, optical telescopes rely on reflection and refraction to work. Most fall into one of three categories:

- Refractor telescopes, which use lenses and prisms to bend (refract) light to a focal point of the eyepiece
- Reflector telescopes, which use mirrors to gather and direct light
- Catadioptric telescopes, which use a combination of lenses and mirrors




*Telescopes can use lenses and mirrors to collect light from stars and bring it into focus where another lens (eyepiece) is placed for observation. Research telescopes are similar to these depictions, but use cameras and various instruments instead of eyepieces.*

# ACTIVITY 2

## REFLECTION AND REFRACTION

Kick off the activity with this video!

### Learning Objectives

For students in **Grades K to 3**, students will be able to:

- Illustrate reflection and refraction using different types of prisms

For students in **Grades 4 to 6**, students will be able to:

- Distinguish between reflection and refraction using different types of prisms
- Explain how refraction in prisms affects different colours of light

For students in **Grades 6 to 12**, students will be able to:

- Distinguish between reflection and refraction using different types of prisms
- Illustrate the laws of reflection and refraction using ray diagrams
- Analyse which experimental variables are relevant when studying light through different prisms
- Explain how refraction in prisms affects different colours of light

### Grades and Timing

This activity is expected to take 30 minutes or less.

### Preparation

Estimated preparation time: 5–15 minutes.

- Gather all required materials.
- If using shoeboxes, consider cutting a small hole (between 3 mm and 1 cm) near the bottom edge of one side of each box ahead of time —one per student group. Shoeboxes are ideal for this activity as they help students see the path of the laser while also protecting their eyes from accidental exposure to reflected or refracted beams. *We recommend making these holes ahead of time for younger students*.
- If you haven't already, remove the small white paper from the laser pointer's battery compartment to enable the connection.
- Read through the activity steps, hints, student sheets, and background information to familiarize yourself with the full context.

### Materials

- Laser pointer
- One or more prisms
- Shoe box or similarly sized open-topped cardboard boxes (one for each team)
- Pencil or other writing tools

ACTIVITY 2

## RUNNING THE ACTIVITY

**Begin: Watch the video with your students**

Divide students into groups, ensuring each group has at least one prism, one shoebox, and one laser pointer. Before beginning, take a moment to review laser pointer eye safety with the class.

**Step 1: *5 min***

Consider starting with a short class discussion using prompts like:

- What kind of prism(s) does your group have?
- What do you think will happen to the laser light when you point it at the prism?
- What do you already know about how light interacts with objects?

**HINT!** *Guide students toward the idea that when light interacts with a material, it's usually reflected, refracted, or absorbed.*

**Step 2: *5 min*** ⚠

Students place a prism in the centre of their shoebox and shine the laser pointer through the hole in the side. In their groups, they observe what happens and discuss whether the laser light is being reflected, refracted, or both.

You may want to bring the class together afterward to compare group conclusions –especially since observations may differ depending on the type of prism each group is using.

**HINT!** *Students may need to adjust the laser pointer slightly up or down to keep the beam parallel to the bottom of the box.*

**Step 3: *10 min*** ⚠

Students continue exploring by rotating the prism to either side (keeping the same face in contact with the box) or lifting and repositioning it to rest on a different side.

You might ask students to draw what they observe in their groups, then contribute a sketch to the board so the class can compare how different prisms behave. It can be helpful to provide an example ray diagram for students to follow.

**HINT!** *Students should notice the reflected and refracted beams shifting. Each side of the prism may produce different patterns of light behaviour.*

**Step 3: *cont'd***

For higher grades, students may benefit from a quick review of the law of reflection and the law of refraction. Remind them that they don't need to know the refractive index to answer the question, this value stays the same, regardless of prism orientation. The only thing changing is the angle of the incident ray.

Consider opening this part of the activity to a class discussion, encouraging students to explain why they think the refractive index is or isn't necessary to determine the outcome.

**Step 4: *5 min***

If possible, give students a chance to observe how sunlight interacts with the triangular prisms. This can be done indoors or outdoors. Note: Only use the triangular prisms for this.

Make sure students understand that they must not look through the prisms at the Sun. Instead, have them direct sunlight through the prism onto a blank surface, such as paper on the ground or a nearby wall, to safely observe how the light behaves. They should be able to get a rainbow (spectrum).

**Notes:**

# ACTIVITY 3

## CONCAVE AND CONVEX PRISMS

Kick off the activity with this video!

### Learning Objectives

For students in **Grades K to 3**, students will be able to:
- Identify convex and concave prisms

For students in **Grades 4 to 6**, students will be able to:
- Evaluate the focal point and focal length of convex and concave prisms
- Compare and contrast convex and concave prisms

For students in **Grades 6 to 12**, students will be able to:
- Compare and contrast convex and concave prisms
- Predict how light rays interact with convex and concave prisms
- Evaluate the focal point and focal length of convex and concave prisms
- Analyse which experimental variables are relevant (or not) when studying how light behaves with convex and concave prisms

### Grades and Timing

This activity is expected to take 30 minutes or less for students in Grades 4–6, and up to 45 minutes for students in Grades 6 and up.

### Preparation

Estimated preparation time: 5-15 minutes
- Gather all required materials.
- If not already done, cut two additional holes in the shoebox from Activity 2: one on either side of the original hole, forming a horizontal line of holes parallel with the bottom of the box.
- If you haven't already, open the battery compartment of the laser pointer and remove the small white paper to enable the battery connection.
- Review the activity steps, hints, activity sheets, and associated background information.

### Material

- Laser pointer
- Convex and concave prisms
- Paper for writing and drawing
- Pens and pencils
- Shoe box or similarly sized open-topped box from Activity 2

## RUNNING THE ACTIVITY

**Begin: Watch the explanation video with your students.**

This activity can be done in multiple ways. Consider which set up will work best for you and your students:

- Split students into two groups, one with the concave prism and one with the convex prism, each with their own shoebox and laser pointer. This setup is recommended for groups of 5–10 students. Groups can take turns using the other prism afterward.
- Have one group with both prisms, one shoebox, and one laser pointer. This works best for small groups of 5 or fewer.
- Demonstrate at the front of the class using both prisms and materials, with students observing. This is recommended for younger students and larger groups (10+ students).

If students will be handling the laser pointers, review eye safety before beginning.

**Step 1: *5 min***

Spark a short discussion using prompts like:

- What is the difference between a convex and a concave prism? *Hold each up for the class to see.*
- How do you expect light to be reflected or refracted through each prism?
- Can you draw a ray diagram of what you think will happen?

