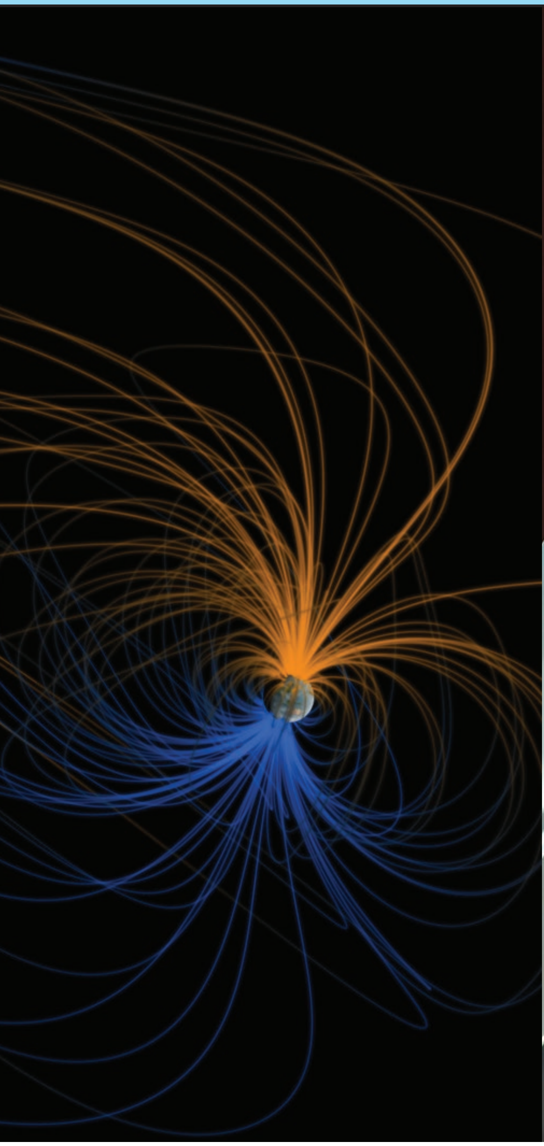
COSMIC FOUNDATIONS

LIGHT, MAGNETISM, AND BEYOND!



À LA DÉCOUVERTE DE L'UNIVERS
DISCOVER THE UNIVERSE

Dunlap Institute for Astronomy & Astrophysics
UNIVERSITY OF TORONTO

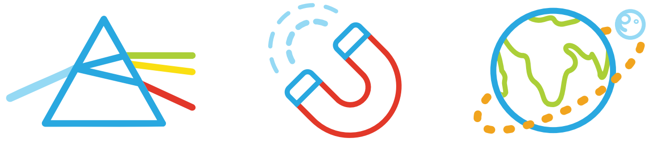
COSMIC FOUNDATIONS

A SERIES OF GUIDES TEACHING THE BASICS OF ASTRONOMY

INTRODUCTION

The science kit in your hands is the result of a collaboration between **Discover the Universe**, an astronomy education program, and **Laurie Rousseau-Nepton**, an Innu astrophysicist and professor at the University of Toronto. Laurie studies the stars and how they form in galaxies using a world-class instrument she helped build.

We created this kit to bring Laurie's research, and the fascinating science behind it, into classrooms. Inside, you'll find activities exploring light and magnetism: two key concepts in both astronomy and everyday life. They're part of school curricula across Canada, but we know it can be hard to find resources. This kit is here to help!



Who is Laurie Rousseau-Nepton?

Laurie grew up around the Quebec city area and studied at Université Laval where she obtained a Ph.D in astrophysics, a first for an Indigenous woman in Canada. She then worked at the Canada-France-Hawaii telescope in Hawaii for a few years, where she developed an ambitious research program which involves dozens of astrophysicists around the world. She is now lives in Toronto with her husband and two daughters where she is a professor of physics and astronomy at the University of Toronto. In her spare time, she enjoys the great outdoors, going for a run, and playing with her kids. Laurie is Innu and a member of the Mashteuiatsh community.

Laurie on the catwalk at the Canada-France-Hawaii, with the Gemini North observatory behind her.

You can meet Laurie in the videos introducing the activities in these guides. You can also learn more about her in the National Film Board documentary North Star (watch it with your students)!

ABOUT THIS PROJECT

Through these guides, we explore the physical world, our environment, and the Universe. We start by investigating the behaviour of light which surrounds us and plays a crucial role in life on Earth, energy, communication, the study of the cosmos, and more! From there, we move on to magnetism, one of the fundamental forces of nature, and while it might not be as well known as gravity, magnetism is just as important! Celestial objects like stars and planets have magnetic properties, and in some cases, these magnetic fields help shape their evolution.

These guides provide everything you need to get started: a full list of materials, safety tips, preparation suggestions, background information, research connections, and helpful teaching hints for each activity.

An important note: most activities don't have expected outcomes or correct answers. You're encouraged to explore alongside your students, noticing patterns and observations together. The exploration and discoveries may vary from class to class, and that diversity of experience is part of what makes science so exciting and meaningful.

Perfect for Any Classroom

These guides include activities suitable for all ages, from preschool through high school. You don't need any prior knowledge to use the activities, everything you need to feel confident is right here!

Each section provides clear instructions and engaging science activities. Many of the activities can be adapted for different grade levels, with optional extensions and challenges for older students.

The suggested grade ranges for each activity are meant as general guidelines. The student activity sheets are grouped by grade level: Kindergarten to Grade 3, Grades 4 to 6, and Grades 7 to 12. There's no single way to teach these activities, and we encourage you to adjust, skip, or assign questions based on what will best support your students' learning and engagement. You know your students best —feel free to adapt as needed!

SUMMARY OF ACTIVITIES

Below is a summary table showing which activities are best suited to each grade level.

Remember, some activities designed for younger students can still be enjoyable and educational for higher grades, but they'll likely move through them more quickly. Conversely, some activities that aren't labelled as best-suited for younger students can be done as a demonstration, and printable handouts are prepared for them at the back of the guide.

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 squares means the activity isn't suitable.

	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 30 mins	✪	✪	✪	✪	✪	✪	✪	●	●	●
2 Reflection and Refraction 30 mins	○	○	○	○	✪	✪	✪	✪	✪	●
3 Concave and Convex Prisms 30-45 mins	○	○	○	○	✪	✪	✪	✪	✪	●
4 Eyeballs 30-60 mins			○	○	✪	✪	✪	✪	✪	●
5 Diffraction 30-45 mins	✪	✪	✪	✪	✪	✪	✪	✪	✪	✪
1 What is Magnetic? 20 mins	✪	✪	✪	✪	✪	✪	✪	●	●	●
2 Magnetic Attraction and Repulsion 20 mins	○	○	○	○	✪	✪	✪	✪	●	●
3 Exploring Magnetic Field Lines 30-45 mins	○	○	○	○	✪	✪	✪	✪	✪	✪
4 Make a Compass 30 mins	○	○	○	○	✪	✪	✪	✪	✪	✪
5 Electromagnet Train 45 mins					○	○	○	✪	✪	✪

Gathering Your Materials

Some teachers and communities may have received physical kits with materials like prisms, coloured paddles, lasers, and magnets. If you have one of these kits, fantastic! You'll find guidance on how to use it throughout the activities.

If not, don't worry! We've designed the activities to be flexible, and some experiments can be reproduced in your classroom using simple, low-cost materials. For the full experience, we recommend purchasing a set of materials to create a kit of your own.

If you've received a Science Kit, it contains:

- This Comic Foundations Teacher's Guide featuring curriculum-connected content, tips for leading activities, and optional student activity sheets tailored to different grade groups.
- A USB key with demonstration videos from Laurie, along with digital copies of the Teacher Guide and student activity sheets.
- Hands-on materials for all activities, including various types of magnets, laser pointers, prisms, and more.

To purchase your own supplies, we recommend ordering through Spectrum Educational Supplies (https://spectrumed.ca/). The prisms, coloured paddles, diffraction gratings, magnets, compasses, and iron filings in the original kit were purchased through Spectrum. All other materials can be purchased through general stores. See a complete and updated list on our website. The videos featuring Laurie are linked in the PDF for each activity.

PLANNING YOUR APPROACH

You can use these activities individually or as a series, depending on your class goals and schedule. While there's no strict order to follow, we provide guidance in the activity descriptions when one activity is best done before another.

Suggested pairings for one-hour class periods:

- Light and Optics: Activity 1 and Activity 5
- Light and Optics: Activity 2 and Activity 3
- Magnetism: Activity 1 and Activity 2 (with Activity 4 as a quick addition if time allows)
- Magnetism: Activity 3 and Activity 4

Feel free to mix and match based on your time and student interest!

Light & Optics

This guide features activities focused on light and optics, using coloured filters, prisms, and diffraction gratings. Students explore how light behaves when it passes through prisms and with different wavelengths, as well as concepts like reflection, refraction, image formation, focal points, and focal length. These activities connect to general science, physics, and even art curricula.

The Light & Optics guide includes the following activities:

- Activity 1: Learning About Colour
- Activity 2: Reflection and Refraction
- Activity 3: Concave and Convex Prisms
- Activity 4: Eyeballs
- Activity 5: Diffraction

Magnetism

This guide features five activities exploring magnetism, and covers magnetic materials, types of magnetism, magnetic fields, Earth's magnetic field, and electromagnetism. These activities connect to general science and physics curricula.

The Magnetism guide includes the following activities:

- Activity 1: What Is Magnetic?
- Activity 2: Magnetic Attraction and Repulsion
- Activity 3: Exploring Magnetic Field Lines
- Activity 4: Make a Compass
- Activity 5: Electromagnet Train

A Fun Way to Bring It All Together

As these activities are designed to be flexible, you might consider turning them into a guided science exploration day!

Start with a few science blocks to introduce the key concepts, either through class discussion or by showing the demonstration videos. Then, set up your classroom with activity stations for Light & Optics and Magnetism, allowing students to rotate through in small groups. Tablets or teacher-led instruction can help guide each group through the experiments. This format works especially well for older students who can safely handle materials like lasers and magnets (always review safety guidelines before handing these to your students).

Feel free to spread this setup over multiple days, or modify it to suit your students and space!

CONNECTING TO LAURIE'S RESEARCH

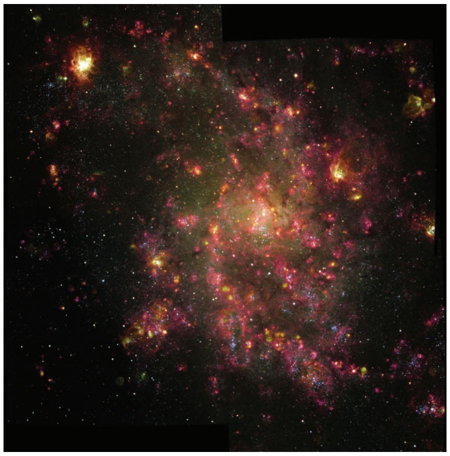
Light and optics are the foundation of astronomy! Light is what allows us to see deep into space, and we use optics to build instruments that help us see distant objects more clearly and study them in greater detail. Telescopes use mirrors and lenses to redirect and focus light to a point. Sensitive digital cameras with colour filters let us study the composition of stars, galaxies, and other celestial objects. Some instruments on telescopes, like spectrometres, use diffraction gratings to split incoming light into its different wavelengths, creating a spectrum, most commonly seen as a rainbow! By capturing the light and studying its unique properties, astronomers can learn a great deal about celestial objects. These are all concepts you'll get to explore in this guide.

The Canada-France-Hawaii Telescope, with a 3.6-metre primary mirror. The yellow structure is the mount, which allows the telescope to point in any direction across the sky.

Magnetism is also central to many physical phenomena studied in the universe. From the magnetic field that protects Earth and creates beautiful aurora, to the powerful fields around stars, planets, and even black holes, magnetism plays a key role in shaping cosmic environments. Magnetic fields influence how gas moves in space, how stars are born, and how planets evolve! They even help protect planets from harmful solar wind and radiation. By studying magnetic fields, astronomers can learn more about the hidden forces that shape the Universe, giving us clues about everything from star formation to the past activity of planets like Mars. These are the kinds of fascinating connections you'll explore through the magnetism activities in this guide.