**Step 2: *5 min***

Students begin by exploring how light interacts with the concave (or convex) prism. Have them place the prism flat-side down in the centre of the shoebox, with the thinnest or thickest part lined up with the hole. They then shine the laser through the hole in the side of the box. They can draw the reflected and refracted lines on the white paper. Invite each group to share what they observed.

**HINT!** *The laser beam should pass straight through the prism with minimal refraction or reflection, travelling directly back toward the same side as the laser.*

**Step 3: *5 min***

For Grades 4 and up, consider prompting students to think about why the angle of the laser didn't change. Encourage them to draw what's happening. If creating diagrams, they should show that the angle of incidence is 0, so the refracted angle is also 0.

**HINT!** *It can be difficult to distinguish between the reflected and refracted beams. The refracted beam is easiest to track, but two reflected beams may appear: one from the near side of the prism and one from the far side. For this reason, focus on observing the refracted beam.*

**Step 3: *cont'd***

For higher grades, note that with a concave prism, the reflected light comes to a point in front of the prism (same side as the laser), while the refracted light spreads out on the far side. The opposite occurs for the convex prism.

**Step 4: *10 min***

Students repeat the previous steps using the other prism.

*HINT!*

*Students should end up with the opposite ray diagram. For the convex prism, reflected light spreads outward while refracted light comes to a focal point. For Grades 4–6, the activity can conclude here.*

**Step 5: *5-10 min***

Students now view an image through the convex prism at different distances. For students in Grades 6 and up, introduce the concept of focal length. *Remind students that concave lenses have negative focal lengths, while convex lenses have positive focal lengths.*

Students are observing how rays converge or diverge to determine the focal point. Note that the curvature of the prism changes at the edges, so encourage them not to move the beam all the way to the edge.

**Step 6: *5 min***

As a final extension for Grades 6 and up, encourage students to reflect on how their experiences with the concave and convex prisms relate to how magnifying glasses work.

If you have one available, ask students to compare how the magnifying glass behaves compared to the prisms. How does the image change when viewed through each? You can also use the laser pointer to show how light moves through the magnifying glass.

**HINT!**

*Magnifying glasses are convex lenses.*

# ACTIVITY 4

## EYEBALLS

### Learning Objectives

For students in **Grades 2 & 3**, students will be able to:

- Understand and sketch how images form in the eye

For students in **Grades 4 to 6**, students will be able to:

- Theorise which types of lenses are needed for different eyesight needs
- Investigate how lenses and refraction are used in everyday life, for example, in magnifying glasses and eyeglasses

For students in **Grades 6 to 12**, students will be able to:

- Analyse which experimental variables are relevant (or not) when studying how light behaves with lenses, including in our eyes
- Theorise which types of lenses are needed for different eyesight needs
- Investigate how lenses and refraction are applied in real life, particularly in magnifying glasses and eyeglasses

### Grades and Timing

This activity is expected to take 30 minutes or less for students in Grades 4–6, and up to 60 minutes for students in Grades 6 and up.

### Preparation

Estimated preparation time: 5-15 minutes

- Gather all required materials.
- If not already done, cut two additional holes in the shoebox from Activity 2: one on either side of the original hole, forming a horizontal line of holes parallel with the bottom.
- If you haven't already, open the battery compartment of the laser pointer and remove the small white paper to allow the battery to connect.
- Review the activity steps, hints, activity sheets, and background information provided.

### Material

- Laser pointer
- Eyeglass lenses
- Paper for writing and drawing
- Pens and pencils
- Shoe box or similarly sized open-topped box from Activity 2

ACTIVITY 4

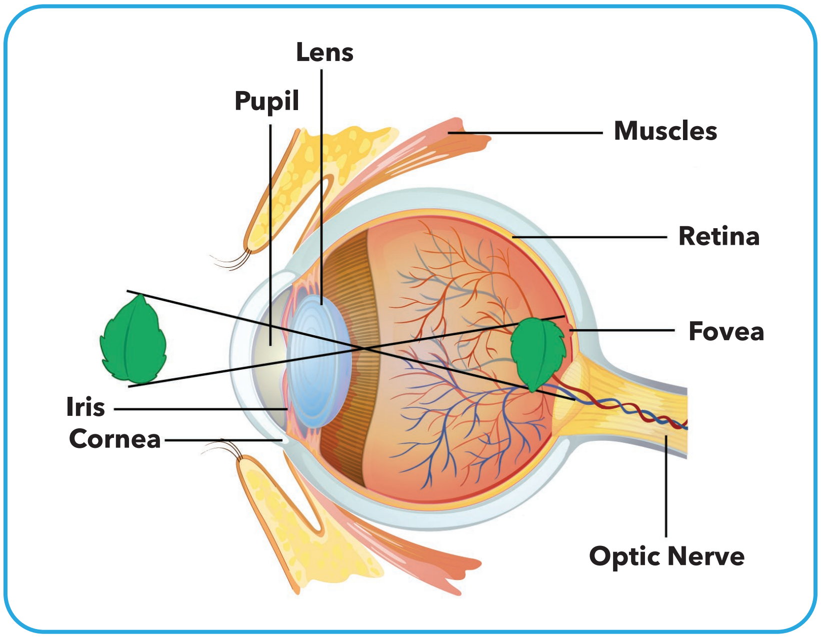
## RUNNING THE ACTIVITY

**Begin:**

This activity starts with some background information about the eye for students. Provide your students with this background information:

- The lens of the eye is convex.
- The image formed on the retina is inverted.
- Nearsightedness and farsightedness are caused by deformities in the eye's lens.
- These conditions are corrected using eyeglasses, which contain lenses held in a frame.

Share the following diagram of the cross section of a human eye:




**Step 1: *5 min***

As a class, discuss how the eye works, including the role of the lens, the difference between near- and farsightedness, and how corrective lenses help. The activity can end here for students in Kindergarten to Grade 3.

Then, split students into groups, each with an eyeglass lens to test, a laser pointer, and a shoebox. Alternatively, you may conduct a demonstration and have students collaborate on the questions together.

**Step 2: *5-10 min***

Students begin by determining what kind of lenses they are using —concave, convex, or another type. Using the methods from Activity 3, have them place the lens in the shoebox and shine the laser beam through the lenses while moving them side to side.

**HINT!** *If the beam diverges, the lens is concave. If the beam converges, it is convex. There's more than one way to figure this out, so encourage creativity!*

**Step 3: *5-10 min***

Students compare their findings with other groups and look for patterns in the type of lens used and the vision issue corrected. They may be surprised to find variety in the results.

Consider making a class list or diagram on the board to track findings across groups.

**HINT!** *Hint: Nearsightedness is treated with concave lenses. Farsightedness is treated with convex lenses.*

**Step 4: *5 min***

For students in Grades 6 and up, turn attention to how light moves through the eye. Have students draw ray diagrams showing how light is focused inside the eye. This can be done in groups or as a class with sketches on the board.

**Step 5: *5 min***

Next, students adapt their diagrams to show nearsightedness and consider how the eye's lens changes in this condition.

**HINT!** *In nearsightedness, the focal length is too short, meaning the image forms in front of the retina. This could be due to a thicker lens with more curvature.*

**Step 6: *5 min***

Then, students repeat the process for farsightedness, again considering how the lens of the eye would be different.

**HINT!**

*In farsightedness, the focal length is too long so the image forms behind the retina. This might be due to a thinner lens with less curvature. Ask students how this would change their ray diagram compared to a normal or nearsighted eye.*

**Step 7: *5-10 min***

For a challenge, you can invite students in Grades 6 and up to apply what they've learned to strong and weak eyeglass prescriptions. Consider turning this into a class discussion.

**HINT!**

*Stronger prescriptions require lenses with greater curvature to bend light more dramatically before it enters the eye. This compensates for a greater deviation from a normal lens. The stronger the prescription, the more the lens must converge or diverge light rays before they reach the eye.*

**Notes:**

# ACTIVITY 5

## DIFFRACTION

Kick off the activity with this video!

### Background and Context

The final activity in this section invites students to explore and experiment with light using a diffraction grating. It's suitable for students of all ages, with added steps and advanced experiment design suggestions for older students to align with their grade-level curriculum. This activity connects directly with general science and physics concepts.

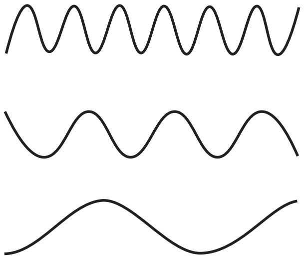
In Activity 1, students learned that light is a form of energy that can be represented by waves. Longer wavelengths correspond to lower-energy light (e.g. red), while shorter wavelengths correspond to higher-energy light (e.g. blue). White light is a combination of all visible wavelengths. Diffraction gratings separate these colours, splitting white light into a rainbow spectrum.

For **Kindergarten to Grade 5**, this is an exploratory activity.

From **Grade 3** and up, students can compare how laser light and white light interact with the diffraction grating and experiment with coloured paddles and different light sources.

For **Grades 9** and up, guide students toward understanding how diffraction gratings split light based on wavelength, and relate this to refraction from Activity 2. Explain how many tiny slits in the grating cause the light waves to interfere, reinforcing or cancelling each other to produce diffraction patterns. Something like the diagram below could be used to support this discussion. It shows three waves with increasing wavelengths. The wavelength is the length from one peak to the next, or one trough to the next.

- Purple light (~380nm) has the shortest visible wavelength (1nm = 1 nanometre = $10^{-9}$m).
- Red light (~700nm) has a longer wavelength.
- For scale, a human hair is about 50,000nm wide.



*Example of 3 different waves, each with a different wavelength. The top wave has the shortest wavelength, the middle wave has a wavelength double that of the top wave, and the bottom wave has the longest wavelength which is double that of the middle wave.*

## Learning Objectives

For students in **Grades K to 3**, students will be able to:
- Compare the diffraction patterns of different light sources

For students in **Grades 4 to 6**, students will be able to:
- Compare the diffraction patterns of different light sources
- Investigate diffraction patterns as a function of distance
- Describe light as a wave, and represent different wavelengths as different colours

For students in **Grades 6 to 12**, students will be able to:
- Compare the diffraction patterns of different light sources
- Investigate and describe diffraction patterns as a function of distance
- Describe light as a wave, illustrating wavelength differences by colour
- Examine and contrast diffraction patterns of different colours of light

## Grades and Timing:

This activity takes 30 minutes or less for most students and up to 45 minutes for Grades 6 and up.

## Preparation

Estimated preparation time: 5-15 minutes
- Gather all required materials.
- If not already done, open the battery compartment of the laser pointer and remove the white paper.
- Poke two aligned holes in the shoebox: one at each end of the longest side.
- Review the activity steps, hints, activity sheets, and background information.

## Materials

- Diffraction grating
- White paper
- Writing materials
- Laser pointer (with flashlight option, Grade 4 and up)
- Coloured paddles (Grade 4 and up)
- Shoe box (Grade 6 and up)

ACTIVITY 5

## RUNNING THE ACTIVITY

**Begin: Watch the explanation video with your students.**

Split students into groups such that each group has a diffraction grating, laser pointer, or light source. If using colour paddles, ensure each group has at least one paddle. If using the laser pointer, review eye safety before beginning.

**Step 1: *5 min***

Consider an opening discussion using the following prompts:

- What is light?
- What does it mean for there to be different colours of light?
- How are they different?

Consider guiding this discussion towards the concept of wavelengths of light.

**Step 2: *5 min***

Students begin by investigating the environment around them with the diffraction grating, looking at well-lit objects and describing their observations.

**Step 3: *5 min*** ⚠

Students explore what different light sources look like through the diffraction grating. It is recommended to use flashlights by shining them through the diffraction grating onto a white sheet of paper, or to look through the grating directly at an artificial light source such as a ceiling light.

**Step 4: *5 min*** ⚠

Focusing on white light from a flashlight, students describe what they see through the diffraction grating in as much detail as they can.

**Step 5: *5 min*** ⚠

For Grades 6 and up, students observe how the diffraction grating interacts with different colours of light by using white light and the coloured paddles. Note that some paddles might work better than others. Students compare and contrast their observations of different kinds of light (laser, white light, blue light) and different colours, and are encouraged to come up with their own explanations.

**HINT!** *Remember that diffraction gratings split light into its component wavelengths.*

**Step 6:** ***10 min***

Students in Grade 7-12 are encouraged to investigate what happens when using the laser and blue light options (on the pointer) through the grating onto a sheet of paper. They can also move the diffraction grating closer to and farther from the paper as they observe the patterns.