Laurie's research focuses on learning more about galaxies and star formation by improving how we observe light. During her studies at Université Laval, she built an optical instrument called SITELLE which is now on the Canada-France-Hawaii telescope in Hawaii and is used by scientists from all around the world. This special instrument, which is both an imaging camera and a spectrometre, allows scientists to get beautiful detailed images of galaxies while providing information about their chemical composition. It's called a Fourier Transform Spectro-imager and it uses advanced math to determine how much light at particular energies is emitted by the celestial object.

Laurie is currently leading an international project called SIGNALS—the Star formation, Ionized Gas, and Nebular Abundances Legacy Survey. Using the SITELLE instrument, this project has collected data from more than 50,000 star-forming regions in 40 nearby galaxies, helping astronomers



The galaxy M33, photographed by Laurie using the SITELLE instrument on the Canada-France-Hawaii Telescope. The red regions highlight areas where new stars are forming.

understand how the local environment affects the characteristics of young star clusters. Laurie is also continuing to develop new instruments in the laboratory she now manages at the University of Toronto.

Bring it Into Your Classroom

Our team created these guides to bring core astronomy concepts into your classroom in fun, hands-on ways. These can work on their own, or be a fun introduction to some of our other astronomy learning modules, available on our website! All our content is designed to spark curiosity and wonder, and to show how deeply connected we are to the Universe around us!

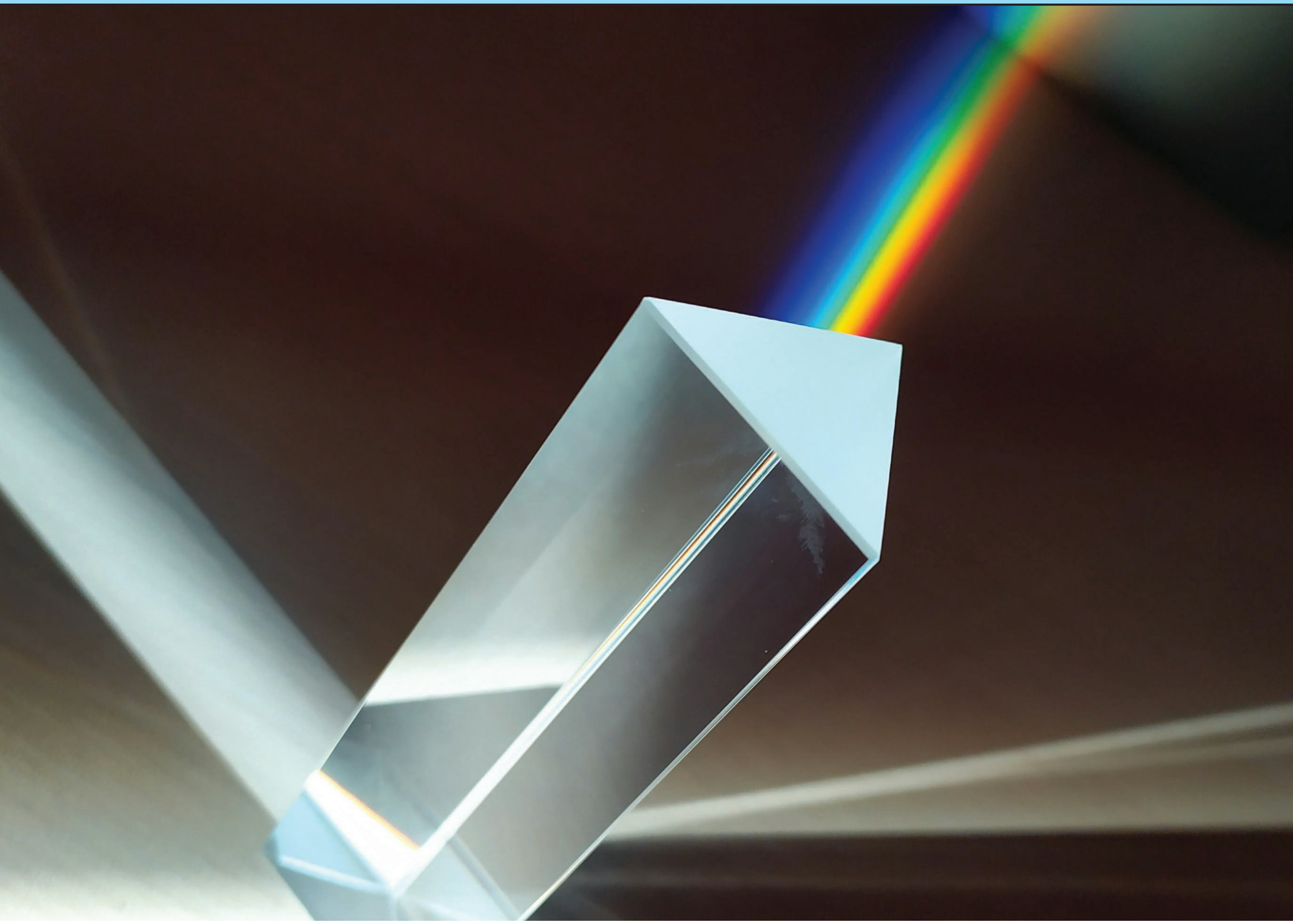
We hope you and your students will enjoy learning about light, magnetism and their cosmic connections. These are more than just physical phenomena, they're the foundations of everything from stargazing to space exploration, and they help us understand our place in the cosmos.

We are honoured to have collaborated with someone as inspirational as Dr. Laurie Rousseau-Nepton in creating this series. As an astrophysicist and a dedicated science communicator, she brings not only her expertise but also a passion for making astronomy more inclusive and inspiring. We believe she's a wonderful role model, and we hope your students enjoy learning from her in the videos.

– The Discover the Universe team

LIGHT & OPTICS

THE COSMIC FOUNDATIONS SERIES



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DEVELOPMENT TEAM

Discover the Universe
CJ Woodford, Lindsay P. Mann, Eesha Das Gupta, Julie Bolduc-Duval

In collaboration with
Laurie Rousseau-Nepton, Dunlap Institute for Astronomy and Astrophysics at the University of Toronto

ILLUSTRATIONS & DESIGN

Lindsay P. Mann

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

Discover the Universe is offered by the Dunlap Institute for Astronomy and Astrophysics at the University of Toronto.

Dunlap Institute for Astronomy & Astrophysics
UNIVERSITY OF TORONTO

September 2025

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.

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4 Eyeballs 30-60 mins			○	○	✪	✪	✪	✪	✪	●
5 Diffraction 30-45 mins	✪	✪	✪	✪	✪	✪	✪	✪	✪	✪

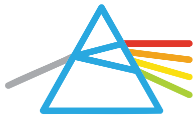
MATERIALS

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.

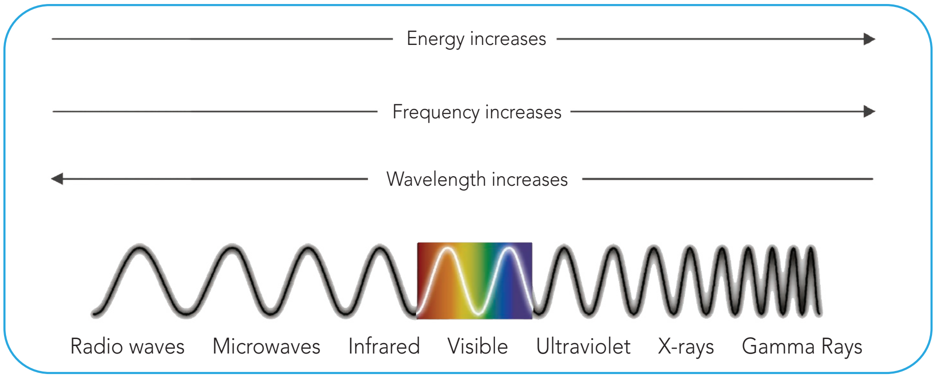
Light is a form of energy that stimulates our eyes and allows us to see the world around us. We're most familiar with *visible light:* the portion of the spectrum that our eyes can detect. But there are many types of light we can't see, such as infrared and ultraviolet light.

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.

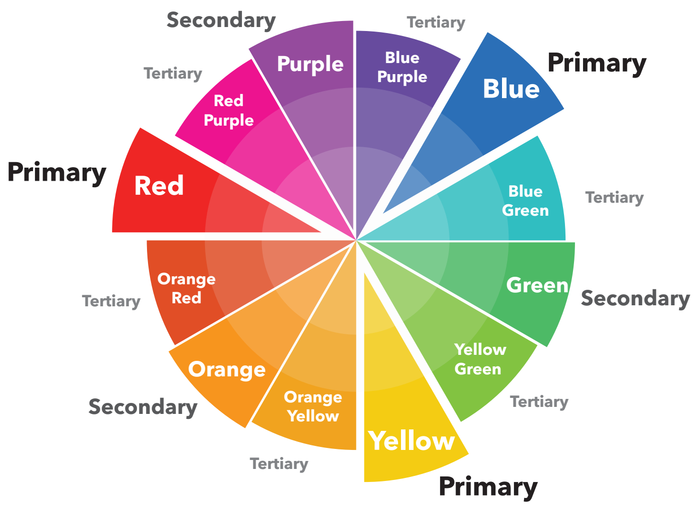
HINT! *The object should appear more intensely coloured. For example, a green object viewed through a green paddle will look even greener.*

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.

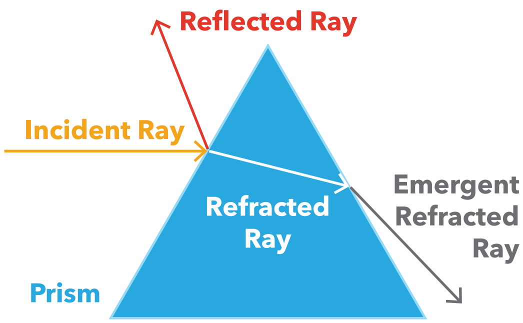
These activities offer an excellent opportunity to introduce or reinforce the concepts of reflection and refraction for students in Grade 6 and up.

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.

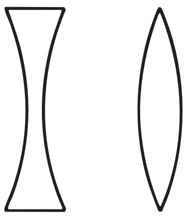
Example of a simple ray diagram. In this illustration, the blue triangle represents a triangular prism, and the arrows show the light rays interacting with it. The incident ray (or incoming ray) enters from the left, where it is then reflected and refracted by the prism.



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.



Concave **Convex**

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.

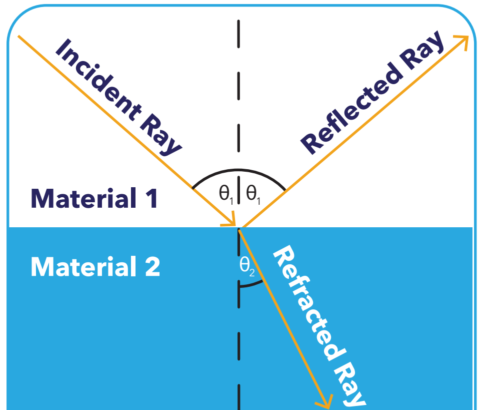
Law of Reflection

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.



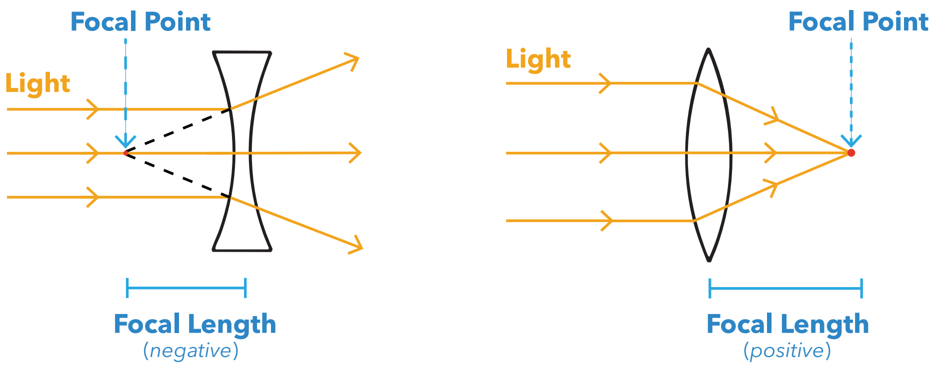
A ray diagram representation of both the law of reflection and the law of refraction, for light interacting at the boundary between two materials with different refractive indices.