**HINT!**

*To get a clearer diffraction pattern, students can use a shoebox to help aim the light in a straight line (as in the adjacent image). Cut one hole at each end of the shoebox. Have students shine the laser through one hole so that only straight light makes it through the box. Then, hold the diffraction grating in front of the hole on the other side, to catch the light coming through the box. This setup helps focus the beam and makes the pattern easier to see.*

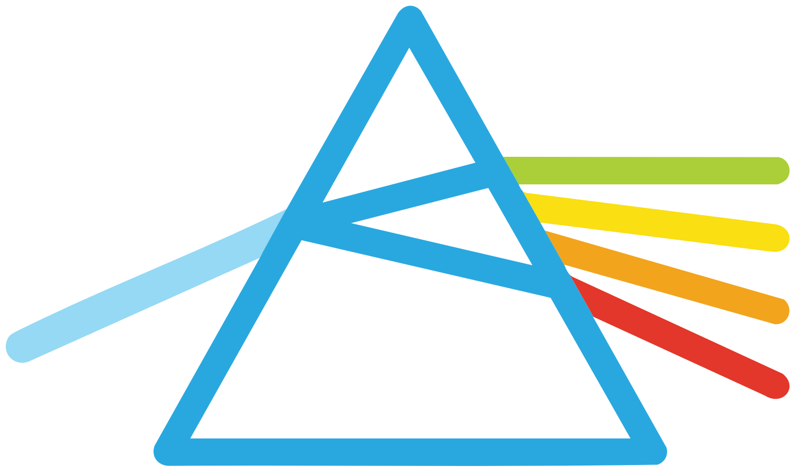
*Moving the diffraction grating closer to the paper will cause the diffracted beams to appear closer together. Moving it farther away will increase the spacing between the beams.*

**Notes:**

# LIGHT & OPTICS

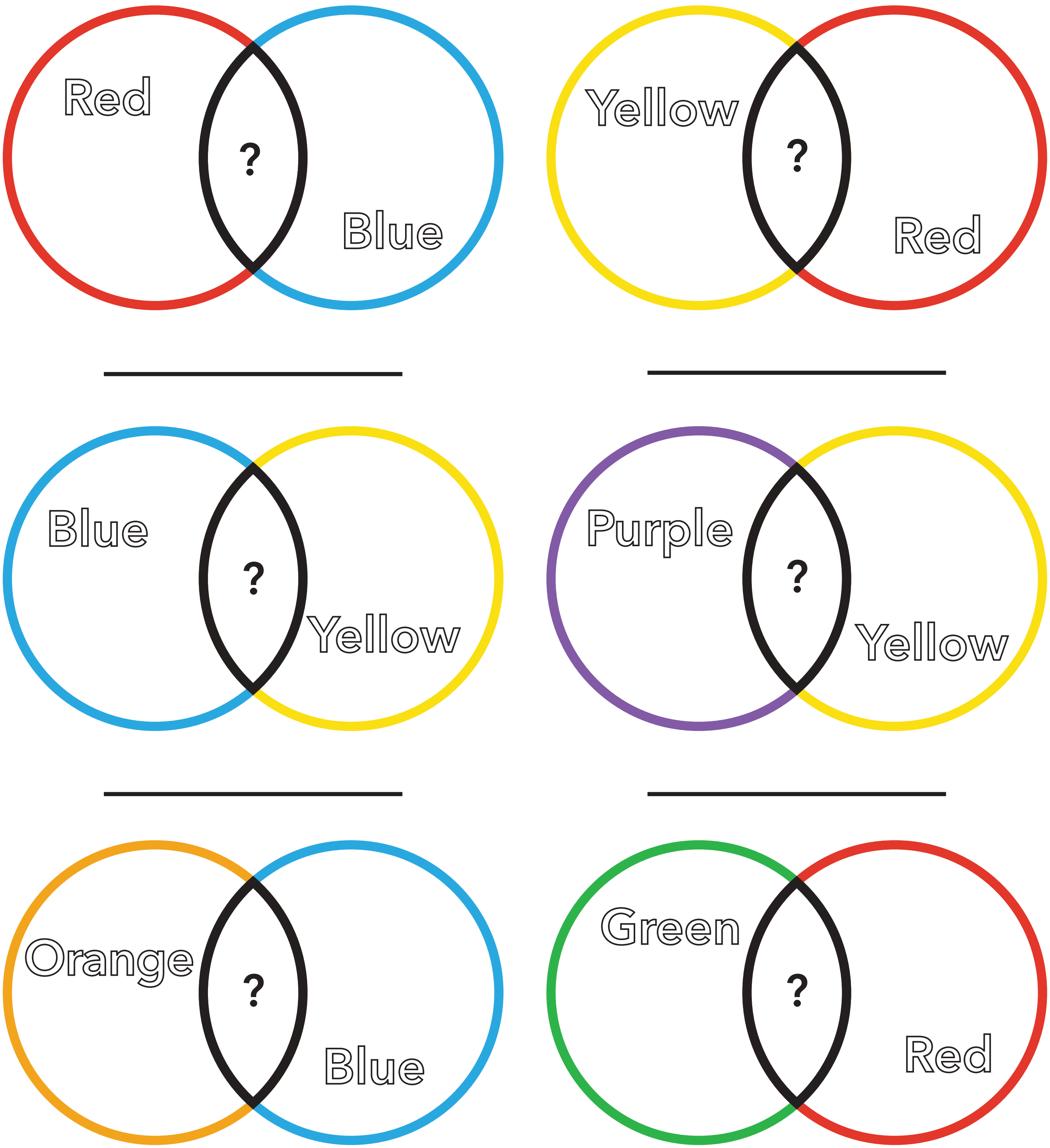
## STUDENT HANDOUTS AND ACTIVITY SHEETS

**Complementary and optional activities for your learners!**



## Kindergarten – Grade 3

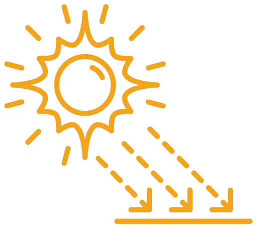
## Combine coloured paddles and then colour in the spaces!

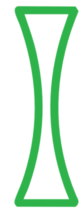


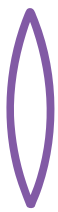
Draw a prism!

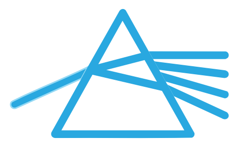
How many light beams did the prism make?
Draw the light beams!

## Match the words to the correct image:









Laser Pointer

Prism

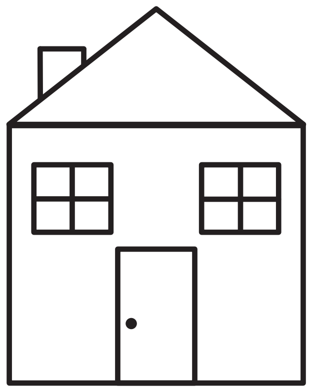
Convex

Concave

Sun Rays

**What was your favourite part of the laser beam activity?
Draw or write your answer!**

**Draw the following image the way your eye first sees an object!** *Hint: it's upside down!*



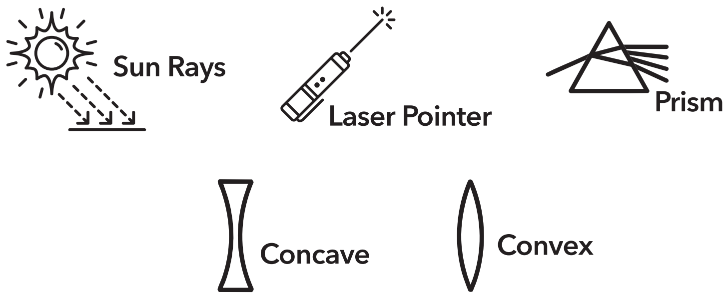
## Draw the pattern you saw through the diffraction window!

# GRADE K-3 ANSWER KEY

## Activity 1

Red + Blue = Purple, Yellow + Red = Orange, Blue + Yellow = Green, Purple + Yellow = Brown/Black, Orange + Blue = Brown/Black, Green + Red = Brown/ Black

## Activity 2

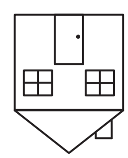



## Activity 3

Drawings will vary based on the prism they saw. This is more about getting them to think about their observations than having "correct" answers.

## Activity 4

Students should be able to reproduce the simple house upside down.



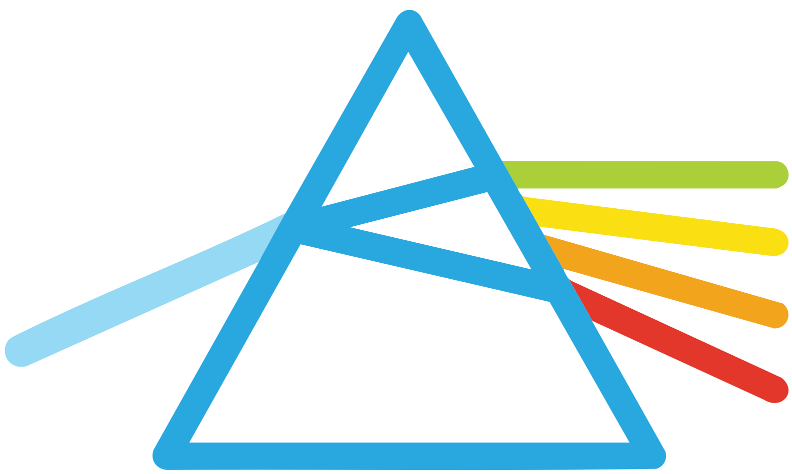
## Activity 5

The rainbow patterns might be interpreted slightly differently and this could be a simple reflection and art activity, or you could watch for colours being applied in the correct order. Violet and Blue are always closest to the light source, then Green, Yellow, Orange, and Red. Some colours are less obvious and may not appear in their work.

# LIGHT & OPTICS

## STUDENT HANDOUTS AND ACTIVITY SHEETS

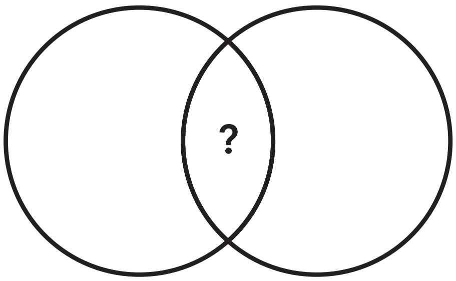
**Complementary and optional activities for your learners!**

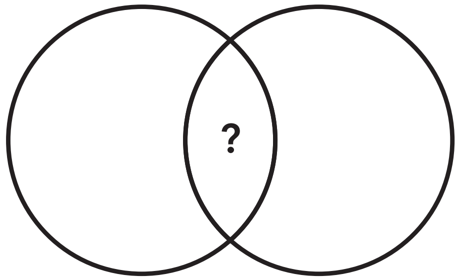


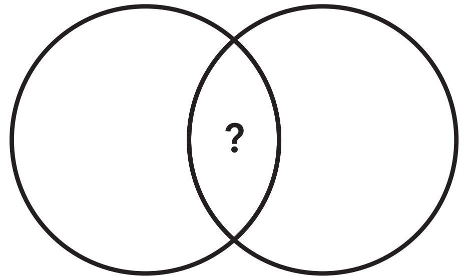
## Grade 4 – 6

**Colour Basics:** **Primary:** Red, Yellow, Blue **Secondary:** Orange, Green, Purple

## Combine two colour paddles and fill in the blanks!




________ + ________ = ________

________ + ________ = ________

________ + ________ = ________

Choose an object that is a different colour than the paddle. Hold up the paddle in front of the object. What colour is the object through the paddle?

________ + ________ = ________

*object colour* *paddle colour*

Choose an object that is the same colour as the paddle. Hold up the paddle in front of the object. What colour is the object through the paddle?

________ + ________ = ________

*object colour* *paddle colour*

***Explore!*** *You can combine primary colours to make secondary colours. Test it out!*

What colours can you get if you combine two primary colour paddles?

What colours can you get if you combine a primary colour paddle with a secondary colour paddle?

What colours can you get if you combine two secondary colour paddles?

## Reflection

Some of the laser light bounces back toward you. This is called **reflection**.

Can you find the reflected beams? Draw lines on the paper at the bottom of the box to show them.

## Refraction

Some light passes through the prism and hits the far wall. This is called **refraction**.

Can you find the refracted beams? Draw lines in a new colour on the paper to show them too!

Draw your prism and the angled light beams. Identify which was Reflected and which was Refracted.

## ACTIVITY 3: CONCAVE AND CONVEX PRISMS

Measure the distance between your prism and where the light rays come together, then draw your prism, the angles of light beams, and where they meet.
Label your diagram.

### Fill in the blanks!

In this activity, we used a ____________________ to shine light through a ____________________ placed inside a box.

We noticed that some of the light bent, which is called ____________________.

Some of the light bounced back, which is called ____________________.

A ____________________ lens brings light together at one point,
while a ____________________ lens spreads light apart.

**Keywords:** concave • laser pointer • reflection • convex • refraction • prism

## Fill in the blanks!

We looked at the human ___________________and learned that its lens is ________________in shape. This kind of lens makes light rays ___________________together.

Sometimes, people's eyes don't bend light the right way, so things can look blurry. Glasses help by using different shaped ___________________ to bend the light so it focuses clearly on the ___________________.

**Keywords:** retina • lenses • eye • convex • come • lens

Try drawing something in your classroom the way your eye sees things before your brain interprets it (upside down)!