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

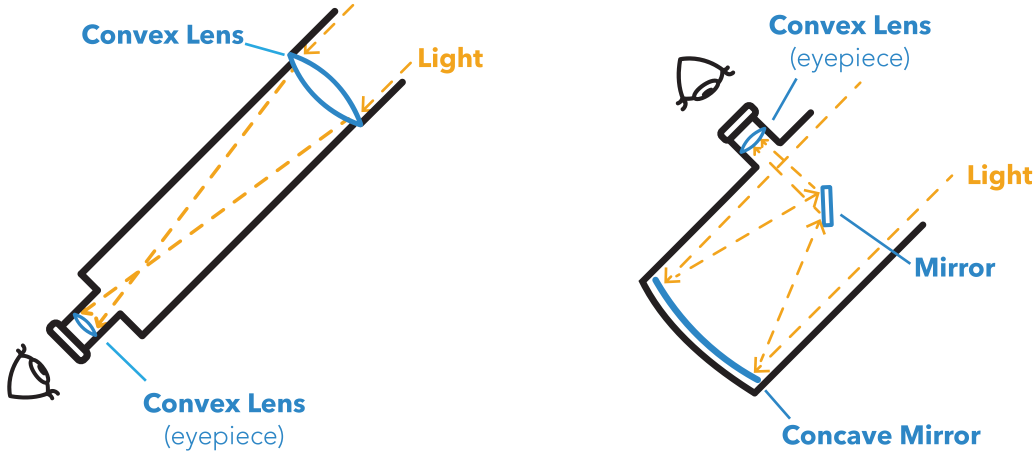
The concepts of reflection and refraction are central to astronomy, both in everyday skywatching and in advanced research!

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

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

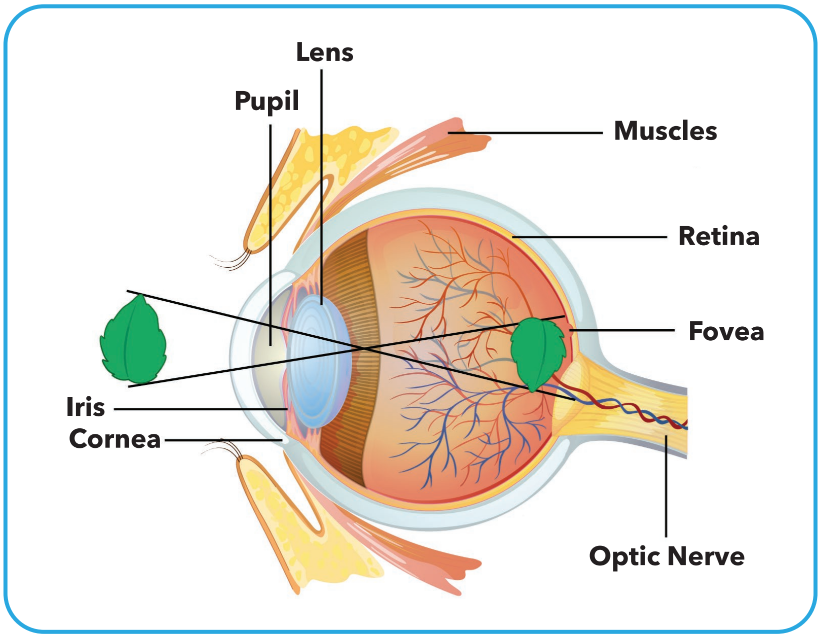
RUNNING THE ACTIVITY

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.

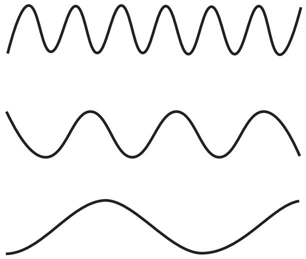
In Activity 1, students learned that light is a form of energy that can be represented by waves. Longer wavelengths correspond to lower-energy light (e.g. red), while shorter wavelengths correspond to higher-energy light (e.g. blue). White light is a combination of all visible wavelengths. Diffraction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

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.

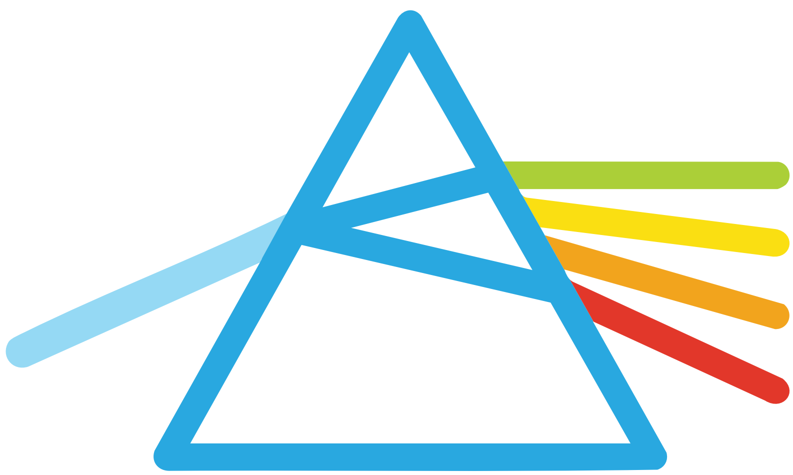
Moving the diffraction grating closer to the paper will cause the diffracted beams to appear closer together. Moving it farther away will increase the spacing between the beams.

Notes:

LIGHT & OPTICS

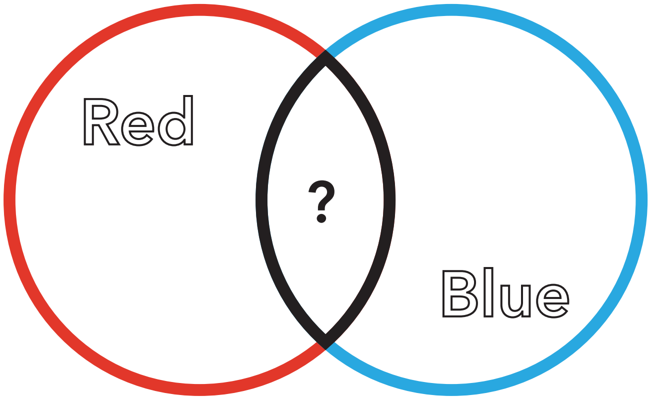
STUDENT HANDOUTS AND ACTIVITY SHEETS

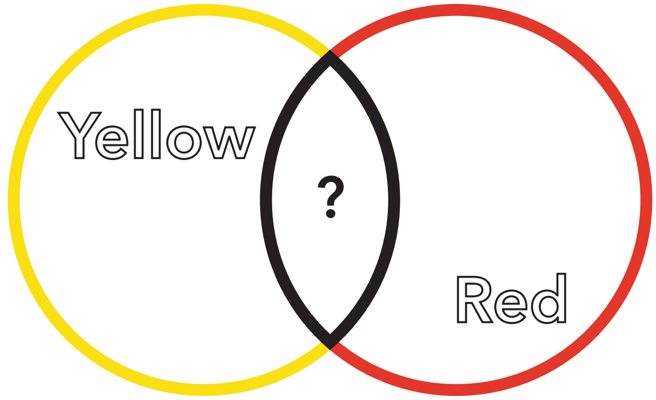
Complementary and optional activities for your learners!

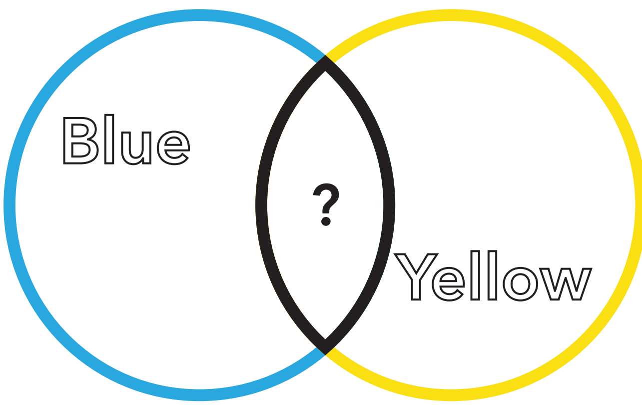


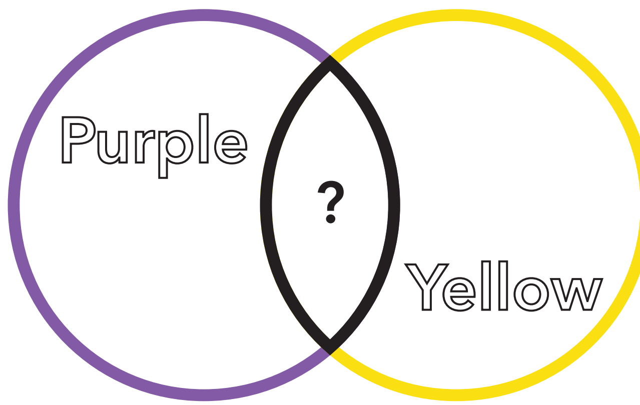
Kindergarten – Grade 3

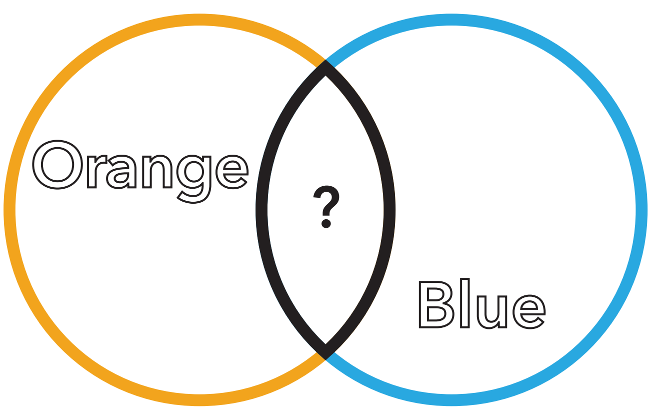
Combine coloured paddles and then colour in the spaces!

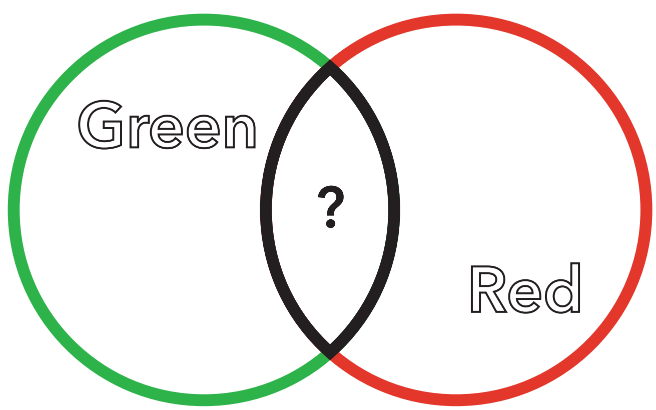








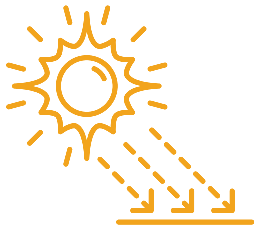


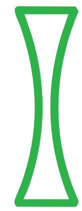


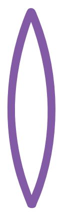
Draw a prism!

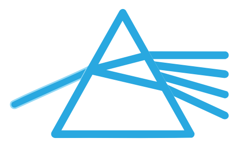
How many light beams did the prism make?
Draw the light beams!