## Draw what you see through the diffraction grating ...

looking at the ceiling lights

What happens to the white light?

pointing the laser through the grating onto a white paper

What do you notice?

looking at the ceiling lights + a colour paddle

How has the colour pattern changed?

# GRADE 4-6 ANSWER KEY

## Activity 1

Expect students to see subtractive colour mixing (like paint, i.e.: red + blue = purple).
Different colour paddles and object should darken the object or make it appear black.
Similar colour paddles will make object should seem more intense.
For the explore section, you can expect answers like: combined primary colours give secondary colours; a primary and secondary colour will be nearly black; and two secondary colours will also be nearly black.

## Activity 2

Students should recreate the visual of their prism in the box, creating a simple ray diagram and correctly label the reflected and refracted light. See video or page 7 of this guide for examples.

## Activity 3

Students should create a simple ray diagram and correctly label the reflected and refracted light, including the measured distance they observed in their box. See video or page 10 of this guide for examples.

**Fill in the Blanks:** In this activity, we used a **laser pointer** to shine light through a **prism** placed inside a box. We noticed that some of the light bent, which is called **refraction**. Some of the light bounced back, which is called **reflection**. A **convex** lens brings light together at one point, while a **concave** lens spreads light apart.

## Activity 4

**Fill in the Blanks:** We looked at the human **eye** and learned that its lens is **convex** in shape. This kind of **lens** makes light rays **come** together. Sometimes, people's eyes don't bend light the right way, so things can look blurry. Glasses help by using different shaped **lenses** to bend the light so it focuses clearly on the **retina**.

## Activity 5

White light, like most ceiling lights, becomes many rainbows, creating a rainbow pattern.
With the laser, students should notice that only red light comes through, creating a pattern of many red points.
Some parts of the rainbow will be stronger or more faint depending on the colour of their paddle. For example, the orange paddle blocks the blues from the end of the rainbow.

# LIGHT & OPTICS

## STUDENT HANDOUTS AND ACTIVITY SHEETS

**Complementary and optional activities for your learners!**

## Grades 7 – 12

## ACTIVITY 1: LEARNING ABOUT COLOUR

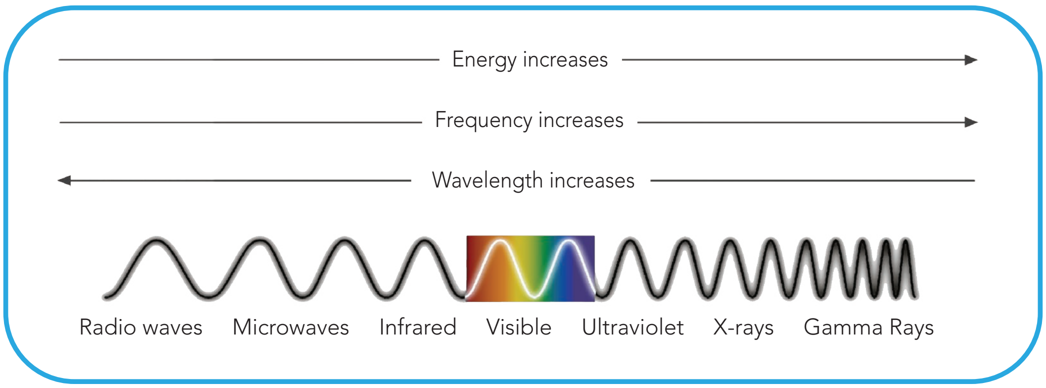
1. **Choose two paddles and hold them up to a white light source or paper.** What colours did you combine? Did the result surprise you? Why or why not?

2. **Try looking through a paddle at something the same colour. Then try looking through the same paddle at something a different colour.** What changed?

3. In art class, when you mix paint, you are removing light when you combine colours; each paint colour absorbs some light, so you see less light reflected back. With light, adding colours means you are combining more light, which can make things brighter, sometimes even turning white.

**Look at what happens when you combine two coloured paddles.** Does it seem more like what happens when you mix paint, or like adding light together? Why do you think that is? *(Hint: are the paddles adding more light or blocking some of it?)*

**Now examine this wavelength diagram and answer the following questions.**




4. In art, we call red, orange, and yellow "warm colours". **But in physics, the colours of light that carry the most energy and are therefore associated with hotter objects**, are __________ and __________.

5. Which colours carry more energy, red light or blue light? Explain in your own words.

6. **At night, you might see stars that look slightly different in colour: Blue-white stars, Yellow stars, Orange or Red stars.** What does the colour of a star tell us about its temperature?

7. Which is hotter: a blue star or a red star?

8. **Challenge** *(Optional)*
Explain why some stars are red and some are blue in fewer than 20 words.

## ACTIVITY 2: REFLECTION AND REFRACTION

1. **Place your prism in the centre of the shoebox. Shine the laser through the hole.** What do you see?

- [ ] The light goes straight through
- [ ] It bends
- [ ] It bounces back

2. **Now describe what happened in your own words.**

3. **Try rotating the prism.** What changed?

4. What do we call it when **light bounces off a surface**? What do we call it when **light changes direction** as it enters a new material?

5. **Draw a simple diagram showing what you saw.** Label: the prism, the incident ray, the reflected ray, the refracted ray (if visible). *You just created a ray diagram!*

6. **True or False**: The angle of the laser affects how the light interacts with the prism. Why?

7. **Astronomers study light by using lenses and mirrors to understand distant objects. Telescopes are simply mirrors and lenses cleverly aligned to collect light.** In your prism activity, you saw that light can change direction by bending (refraction) and bouncing (reflection). If a telescope could not bend or reflect light properly, what do you think you would see when looking through it? How would the image be different?

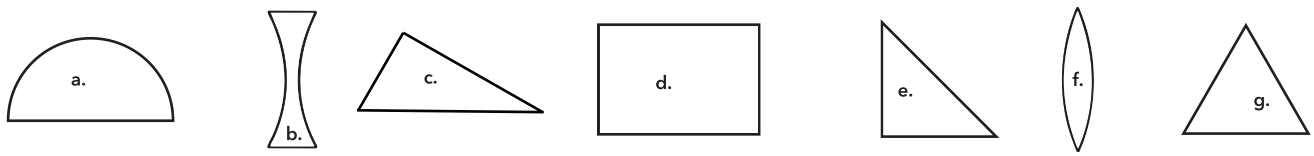
8. **Optional: If you used the triangle prism with sunlight or a flashlight**, what did you see? What caused it? *(Hint: think about white light!)*

9. **Challenge** *(Optional)*
Refer back to the ray diagram you drew for question 5.