Match the words to the correct image:









Laser Pointer

Prism

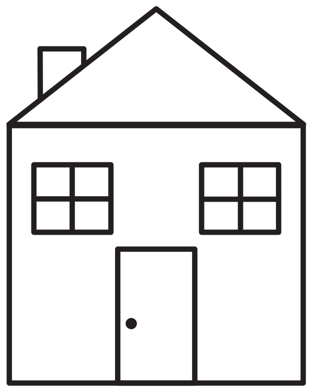
Convex

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!*



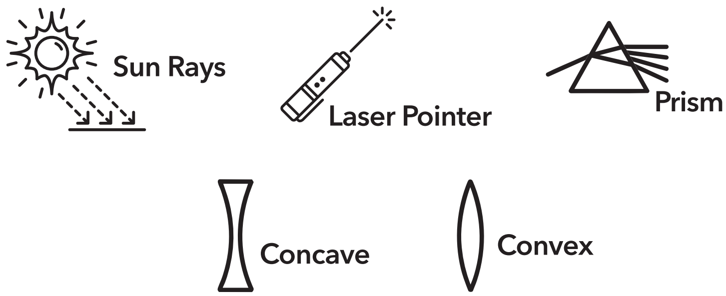
Draw the pattern you saw through the diffraction window!

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

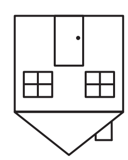


Activity 3

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

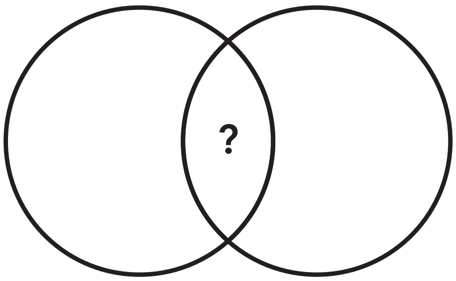
STUDENT HANDOUTS AND ACTIVITY SHEETS

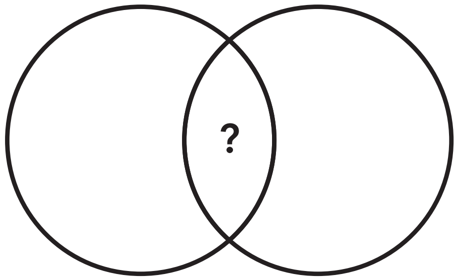
Complementary and optional activities for your learners!

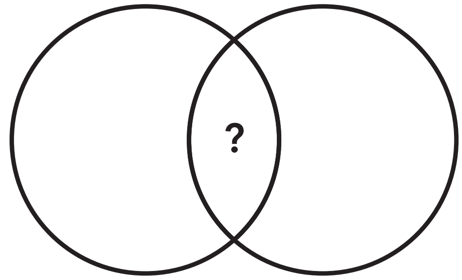
Grade 4 – 6

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 <u>different colour</u> 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 <u>same colour</u> 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?

ACTIVITY 2: REFLECTION AND REFRACTION

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

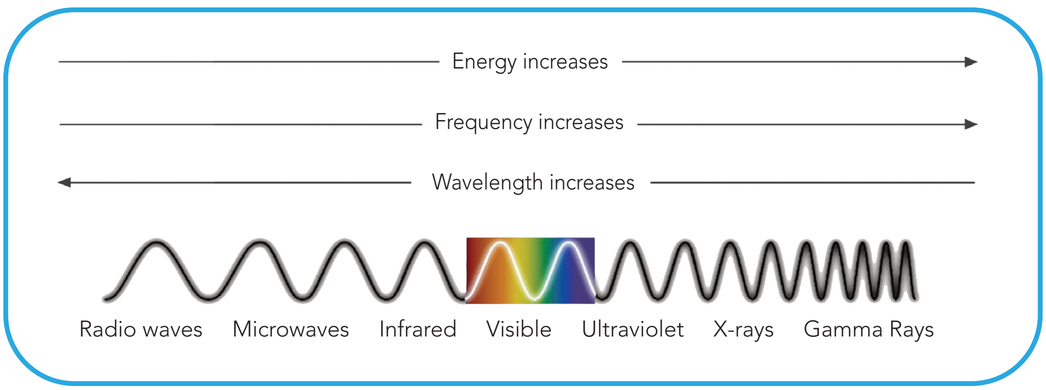
1. **Choose two paddles and hold them up to a white light source or paper.** What colours did you combine? Did the result surprise you? Why or why not?

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?

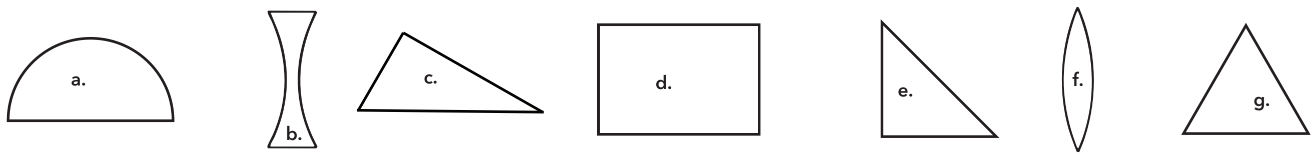
8. **Optional: If you used the triangle prism with sunlight or a flashlight**, what did you see? What caused it? *(Hint: think about white light!)*

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?

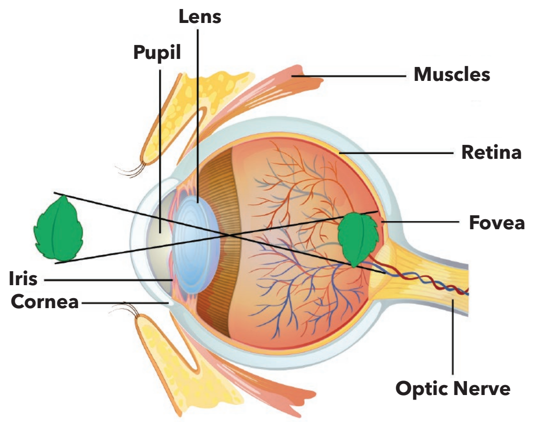
8. Which one has a **negative focal length**: Concave or Convex? Why?

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.

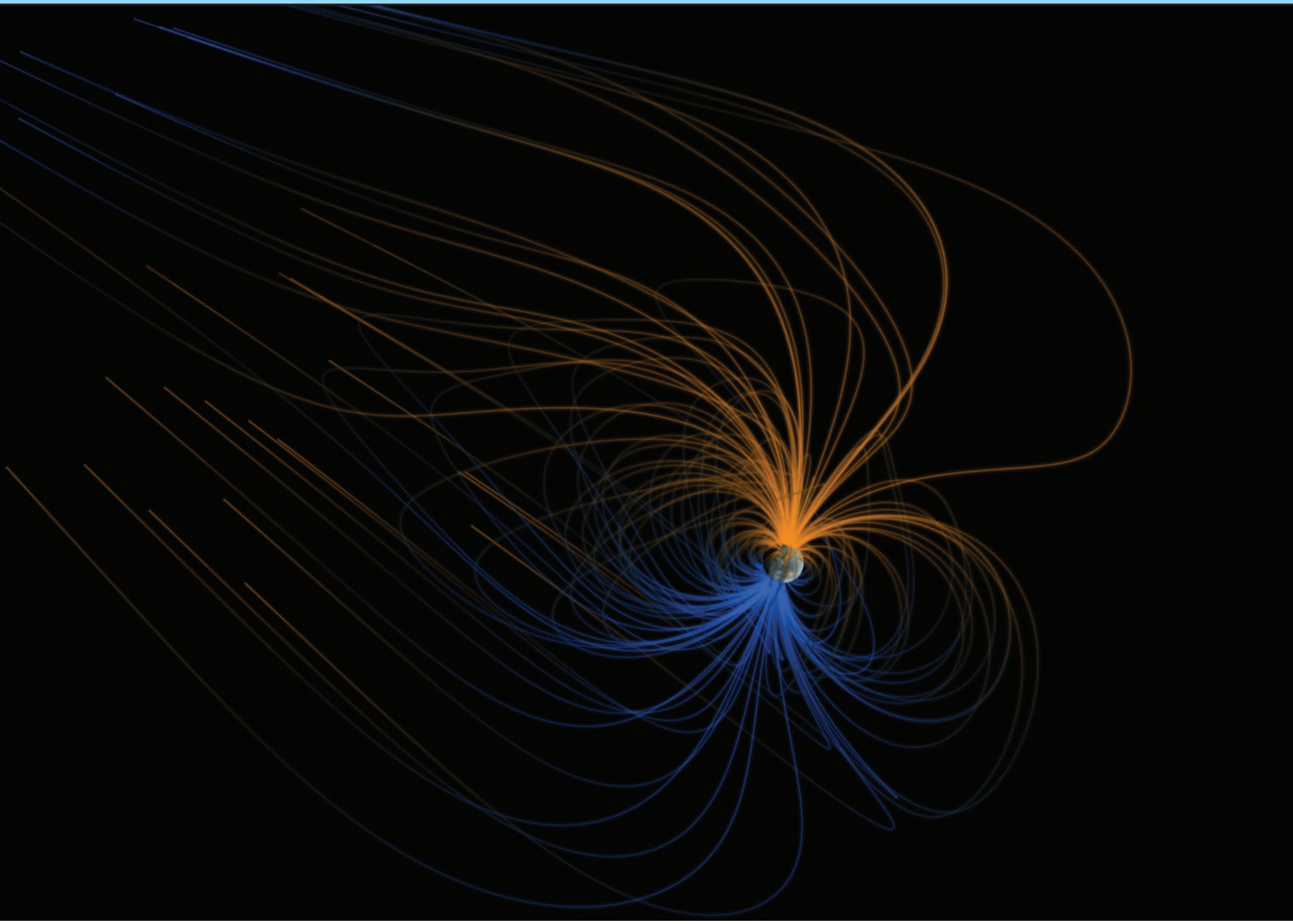
4. Expected: Students should observe that red light or the red end of the spectrum spreads out the furthest from the centre. This shows that red light has the longest wavelength because in diffraction patterns, longer wavelengths bend more and spread further apart. Accept answers that connect distance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

MAGNETISM

THE COSMIC FOUNDATIONS SERIES



À LA DÉCOUVERTE DE L'UNIVERS
DISCOVER THE UNIVERSE

Dunlap Institute for Astronomy & Astrophysics
UNIVERSITY OF TORONTO

MAGNETISM

THE COSMIC FOUNDATIONS SERIES

À LA DÉCOUVERTE DE L'UNIVERS
DISCOVER THE UNIVERSE

DEVELOPMENT TEAM

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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

Discover the Universe is offered by the Dunlap Institute for Astronomy and Astrophysics at the University of Toronto.

Dunlap Institute for Astronomy & Astrophysics
UNIVERSITY OF TORONTO

September 2025

Safety Guidelines for Magnetism Activities

For the safety of both you and your students, please follow these precautions whenever conducting activities involving magnets or iron filings:

MAGNETS SAFETY

Students should always be closely supervised when handling magnets. Extra caution is needed with younger students to ensure magnets are not swallowed. If a student swallows one or more magnets, contact emergency services immediately.

Pay close attention when separating or handling magnets. To safely separate them, grasp the outer magnet, slide it off the stack, and pull it away quickly. Whenever possible, use magnets on a metal table or surface to prevent them from snapping together unexpectedly.

Magnets are often made of composite materials and can break. Do not use broken magnets, as they may have sharp edges. Handle magnets carefully and avoid dropping them or allowing them to “snap” together, even from short distances.

Magnets can corrode over time. Keep them dry and store in a cool, dry place away from moisture.

NEODYMIUM MAGNETS SAFETY

The small disc-shaped neodymium magnets are very strong and require extra caution. They should only be handled by older students. We recommend these be used by Grade 9 and up.

Neodymium magnets are prone to breaking because they are made of a composite material and are very strong. Use with care and discard of broken magnets safely.

Always keep your hands far apart when handling neodymium magnets in both hands. Keep neodymium magnets away from magnetic media such as credit cards, mobile phones, computers, and medical devices like insulin pumps. Individuals with implanted medical devices, including pacemakers, should not handle or be near neodymium magnets.

IRON FILINGS SAFETY

Iron filings are not dangerous but must be handled with care to avoid spills. If iron filings come into direct contact with a magnet, they cannot be removed.

To prevent contamination, avoid opening the iron filings bag whenever possible. If the filings must be taken out, ensure all nearby magnets are sealed in plastic bags before use.

MAGNETISM

This guide includes five hands-on activities that explore magnetism using different types of magnets and magnetic materials. Students will investigate the magnetic properties of materials, how magnets interact, magnetic fields (including Earth's magnetic field), and electromagnetism. These activities connect to a variety of curriculum areas, including general science and physics.

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 What is Magnetic? 20 mins	✪	✪	✪	✪	✪	✪	✪	●	●	●
2 Magnetic Attraction and Repulsion 20 mins	○	○	○	○	✪	✪	✪	✪	●	●
3 Exploring Magnetic Field Lines 30-45 mins	○	○	○	○	✪	✪	✪	✪	✪	✪
4 Make a Compass 30 mins	○	○	○	○	✪	✪	✪	✪	✪	✪
5 Electromagnet Train 45 mins					○	○	○	✪	✪	✪

MATERIALS

Included in the Science Kit:

- Bar magnets (2 - large, blue and red)
- Block magnets (12 - small, colourful)
- Neodymium disc magnets (6)
- Compasses (10)
- Measuring tapes (5)
- Iron filings bags (5)
- Sewing needles (5)
- Copper wire (20 gauge, 2 metres)
- Batteries (2 - AAA)
- Dowel (16mm)
- Paper clips

Materials you may need to provide:

- Writing utensils (e.g. pencils, pens, etc.)
- Writing and drawing paper
- An assortment of both magnetic and non-magnetic materials, such as nails, small rocks, nickels/dimes, small pieces of plastic, small pieces of paper, cutlery
- Bowl or other container that can hold water

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 MAGNETISM

Begin by watching the Introduction to Magnetism video with your class!

After watching the intro video and before diving into the activities in this section, you might want to start with a few big-picture questions for your students:

- What is a magnet?
- How can we tell if something is magnetic?
- How do we use magnets in our everyday life?
- What is magnetism?

See if your students agree on some of these answers or if there are differences of opinion, both can lead to great discussions! You can also encourage them to think about where they encounter magnets in daily life, from simple examples like fridge magnets to more advanced technology like MRI (magnetic resonance imaging) machines used in hospitals.

Magnetism is a force that comes from the magnetic properties of matter, causing attraction or repulsion between materials. Whether something is magnetic depends on the properties inside the material. A magnet is any object or material that produces a magnetic force on other materials. While we often think of magnets as being permanently magnetic, there are actually different types of magnets made from different materials. Ferromagnetic materials are particularly affected by magnets, which is why we often call them magnetic materials.

Magnets have an invisible magnetic field around them. This means objects don't need to be touching a magnet to feel its pull or push; the force can act at a distance. The closer something is to the magnet, the stronger the force will be.

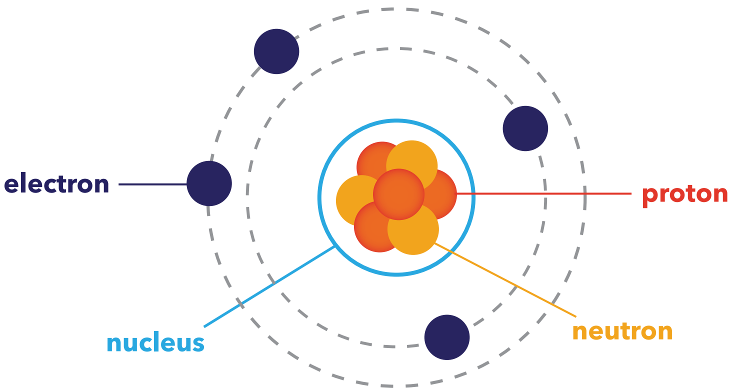
Magnetism is also an important force in astronomy as many celestial objects have magnetic fields, like Earth and many other planets. Earth acts like a giant magnet, with north and south magnetic poles. The same is true for the Sun, most stars, and even some celestial objects including black holes! On Earth, the magnetic field protects us from dangerous cosmic radiation and charged particles, and it plays a key role in the creation of the beautiful aurora!

We'll explore these ideas more through the activities in this guide, with specific research connections highlighted along the way.

Advanced Magnetism

Magnetic and electric properties of matter are closely related and influence each other. This is why the term electromagnetism is often used to describe how these forces interact. In this section, we will be focusing on magnetism, but we'll also mention electric properties where it helps explain how magnetic forces work.

All matter is made of atoms, which are very small. Atoms have even smaller particles in them called protons and electrons. Protons carry a positive electric charge and are found in the centre of the atom, called the nucleus. Electrons have a negative charge and move around the nucleus, usually in stable orbits, although they can sometimes move closer or farther away. Electrons can also move freely, outside of atoms.



A visual representation of an atom. There have been many models of the atom throughout history, and this representation is showing the Bohr Model. We know today from quantum mechanics that this isn't quite right, but this representation is helpful for understanding the parts of the atom and for practical applications like in chemistry.

The movement of electrons (or electric charge) is called electricity. Electrons also spin, and it's this combination of moving charge and spin in the atom that creates a magnetic moment, making each electron act like a tiny magnet. Magnetic materials allow stronger magnetic moments both within their atoms and overall for the whole material. In some materials, these magnetic moments line up more easily, creating a stronger overall magnetic effect. The strength of these magnetic moments determines how strong a material's magnetic field is. Like gravity, magnetic forces act through a field; its stronger close to the magnet and weaker farther away.

ACTIVITY 1-2

MAGNETIC SUBSTANCES, ATTRACTION, AND REPULSION

Background & Context

In the next two activities, students explore the magnetic properties of everyday objects by testing and observing interactions with permanent magnets. Activity 1 is recommended for students in Kindergarten and up, while Activity 2 is suitable for students in Grade 4 and up. Both activities offer opportunities to add extra steps or challenge questions for older students —particularly around magnetic poles and magnetic properties. These activities connect directly with general science, physics, and earth science curricula.

For students in **Kindergarten through Grade 3**, Activity 1 is exploratory. Students are encouraged to test everyday objects, observe which are attracted to the magnets, and to look for any patterns or consistent behaviours.

For students in **Grade 4 and up**, Activities 1 and 2 build on the foundations by encouraging students to create hypotheses about which materials are magnetic before they explore with the magnets. They'll test their hypotheses by observing patterns in how the materials respond. In Activity 2, students also explore how the poles of magnets interact and determine the relative strength of magnetic fields by conducting a series of experiments.

Students may notice in Activity 1 that some materials react to the magnets and others do not. Younger students can simply group materials as magnetic or non-magnetic, while older students can take it further by exploring terms like ferromagnetic, diamagnetic, and paramagnetic (see the next section for details).

As students investigate, encourage them to come up with their own explanations for what they observe. For Grades 4 and up, you can help guide the discussion using some of the key concepts listed below.

KEY CONCEPTS FOR DISCUSSION

Magnetic Poles

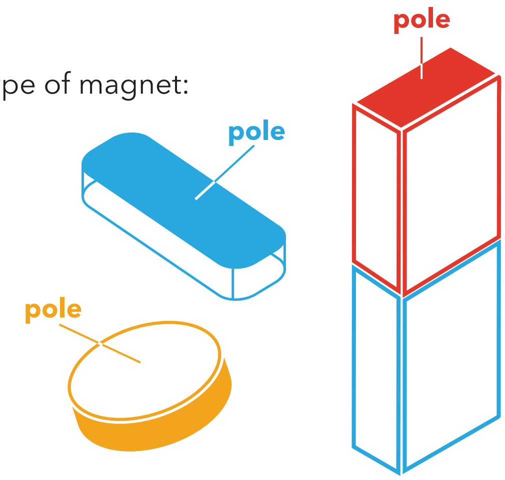
The magnets used in these activities are permanent magnets made of ferromagnetic materials. Magnets always have two poles: a north pole and a south pole. Opposite poles attract each other, while like poles repel.

The location of the poles is different depending on the type of magnet:

Multi-coloured block magnets have their poles on the two largest flat sides.

Bar magnets have their poles at the ends of the longest sides.

Disc magnets have their poles on their faces, the flat circular top and bottom.



Safety note: Disc magnets are not provided for Activities 1 and 2, and we do not recommend using neodymium magnets for these activities.

Dipole

"Dipole" simply means "two poles." All magnets are dipoles, they always have both a north and a south pole.

Magnetic properties

The magnetic properties of a material depend on how easily the atoms in the material form magnetic moments (tiny magnetic forces), especially when near a magnetic field.

Ferromagnetic

Ferromagnetic materials have atoms that easily create strong magnetic moments. When a magnet is nearby, the whole material can act like a magnet and will be attracted to it. Some examples of ferromagnetic elements are iron, nickel, and cobalt. Everyday objects made of ferromagnetic materials include paper clips (iron), dimes and nickels (iron, nickel), metal keys (nickel), sewing needles (iron, nickel), and metal cutlery (iron).

Paramagnetic

Paramagnetic materials have fewer atoms that can align, and their magnetic moments are weaker. They show a slight attraction to magnets, but much less than ferromagnetic materials. Some examples of paramagnetic elements include aluminum, magnesium, molybdenum, and lithium. Everyday objects made of paramagnetic materials include aluminum cans.

Diamagnetic

Diamagnetic materials don't form magnetic moments or dipoles and typically won't react to magnets. In some cases they may be slightly repelled. Most elements are diamagnetic, such as copper, silver, and gold. Many everyday objects are made of diamagnetic materials, including plastics, fabric, and wood.

Temporarily magnetic

Many ferromagnetic materials become temporarily magnetic; their atoms only align in an external magnetic field. However, ferromagnetic materials can become permanent magnets after strong or repeated exposure to a magnetic field. Paramagnetic materials can be temporarily magnetic, but don't typically become permanent magnets.

Notes:

ACTIVITY 1

WHAT IS MAGNETIC?

Kick off the activity with this video!

Learning Objectives

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

- Determine materials that can become temporarily magnetic
- Predict which types of materials will react to a magnet

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

- Determine materials that can become temporarily magnetic
- Predict which types of materials will react to a magnet
- Categorize materials based on their observed magnetic properties and, if desired, compare their findings with the established categories of ferromagnetic, paramagnetic, and diamagnetic

Grades and Timing

This activity is expected to take 20 minutes or less.

Preparation

Estimated preparation time: 15-20 minutes

- Gather all required materials.
- Read through activity steps, hints, activity sheets, associated background information and context, as well as the safety sheet

Materials

- Bar and/or block magnets
- Paper clips
- Magnetic and non-magnetic materials e.g., nails, small rocks, pieces of plastic, coins, small pieces of paper, cutlery, etc.
- Writing materials (e.g. paper, pencils, etc.)

RUNNING THE ACTIVITY

Begin: Watch the video with your students

Divide your class into no more than five groups, ensuring each group has at least two block magnets and several objects they can test for magnetism. Before starting, take a moment to review magnet handling safety with the class.

If you're unsure whether your students can or should handle the magnets, you can lead this activity as a class demonstration, guide discussions, and use the activity sheets.

Step 1: *5 min*

Begin with a short class discussion using prompts like:

- What is a magnet? What does a magnet do?
- What kinds of objects are magnetic, or react to magnets? How do they react?

HINT! *Guide students toward the idea that some materials can become temporarily magnetic when exposed to a magnet. These materials are attracted to the magnet, and often stick to it, but are not magnets themselves. Magnets, on the other hand, are made of materials that are permanently magnetic.*

Step 2: *5-10 min*

Students test which materials the magnets can and cannot pick up. Encourage them to look for patterns in how the magnets interact with different materials.

For students in **Kindergarten to Grade 3**, the activity can end here as a hands-on exploration of what is magnetic.

For **Grades 4 and up**, encourage students to sort the tested materials into groups based on how they responded to the magnet. Ask them to come up with names or descriptions for each group. Invite students to share their groupings and discuss any differences or observations as a class.

For a bit of a challenge, you can pose a question for deeper discussion either in small groups or as a class. For example: Why do you think some objects stick to magnets while others don't?