In your own words, explain: where did reflection happen in your setup; which surface(s) caused it; where did refraction happen; which surface(s) did the light pass through?

If you change the angle of the laser, how do you think the reflected and refracted beams will change? Explain your reasoning based on what you saw in your experiment.

## ACTIVITY 3: CONCAVE AND CONVEX PRISMS




1. Which of the above prism(s) do you think **will bring the laser beams together**? Why?

2. Which prism(s) do you think **will spread the beams apart**? Why?

3. **Place a prism flat-side down inside the box. Shine the laser through the side hole.** What do you see with the first prism?

- [ ] The beam bends inward
- [ ] The beam spreads outward
- [ ] Nothing changed

Which prism was it?

4. **Now try a different prism and repeat.** What do you see with the second prism?

- [ ] The beam bends inward
- [ ] The beam spreads outward
- [ ] Nothing changed

Which prism was it?

5. **Sketch what happened with both concave and convex prisms. Include:** the laser beam, the prism, and arrows showing light's path. Label: incident ray, refracted ray, and focal point (if there is one).

6. **What is focal length?** Try defining it in your own words. Try to measure the focal length of the lenses. Repeat the measurement a few times, be as precise as possible.

7. Which type of lens has a **positive focal length**: Concave or Convex? Why?

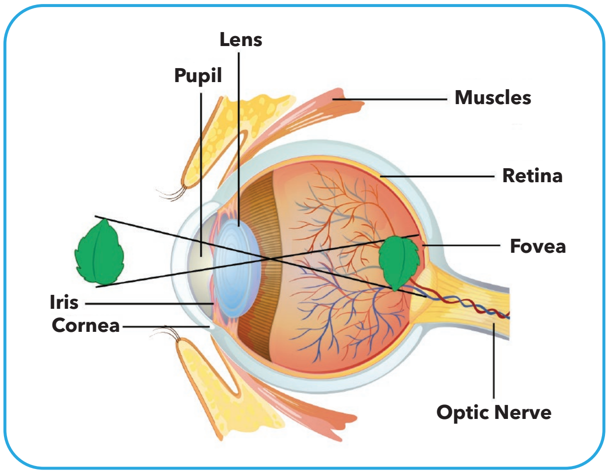
8. Which one has a **negative focal length**: Concave or Convex? Why?

9. How do magnifying glasses change what we see?

10. Convex lenses bend light rays _______ , which helps telescopes gather _______ light from distant stars.  Concave lenses bend light rays _______ , which are better for ________ light.

**Keywords:** Together • Apart • More • Less • Spreading • Focusing

## ACTIVITY 4: EYEBALLS




1. **Review the diagram of the human eye.** What kind of lens does the eye use to focus light?

2. **True or False:** The image that forms on the retina is upside down.

3. **What do corrective lenses** (like glasses) **actually do** to help us see better?

4. **Use the shoebox and laser pointer to test the lens provided.** When you shine the laser through the lens, do your best to go through the centre of the lens, where the pupil might be. Does the beam:

- ☐ Come together at a point? ⟶ Convex lens
- ☐ Spread apart? ⟶ Concave lens
- ☐ Do something else? Describe it.

5. **These lenses are used to help people who are farsighted** (have trouble seeing things up close). In your own words, explain how bending light with this lens helps bring close-up objects into clearer focus.

6. **Sketch how the laser beam moves through the lens.** Label: laser beam, type of lens, incident ray, refracted ray(s), focal point (if there is one).

7. **In a healthy eye, the lens bends light so the image forms on the retina,** but in nearsightedness, where does the focal point fall?

☐ In front of the retina ☐ Behind the retina

8. In farsightedness, the focal point lands:

☐ In front of the retina ☐ Behind the retina

9. **Challenge** *(Optional)*
Stronger prescriptions mean the lens has to bend the light more. What does that mean for the shape of the lens?

If someone wears glasses so thick they look like magnifying lenses, do they likely have a convex or concave lens? Why?

Telescopes also use lenses and mirrors to bend light and bring distant objects into focus. What might happen if a telescope used a concave lens instead of a convex one?

## ACTIVITY 5: DIFFRACTION

1. Light behaves like a ________ and travels in ________ lines unless it is ________, ________, or ________.

When we pass light through a diffraction grating, it spreads out into a ________ of colours. These colours represent different ____________.

**Keywords:** wave • reflected • spectrum • straight • absorbed • refracted • wavelengths

2. **Make notes on your observations!**
Look through the diffraction grating at the ceiling light and then the ceiling light + a coloured paddle. What do you notice?

**Now shine the laser beam through the grating onto a sheet of paper.** What's different here?

*Challenge:* **use the box to focus and direct the light** *(pictured)* **through the grating** to observe and describe what happens when you use a flashlight and a Blue LED.

3. Do the patterns look different depending on the light source? The colour? The distance from the paper? **Describe something that surprised you.**

4. **Which colour or part of the light pattern spread out the furthest** (was farthest from the centre)? What do you think that tells you about the wavelength of that colour of light?

5. **If light spreads less when its wavelength is shorter,** which visible colour has the shortest wavelength? Circle one:

Red    Yellow    Green    Blue    Violet

6. **Challenge** *(optional)*
Astronomers use diffraction (with tools called spectrometers) to spread out starlight into a rainbow of colours. Stars give off light across the whole visible spectrum, but they are not equally bright in every colour.

When you use a diffraction grating, some parts of the pattern might look brighter than others. If you looked at the light from a very hot star through a spectrometer, which part of the spectrum do you think would be the most intense (brightest)? Why do you think that is?

# GRADE 7-12 ANSWER KEY

## Activity 1

1. Expected Concepts: Students may say they combined red + blue, blue + green, etc.
Surprises may include unexpected shades or muddiness.
Look for: recognition that light mixing doesn't behave exactly like paint mixing.

2. Expected Concepts: When viewed through the same colour, the object might appear brighter or unchanged. When viewed through a different colour, the object may look darker, greyed out, or shifted.
Look for: signs that students noticed colour filtering (absorption of some wavelengths).

3. Expected Concepts: Paint mixing is subtractive: pigments absorb some light and reflect others. Light mixing is additive: all wavelengths add together. Blue + yellow light ≈ combining most visible wavelengths close to white. The paddles block some of the light (i.e.: the red paddle allows red light to pass through but blocks other colours, although not perfectly). When we look at a white light (or white paper) with two paddles, we block more light and the object appears darker. They are subtracting light.
Look for: awareness of additive vs. subtractive colour theory.

4. Correct Answer: Blue and violet

5. Correct Answer: Blue light. Why: Shorter wavelengths = higher frequency = more energy.
Look for: mention of shorter wavelengths or higher energy.

6. Expected Concepts: Colour indicates surface temperature. Blue stars are hotter, red stars are cooler.
Look for: linking colour to temperature via energy or wavelength.

7. Correct Answer: Blue star

8. Challenge Question (Optional)
Look for: stars that are hotter emit higher-energy light, which makes them appear blue; it's opposite for red stars

## Activity 2

1. All three answers may be correct depending on the prism. This is more about exploration than finding "correct" answers.

2. Look for: students noticing bending, splitting, or changes in direction. They may describe how the beam exits the prism at a different angle or partially reflects off the surface.

3. Expected: the exit direction of the beam changes; some students may note changes in brightness or additional reflections inside the prism.

4. Expected: Reflection: the beam that bounced back from the prism surface or at the interface where it didn't enter the prism.
Refraction: the beam that bent as it passed through the prism and exited at a different angle.

5. Look for: labelled diagram with a straight incident ray entering the prism, bending inside, and exiting at a new angle. Reflected ray may also be shown. Labels: prism, incident ray, reflected ray (if shown), refracted ray.

6. Correct answer: True
Expected: Because the angle determines whether the light enters or reflects, and how much it bends due to refraction.

7. Expected: Students should explain that without bending or reflecting light properly, a telescope would not be able to focus light, resulting in a blurry, unfocused, or distorted image.
Look for: light not forming a clear picture. Stronger answers will connect this to what they observed with the prism –how changing angles affected where the light went.

8. Expected: a rainbow or spectrum of colours; white light splitting into its component wavelengths through refraction.

9. Expected: In their diagrams, students should show the incident ray hitting the prism, some light bouncing off (reflection), and some bending as it passes through (refraction).
Look for: Reflection happens on the surface where the laser first hits or where it exits without passing through; refraction happens when light passes through the prism's surfaces, changing direction inside the prism. If the laser angle changes, the angles of both reflection and refraction should also change, making the beams move to different spots inside the box. Students should explain this using what they observed–steeper angles make the light bend more or reflect in different directions

## Activity 3

1. Correct Answer: Convex (f.). These bend light rays inward toward a focal point because the shape causes refraction to converge the rays.

2. Correct Answer: Concave (b.). These spread the rays outward because the light bends away from the thicker edges due to the shape and angle of entry/exit.

3. Expected: If the beam bends inward, students should select "The beam bends inward" and identify the convex prism. If the beam spreads outward, they should select "The beam spreads outward" and identify the concave prism.
If nothing changed, they likely didn't aim the laser correctly or used a prism shape that didn't alter the beam noticeably. Strong answers will correctly match convex = inward bending, concave = outward spreading.

4. Look for: students noting a change in behaviour and matching it to the correct shape.

5. Look for: Convex = rays converging to a focal point, Concave = rays diverging, Labelled: laser beam, prism, incident ray, refracted ray, focal point (if applicable). See example on page 7.

6. Expected concept: The distance between the lens and the point where light rays converge (convex) or appear to diverge from (concave).
Accept phrasing like: "How far the light travels before it comes together (or appears to)."

7. Convex. Why? Because light rays actually converge at a point in front of the lens.

8. Concave. Why? Because light rays diverge, and the focal point is virtual—behind the lens.

9. Expected answer: They enlarge the image by bending light to make it appear closer—convex lenses create a larger virtual image.

10. Convex lenses bend light rays **together**, which helps telescopes gather **more** light from distant stars. Concave lenses bend light rays **apart**, which are better for **spreading** light.

## Activity 4

1. Answer: Convex (it brings light rays together to form an image on the retina)

2. Answer: True – The brain flips the image right-side up

3. Answer: They bend (refract) light before it enters the eye so that it focuses correctly on the retina.
• Concave lenses spread light for nearsighted eyes (moves the focal point back)
• Convex lenses converge light for farsighted eyes (moves the focal point forward)

4. Answer: Come together at a point: Convex lens. It might be difficult to get a focus since the lens isn't uniform.
Expect: Accept any reasonable description, e.g., distorted, diffused if it's a complex/compound lens

5. Look for: Students should explain that convex lenses bend light inward, helping focus light sooner. This shifts the focal point forward, allowing people who are farsighted (whose eyes focus light too far back) to see nearby objects more clearly. Accept answers that mention bending light together, focusing light on the retina, or bringing close objects into clearer focus.

6. Look for: Beam bending toward a point = convex; Beam diverging = concave; Clear labelling: lens, beam path, incident ray, refracted ray(s), focal point (if present). Drawings should be similar to the ones depicted on page 7 of the guide.

7. Answer: In front of the retina

8. Answer: Behind the retina

9. Challenge (Optional)
Answer: More curved/thicker lens = more bending of light (greater refraction)
Answer: Convex – these lenses make things appear larger and are used to correct farsightedness
Answer: The light would spread out instead of coming to a focus, so the image would not form at all

## Activity 5

1. Light behaves like a **wave** and travels in **straight** lines unless it is **reflected, refracted,** or **absorbed**. When we pass light through a diffraction grating, it spreads out into a **spectrum** of colours. These colours represent different **wavelengths**.

2.Look for…
Ceiling Light: will produce many spectra (rainbows) in all directions; depending on the type of light (LEDs, light bulb, fluorescent), the result might vary and show only a partial spectrum.
Ceiling Light + Coloured Paddle: the colour paddle will filter some colours; for example, the blue part of the spectrum disappears through the orange paddle.
Laser Beam: since the laser only emits red light, you won't see a rainbow, just a pattern of red dots.
Blue LED: Narrower spread; mostly blue and nearby colours

3. Look for…
Yes – students should note that the pattern changes with colour and intensity.
With a greater distance to the paper, the pattern will spread further apart.
Finally, accept any reasonable observation.

## 7-12 ANSWER KEY CONTINUED

4. Expected: Students should observe that red light or the red end of the spectrum spreads out the furthest from the centre. This shows that red light has the longest wavelength because in diffraction patterns, longer wavelengths bend more and spread further apart. Accept answers that connect distance from the centre to longer wavelength.

5. Answer: Violet – Violet light has the shortest wavelength, so it spreads the least and stays closest to the centre in the diffraction pattern.

6. Challenge (Optional)
Expected: Students should explain that the blue or violet end of the spectrum would be the most intense (brightest) for a very hot star. This is because hotter stars emit more light at shorter wavelengths, meaning their energy peaks in the blue or violet range. Accept answers that mention brightness shifting toward the blue/violet end, or that hot stars give off more energy in shorter wavelengths, leading to greater intensity in those colours.