If you've already introduced terms like ferromagnetic, paramagnetic, and diamagnetic, you can bring them back here. If not, this is a great opportunity to begin introducing those categories based on how materials behave in the presence of a magnetic field.

Take it Further!

Magnets can pick up certain objects because those objects are ferromagnetic: they become temporarily magnetic when exposed to a magnetic field. When a magnet is brought near a ferromagnetic material, the atoms inside the material align with the magnetic field, causing attraction.

Other materials, like paramagnetic and diamagnetic substances, don't have enough atoms aligning to create a noticeable reaction, so they won't stick to the magnet. Ferromagnetic materials include metals like iron and steel. In contrast, materials like plastic, copper, and glass are diamagnetic and won't react.

Students will likely sort objects into two main groups: those that react to the magnet and those that don't. The first group likely contains ferromagnetic materials, while the second includes a mix of paramagnetic and diamagnetic ones. These are often described simply as magnetic and non-magnetic materials.

Step 3: *5 min*

Students are encouraged to build "trains" using magnetic materials. First, they can test how many paper clips they can pick up in a row to make a paperclip chain. Then, they can try stacking magnets to see how many they can pick up the same way.

As a challenge, invite students to think creatively about how to increase the strength of their magnet. This can be set up as a friendly competition between groups to create the longest paperclip train using their best magnet-enhancing ideas. Alternatively, it could lead to a class brainstorm and demonstration.

HINT! *You might guide the discussion by asking what students know about why magnets can pick up ferromagnetic materials, and what might help increase that effect. One simple method is to stack the magnets so their poles are aligned in the same direction, which strengthens the magnetic field.*

This is often easiest to do as a class demonstration using the larger bar magnets:

- Start by testing one bar magnet and recording how many paper clips it can pick up in a chain.
- Then, stack two bar magnets so that the red ends are touching and the blue ends are touching. (You may want to secure them together with a binder clip or rubber bands.)
- Try building a new paperclip train using the stacked magnets, and compare the results with the first test.

ACTIVITY 2

MAGNETIC ATTRACTION AND REPULSION

Kick off the activity with this video!

Learning Objectives

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

- Understand magnetic poles, and that they attract and repel
- Test how magnets can interact with each other

For students in **Grades 4 and up**, by the end of this activity, students will be able to:

- Understand magnetic poles, as well as the concept of attraction and repulsion
- Theorize and test how magnets interact with each other
- Measure the distance of influence of magnets

Grades and Timing

This activity is expected to take 20 minutes or less.

Preparation

Estimated preparation time: 5-15 minutes

- Gather all required materials.
- Read through the activity steps, hints, activity sheets, background information, and safety guidelines in the introduction to the magnetism section.

Materials

- Bar and/or block magnets (2 per group)
- Ruler or measuring tape
- Writing materials (e.g. paper, pencils, etc.)

RUNNING THE ACTIVITY

Begin: Watch the video with your students

Split students into groups of two or three, ensuring each group has at least two magnets and one measuring tape or ruler. Before beginning, take a moment to review magnet handling safety with the class.

If you're unsure whether your students can or should handle the magnets, you can lead this activity as a class demonstration, guide discussions, and use the activity sheets.

Step 1: *5 min*

Students try to pick up one magnet with the other, experimenting with different orientations. Ask them to describe what they observe and identify any patterns.

HINT!

Magnets always have two poles: a north (N) and a south (S):

- *Bar magnets have their poles at the ends of their longest sides, usually marked with red and blue colours.*
- *Block magnets have their poles on the largest flat faces and are not colour-coded.*
- *Opposite poles attract, while like poles repel.*

For students in Kindergarten to Grade 3, the activity can end here as a hands-on exploration of how magnets interact.

Step 2: *10 min*

Students prepare their space by placing their magnets next to a ruler or measuring tape, with the poles pointed toward each other. They then investigate how the magnets interact as one is moved closer to the other in different orientations along the measuring tape. Encourage students to repeat each test at least twice to ensure accurate results.

For students in Grade 6 and up, consider having them record their measurements with estimated uncertainty and explain any variability in their results.

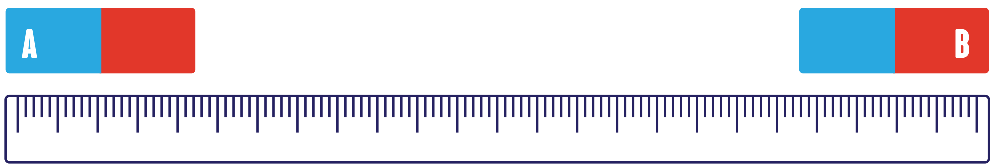
HINT!

If you're using measuring tapes, consider taping them down so they stay in place during the activity.

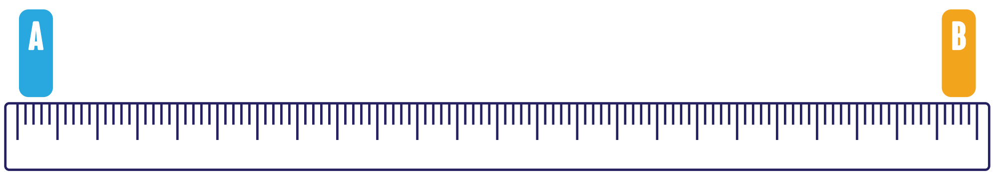
When using bar magnets, lay them flat (horizontally) on the table with the coloured ends pointing along the measuring tape. The poles are at the ends, identified by the red and blue colours.

When using block magnets, lay them on their longest, thinnest side, perpendicular to the measuring tape. The poles are located on the large flat faces along the long side.

Example of bar magnet set up:



Example of block magnet set up:



Step 3: ***5 min***

Students stack the magnets so that their poles are touching; first with opposite poles, then with like poles. Encourage them to reflect on their earlier observations from Step 1 and consider whether their ideas have changed or deepened.

You might also ask students to summarize and share their findings with the class, opening up a discussion about any differences in observations or conclusions.

Notes:

ACTIVITIES 3 - 4

MAGNETIC FIELDS, FIELD LINES, AND COMPASSES

Background & Context

In the next two activities, students discover magnetic field lines around magnets by observing how iron filings and compasses react. It is recommended that students complete Activities 1 and 2 first, as those introduce the foundational concepts of magnets and dipoles. Both activities can be adapted to include extra steps or challenge questions for older students, particularly around magnetic poles, polarity, magnetic fields, and relative field strength. These activities connect directly to general science, physics, and Earth science curricula.

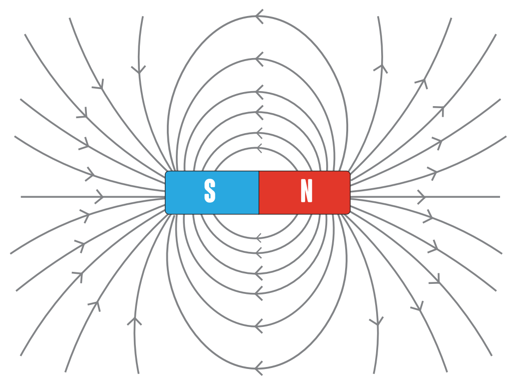
For **Kindergarten to Grade 3**, these activities should be done as an exploratory class demonstration. In Activity 3 you'll explore the shape of magnetic field lines. In Activity 4, students can observe how a compass needle behaves in different orientations around a magnet and look for patterns.

For **Grades 4 and up**, these activities combine hands-on observation with critical thinking. In Activity 3, students identify the shape and direction of the magnetic field around different types of magnets using both iron filings and compasses. They are encouraged to relate their findings to real-world applications, such as navigation and circumstances where a compass might not work effectively.

In Activities 1 and 2, students learned about magnetic poles and how they interact, specifically that like poles repel and opposite poles attract. These interactions are caused by magnetic fields, which are a type of non-contact force (a force that acts without physical contact). Magnetic fields carry the magnetic force and often cause objects to move, as students would observe when bar magnets pushed and pulled each other.

Magnetic fields have both shape and direction. We usually represent them using field lines, which help visualize how the force behaves in space. You can see an example of magnetic field lines around a bar magnet in the diagram below.

A bar magnet with magnetic field lines. Magnetic field lines are not visible, and are illustrated here to show the force field's shape and direction (north to south), indicated by the shape of the line and the direction of the arrow respectively.



ACTIVITIES 3 - 4 • BACKGROUND & CONTEXT

Compasses use Earth's magnetic field to determine direction. The simplest compasses consist of a small piece of ferromagnetic material (the needle) suspended so it can spin freely with minimal resistance. When no other magnets are nearby, the needle aligns with Earth's magnetic field lines.

Earth's magnetic poles are close to, but not exactly aligned with, its geographic poles, so in most locations, compasses point roughly toward geographic North. However, because the magnetic poles shift over time and don't perfectly match the geographic poles, compass accuracy decreases the closer you are to the North or South Pole.

Interestingly, Earth's magnetic poles are also inverted relative to the geographic ones. The magnetic south pole is located near the geographic North Pole, and vice versa.

As students investigate, encourage them to come up with their own explanations for what they observe. For students in Grades 4 and up, you can help guide the discussion using some of the following key concepts.

Notes:

KEY CONCEPTS FOR DISCUSSION

Forces and Fields

A force is an influence on an object that does or could cause the object to move. We often experience contact forces, where two objects must touch to experience the force. Non-contact forces include gravity and magnetism, where forces act at a distance through a force field. Fields describe how forces interact with and through matter. Force fields are often represented by lines in a diagram, and indicate the shape and direction of the force.

Magnetic field

A magnetic field is the force field created by objects with magnetic properties. These fields flow from the north magnetic pole to the south magnetic pole.

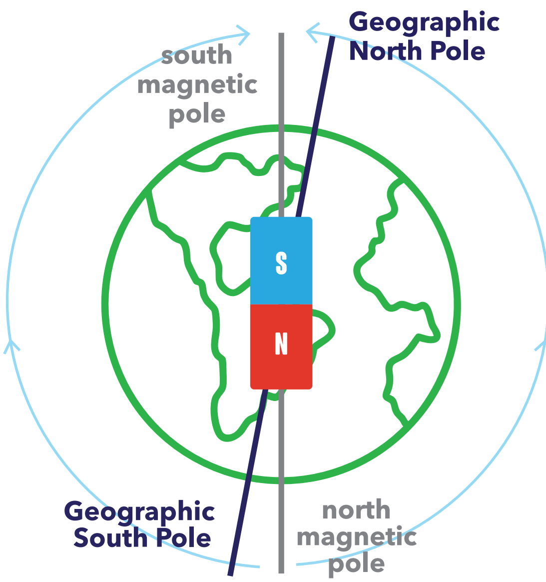
Magnetic Poles

Magnets always have two poles: a north and a south. In Activities 1 and 2, we focused on the poles of permanent magnets made from ferromagnetic materials. However, anything that has a magnetic field also has a north and south magnetic pole, including the Earth. While Earth's magnetic poles are close to the geographic poles, they are not located in exactly the same place.

Geographic or Orbital Poles

Geographic or orbital poles are the fixed points at the top and bottom of a spinning object. For Earth and other planets, we usually refer to these as the North and South poles.

The Earth's geographic and magnetic poles don't quite line up. The magnetic south pole is close to the geographic North Pole, which is where polar bears live. The magnetic north pole is close to the geographic South Pole, which is where penguins live. A compass will follow the magnetic field lines of the Earth's magnetic field, which flows from magnetic north to magnetic south, and therefore points towards the geographic North Pole. The difference between the geographic poles and magnetic poles is more noticeable the closer to the poles you travel.



Research Connections

Magnetic fields are a key feature of star-forming regions and give astronomers important clues about what's happening as stars are born. Stars usually form in areas filled with hot gas that becomes compressed over time. This gas is ionized, meaning some of its atoms have gained or lost electrons because of the intense heat. The movement of these electrons generates a magnetic field, which plays a role in shaping how stars form. They can influence what types of stars emerge from the gas and how quickly the process happens.

Studying ionized gas to learn more about star formation is an active field of research. Laurie Rousseau-Nepton leads the SIGNALS project, which stands for the Star formation, Ionized Gas, and Nebular Abundances Legacy Survey. This and related projects are analyzing star-forming regions to identify how the local environment affects young star cluster characteristics, including the strength and shape of the magnetic fields within.

We know that Earth has a magnetic field and that its magnetic poles don't line up with its geographic poles. Earth isn't the only planet with a magnetic field, many others, including Saturn and Jupiter, have one too. However, scientists are still working to understand exactly how planets generate these fields.

Current research suggests that, much like a spinning electron creates a magnetic moment, the rotation of Earth's molten core generates its magnetic field. Earth, like many terrestrial planets, is not solid all the way through. We live and play on the surface, called the crust. Beneath it are layers of magma (very hot, liquid rock). When magma reaches the surface, we call it lava. At the centre of the planet is a core made mostly of iron, a ferromagnetic material, that spins within the magma. This movement of iron through ionized molten rock, where electrons move more freely, is what researchers believe generates Earth's magnetic field. This process is known as the "dynamo effect," and it remains an active area of scientific investigation.

Interestingly, Earth's core doesn't necessarily spin along the same axis as the rest of the planet, which helps explain why the magnetic poles don't align perfectly with the geographic poles. Now think about other terrestrial (rocky) planets and celestial objects. Which ones do you think have a magnetic field? Why or why not?

Using the idea of the dynamo effect, we can guess that objects without a noticeable magnetic field might not have a spinning core at their centre. This is what we find with Mars and the Moon: both are considered "geologically dead," meaning there is little or no movement happening beneath their surfaces. In the case of Mars, we know that it once had a magnetic field because we can still see traces of it in rocks on the surface. Some of these rocks are permanently magnetized, suggesting that Mars once had a strong magnetic field created by a dynamic interior.

ACTIVITY 3

EXPLORING MAGNETIC FIELD LINES

Kick off the activity with this video!

Note: *Normally, a compass needle points away from the magnet's north pole and toward its south pole. However, if the compass needles were re-magnetized by being stored near other magnets, they may flip and point in the opposite direction. Even so, the overall shape of the magnetic field will still be visible.*

Learning Objectives

For **all students**, by the end of this activity, students will be able to:

- Assess the shape and direction of a magnetic field
- Realize that magnetic forces can act even without contact
- Understand that magnetic fields become weaker or stronger at different distances

Grades and Timing

This activity is expected to take 30 minutes or less for students in Grades K - 5, and up to 45 minutes for students in Grades 6 and up.
For students in Kindergarten to Grade 3, we recommend doing this activity as a class demonstration.

Preparation

Estimated preparation time: 5-15 minutes

- Gather all required materials.
- Read through activity steps, hints, activity sheets, associated background information and context, as well as safety concerns from the introduction of the magnetism section.

Materials

- Bar and/or block magnets
- Compass
- Iron fillings bags (5)
- Neodymium magnets (optional)
- Tissue box or other thin, small cardboard box (optional)
- Small plastic bags (optional)
- Writing materials (e.g. paper, pencils, etc.)

RUNNING THE ACTIVITY

Begin: Watch the video with your students

Divide students into no more than five groups, ensuring each group has at least one bag of iron filings and one or two bar or block magnets. Before starting, take a moment to review magnet-handling safety with the class.

If you're not sure whether your students can or should use the magnets, you can lead this activity as a class demonstration and discussion. Similarly, if you're unsure whether older students should handle the iron filings outside their original bag, consider doing those parts of the activity as a class demonstration and discussion instead.

Step 1: *5 min*

Consider starting with a short class discussion using prompts like:

- How do magnets interact with each other?
- What does "temporarily magnetic" mean? How does an object become temporarily magnetic?
- What does it mean for something to be permanently magnetic?
- What is a "field"?

HINT! *Guide students to recall their experiences in Activities 1 and 2, where they found that magnets have two poles. Like poles repel each other, while opposite poles attract.*

Step 2: *5-10 min* ⚠

Students use the bag of iron filings to illustrate the magnetic field lines around a single magnet. Encourage students to lay the bag flat on a surface, then place the magnet on top. They may need to gently shake the bag with the magnet resting on it to help the iron filings align along the magnetic field lines. Remind students to keep the bag sealed at all times. If you're doing a class demonstration, consider using an overhead projector or a live camera feed to display the view from above on a smart board or screen.

Ask students to describe what they see and explain it based on what they already know about magnets and ferromagnetic materials like iron. Encourage them to move the magnet across the bag and experiment with different orientations to see how the pattern changes. Specifically, have them try laying the bar magnet on its longest side, and the block magnet on its narrowest or thinnest side.

HINT!

The poles are located on different faces depending on the magnet: bar magnet poles are on either end, while block magnet poles are on the largest flat faces. *See illustration on page 5 for reference.*

Students should observe that the magnetic field is stronger closer to the magnet and weaker further away. This is shown by more iron filings aligning close to the magnet, and fewer or none aligning farther away.

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

Students in Grades 4 and up investigate the magnetic field lines further by using one or more compasses and comparing what they observe to the patterns formed by the iron filings. Encourage students to move the compass around the entire magnet and note how the needle reacts at different positions.

Students can ignore the N, S, E, and W markings on the compass and simply focus on how the arrow moves in response to the magnet.

HINT!

Students should find that the compass needle changes direction as it gets closer to the magnet, aligning with the magnet's magnetic field. They will notice that the compass needle points in the same direction as the iron filings at the same locations around the magnet.

Step 4: ***5-10 min***

Students investigate how the field lines change in different situations:

- What happens when the orientation of the magnet is flipped?

Students will not see anything change with the iron filings. However, when using the compass, they should find that the direction of the magnetic field shifts.

- How do the field lines change when using more than one magnet?

Depending on the orientation of the magnets, students may observe the magnetic field lines either connecting between the magnets or diverging from one another.

Step 5: ***10-15 min*** ⚠

For students in Grades 6 and up, take the investigation further by observing the magnetic field lines using iron filings in more detail. If your materials allow the filings to be sprinkled, students can gently sprinkle them into a tissue box or shallow cardboard container over one or more magnets to see the patterns more clearly. If using sealed bags of iron filings, students can continue exploring by placing magnets on or around the bag in different orientations, as in Step 2.

Students compare what they observe here with the patterns they saw earlier in Steps 2 and 3, reflecting on similarities and differences.

HINT! *If sprinkling filings, the bar or block magnets should be placed in sealable plastic bags beforehand to avoid direct contact with the filings, ensuring the materials stay separate. Remind students not to remove the magnets from their plastic bags until all iron filings have been safely returned to their container. This helps prevent filings from sticking to the magnets or scattering across the workspace.*

Step 6: *10 min* ⚠

This final challenge step is best done as a demonstration or with students in Grade 9 and up. Students are encouraged to make predictions about how the magnetic field of neodymium magnets might be similar to or different from that of the bar and block magnets. They then test their hypotheses by repeating Steps 2 to 5 using the neodymium magnets.

HINT! *The behaviour of the magnetic field will follow the same patterns, but it will be significantly stronger. The magnetic poles of neodymium magnets are typically on the flat top and bottom surfaces, so the field will appear to emerge from those faces.*

If you're short on time, consider putting the iron filings back in their bag and only repeating Steps 2 and 3 with the neodymium magnets.

Notes:

ACTIVITY 4

MAKE A COMPASS

Kick off the activity with this video!

Learning Objectives

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

- Recognize that the magnetic force can be used to create a compass
- Understand that the Earth acts like a giant magnet with north and south magnetic poles

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

- Explain that the magnetic force can be used to create a compass
- Recognize that ferromagnetic materials can become temporary magnets
- Understand that the Earth acts like a giant magnet with North and South Poles

Grades and Timing

This activity is expected to take 30 minutes or less.
For students in Kindergarten to Grade 3, we recommend doing this activity as a class demonstration.

Preparation

Estimated preparation time: 15-20 minutes, 30 minutes for young students if doing a demonstration

- Gather all required materials.
- Read through activity steps, hints, activity sheets, associated background information and context, as well as safety concerns from the introduction of the magnetism section.
- For students in **Kindergarten to Grade 5**: Complete Step 1 ahead of time if the needle is not already magnetized. You can test whether it's magnetized by trying Steps 2 and 3.

Materials

- Bar and/or block magnets
- Sewing needle
- Small bowl of water
- Small piece of paper, card paper, or cardboard
- Writing materials (e.g. paper, pencils, etc.)

RUNNING THE ACTIVITY

Begin: Watch the video with your students

Divide students into no more than five groups, ensuring each group has one sewing needle and one bar or block magnet. Before beginning, take a moment to review magnet-handling safety with the class.

If you are not sure whether your students can or should handle the magnets or the sewing needle, you can instead lead this activity as a class demonstration and discussion. For students in Kindergarten to Grade 3 it is recommended to do this activity as a class demonstration.

Step 1: *5 min*

Students magnetize their sewing needle, if it hasn't already been done. **For students in Kindergarten to Grade 5, consider magnetizing the needles ahead of time or demonstrating the process to the class.**

To magnetize the needle, rub the tip of the sewing needle along the magnet in one direction only. Repeat this motion at least 20 times, always in the same direction. This process turns the needle into a temporary magnet.

Step 2: *5-10 min*

Students create a simple compass using the sewing needle, a bowl of water, and a small piece of paper or cardboard. The paper should be placed on the surface of the water, with the needle carefully placed on top. This allows the needle to float freely and align with the magnetic field.

You can have students discuss the following questions in their groups before sharing with the class, or lead a full-class discussion:

- What do you know about compasses?
- Does the compass you made behave as you would expect? Why or why not?
- Would you trust this compass to guide you if you were lost? Why or why not?

HINT! *If the needle doesn't turn or align North, try remagnetizing!*

Step 3: *5-10 min*

Students place the magnet near their compass needle and move the magnet around, observing how the needle responds to the magnetic field. This marks the end of the activity for students in Kindergarten through Grade 5.

HINT!

Rubbing the needle with a magnet causes the electrons in the needle's atoms to align, making it temporarily magnetic.

The paper and water allow the needle to float and turn freely. You can invite students to brainstorm other ways this could be done.

Students in Grades 6 and up are encouraged to reflect on two key questions:

- Why did we rub the needle on the magnet?
- Why was the compass set up using paper and water?

HINT!

At either magnetic pole, the magnetic field lines are perpendicular to the Earth's surface, they point straight up or down. This means that if a compass is held flat, it may spin or point in a random direction. If the compass can move in three dimensions, it would point straight down at the magnetic south pole and straight up at the magnetic north pole. You may also want to remind students that the Earth's magnetic poles are named opposite to its geographic poles and do not align perfectly with them.

Step 4: *5-10 min*

For students in Grades 6 and up, ask them to consider how their compass would behave at the magnetic north or south pole. Encourage students to be creative in their thinking. You may want to guide the discussion based on what they know about the direction of magnetic field lines at the poles of a magnet.

Notes:

ACTIVITY 5

ELECTROMAGNET TRAIN

Background & Context

In Activity 5, students explore the interaction between electricity and magnetism through a demonstration of an electromagnetic train. It is recommended that students complete Activities 3 and 4 beforehand, as this activity builds on foundational concepts of magnetism and magnetic fields. Activity 5 is not recommended for students below Grade 4. It offers opportunities to add more steps and challenge questions for older students, particularly around magnetic fields, electric circuits, and electromagnetism. This activity connects directly with general science and physics curricula.

For students in **Grades 4 through 8**, Activity 5 is exploratory and should be done as a demonstration. Students observe the behaviour of the electromagnetic train and are encouraged to apply their understanding of magnets to explain what is happening.

For students in **Grade 9 and up**, Activity 5 combines hands-on observation with critical thinking. Students are encouraged to create and test hypotheses to investigate how changes affect the electromagnetic train's behaviour.

Electricity and magnetism are related. We often refer to them together as electromagnetism. There's a rich history of how scientists discovered the connection between these forces, and we benefit from that work every day through technologies like batteries and electric motors.

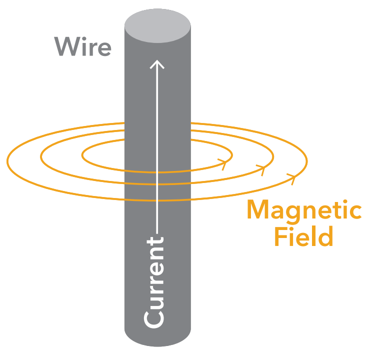
For Activity 5, we'll focus on one key part of electromagnetism: that moving electric charges create a magnetic field.

Moving electric charges —especially electrons— are what we call electricity. We experience electricity constantly: when we turn on lights, use and charge appliances, and more. Electricity also exists in nature, such as in lightning or in the electrical signals in our brains!

Think about electrical appliances. They usually have a cord that connects them to an outlet. This cord contains at least two wires, which connect the appliance to the electric current in your home. When plugged into an outlet, electricity flows through the wires, and that moving charge creates a magnetic field around them.

In Activities 3 and 4, we explored the magnetic field around permanent magnets. Remember that force fields show the shape and direction of a force, and the more field lines you see, the stronger the force in that region. Permanent magnets have two poles, a north and a south, with magnetic field lines flowing from north to south. This directional flow is what causes opposite poles to attract and like poles to repel.

A moving electric charge, such as electricity flowing through a wire, isn't the same as a permanent magnet, so the magnetic field it creates looks different. Around a live wire, the magnetic field wraps in circles around the wire, as shown below.



The magnetic field around a wire with electricity flowing through it. The direction of the magnetic field is related to the direction of electric current in the wire.

While a straight wire carrying electricity produces a circular magnetic field around it, that field doesn't resemble the kind we see around a bar magnet. But if we take that wire and form it into a loop, something interesting happens: the magnetic field created by the moving electric charge through the loop starts to resemble the magnetic field of a permanent magnet.

This loop doesn't have physical or "tangible" magnetic poles like a bar magnet does. Instead, the magnetic field flows through the centre of the loop and spreads out around it in a similar shape to that of a bar magnet's field.

When you bring a permanent magnet close to the loop, the two magnetic fields interact just like two magnets would: opposite magnetic poles attract, and similar poles repel. However, because the loop doesn't have defined magnetic poles that stick out like a magnet's ends, the magnet won't latch on or stick to the loop. Instead, it will pass through or be pushed away depending on the interaction of the fields (diagram on following page).

Batteries store energy. Most household batteries, like AA and AAA, store energy as chemical potential energy. This means the energy isn't being used right away but can be converted into a usable form later. When a battery is placed in a circuit, such as in a flashlight, its chemical potential energy is transformed into electrical energy, or electricity.

The simplest circuit you can make is a loop of wire with each end touching opposite ends of a battery. This setup drains the battery's energy very quickly, a process often called "shorting out" the circuit or the battery. In Activity 5, we'll intentionally create a short circuit using copper wire and a battery.

Placing the battery inside uniformly coiled copper wire creates a closed circuit that allows electricity to flow. As electricity moves through the wire, each loop generates a magnetic field. These magnetic fields all point through the centre of the coiled loops.

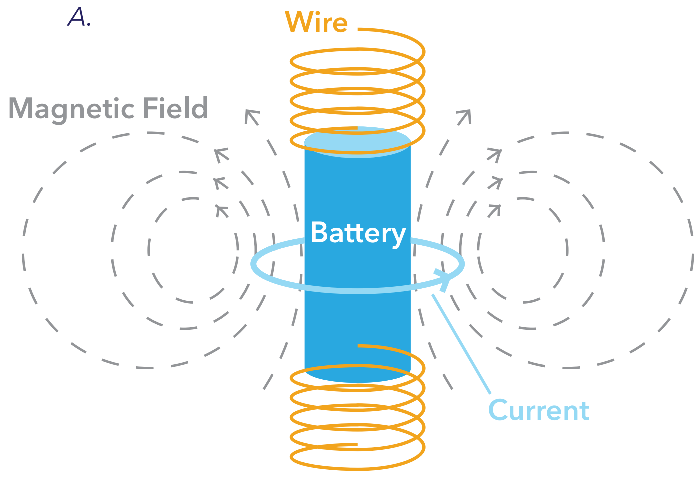
To create the electromagnetic train, magnets are placed on either end of the battery before it's inserted into the coil. These magnets interact with the magnetic field generated by the flowing electricity. When both magnets are oriented with the same poles facing outward, one magnet is pulled forward by the magnetic field and the other is pushed, causing the battery and magnets to move through the coil.

When a battery is connected to a copper wire, a circuit is created and current flows through the wire. The current produces a magnetic field around the wire, which is influenced by the direction of the current.

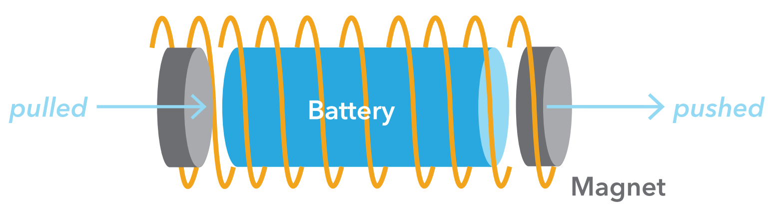
When a current-carrying wire is looped, the magnetic field flows through the centre of the loop and curves back around the outside, as pictured in figure A.

When a current-carrying wire is coiled (many loops in a row), the magnetic field is concentrated through the centre of the coil, strengthening the magnetic field. This acts like a bar magnet with a north and south pole, which then pushes and pulls magnetic materials, depicted in figure B.

A.



B.



KEY CONCEPTS FOR DISCUSSION

Electromagnetism

Electromagnetism describes the relationship between electricity and magnetism. Scientists have discovered that moving electric charges produce a magnetic field, and changing magnetic fields can generate electricity. These two forces are deeply connected and are often studied together. Electromagnetism is what makes motors, generators, and many everyday technologies work.

Electricity

Electricity is the flow of electric charge, usually carried by electrons. It moves through wires in a circuit and can be used to power lights, motors, and other devices. When electricity flows through a wire, it creates a magnetic field around the wire. This connection between electricity and magnetism is what drives the electromagnetic train in this activity.

Magnetic field

A magnetic field is the area around a magnet or a moving electric charge where magnetic forces can be felt. You can think of it as an invisible pattern that shows the direction and strength of the force. In this activity, the magnetic field is created by the flow of electricity through the copper wire and interacts with the magnets on the battery to push the train forward.

Energy, Potential Energy

Energy is the ability to do work or cause change. Batteries store potential energy, which is energy waiting to be used. In this case, it's stored as chemical energy. When the battery is placed into a circuit, the potential energy becomes electrical energy, powering the flow of electricity through the wire. That electrical energy then creates a magnetic field, which is part of the demonstration in this activity.

Notes:

ACTIVITY 5

Kick off the activity with this video!

Learning Objectives

For students in **Grade 4 to Grade 8**, by the end of this activity, students will be able to:
- Describe electromagnetism and its relevance to everyday life
- Identify magnetic forces
- Categorize different types and forms of energy

For students in **Grades 9 to 12**, by the end of this activity, students will be able to:
- Describe electromagnetism and explain how electromagnetism applies to real-world technologies
- Identify magnetic forces
- Categorize different forms and types of energy
- Infer the shape and direction of a magnetic field by analysing how it affects nearby magnets or objects
- Optional: Apply the right-hand rule to determine the direction of magnetic fields around current-carrying wires

Research Connections

In this activity, you'll explore the connection between electricity and magnetism. In previous activities, you explored how planets can have magnetic fields. We saw the effects of Earth's magnetic field using a compass.

Aurora are among the most visible effects of a planet's magnetic field. When charged particles from solar wind reach a planet with a magnetic field, they are guided along magnetic field lines toward the poles. There, they collide with gases in the upper atmosphere (often oxygen or nitrogen) producing glowing light displays known as aurora. On Earth, these are called the aurora borealis (northern lights) and aurora australis (southern lights). Similar displays have been observed on planets like Jupiter and Saturn, confirming the presence of strong magnetic fields.

Not all planets or moons have magnetic fields, but whether or not they do can have a big impact.

Planets without magnetic fields are more vulnerable to solar wind, which can gradually strip away their atmospheres. This may be what happened to Mars. Today, Mars doesn't have a global magnetic field, but rocks on its surface are magnetized. These rocks suggest Mars once had a magnetic field, which protected it long ago, but that field no longer exists today.

We can also learn about ancient magnetic fields by studying the magnetized rocks on Earth, the Moon, and Mars. These rocks act like tiny record-keepers, preserving the direction and strength of the magnetic field at the time they formed.

Understanding which celestial bodies have magnetic fields, and which ones used to, helps astronomers learn more about a planet's history, internal structure, and potential to support life.

Grades and Timing

This activity is expected to take 45 minutes or less.

Preparation

Estimated preparation time: 20 - 30 minutes.

- Gather all required materials.
- Read through activity steps, hints, activity sheets, associated background information and context, as well as safety concerns from the introduction of the magnetism section
- Wrap the copper wire tightly around the dowel to form even coils. It may help to tape one end of the wire to the dowel to hold it in place while you wrap. If the coil is kinked or uneven, the train may not work properly.

Materials

- Neodymium magnets (6)
- AAA batteries (2)
- Copper wire
- Dowel
- Tape (optional)
- Writing materials (e.g. paper, pencils, etc.)

RUNNING THE ACTIVITY

Begin: Watch the video with your students

Because this activity uses neodymium magnets, we recommend running it as a class demonstration for all students. For Grades 9 and up, you may choose to let students take turns investigating and pushing the train themselves.

Before you begin, take a moment to review magnet-handling safety with the class.

Step 1: *5-10 min*

Start with a short class discussion using prompts like:

- What is an electromagnet? How is it different from a bar magnet or ferromagnet object?
- Have you heard of "electromagnetism" before? How is it different from magnetism? What do you know about electricity?
- What are batteries? How do they work?

HINT!

Electromagnets rely on both electricity and magnetism to work. While they can operate in different ways, they always depend on the interaction between these two forces.

Batteries store energy, usually as chemical potential energy. When connected to a circuit, a chemical reaction inside the battery produces electricity.

Step 2: *5 min*

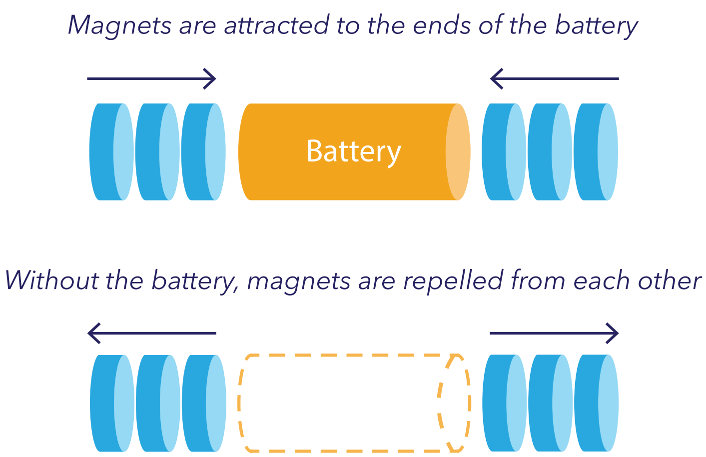
Assemble the electromagnetic train:

1. Slide the coil off the dowel and lay it on a flat surface. Adjust the spacing/shape of the coil as needed, so the coils do not touch each other.
2. Split the neodymium magnets into two sets of 3. They are very strong magnets, so be careful not to pinch yourself!
3. Place the two sets of magnets on either end of the battery.

HINT!

Make sure there are no kinks in the wire. The train will not work if there are uncurved or pointed areas on the wire.

Make sure the magnets are attached straight to the battery (not crooked) and in the correct orientation. The two groups of magnets should repel each other if the battery isn't between them. See following diagram for reference.



How to assemble the disc neodymium magnets and the AAA battery for the electromagnetic train. The six magnets should be split into two groups of three, and should repel each other without the battery in place. The magnets will attach to the ends of the battery.

Step 3: *20–30 min*

Place the battery-magnet system inside one end of the coil and give it a gentle push. It should glide through the coil. For students in Grade 9 and up, consider allowing them to take turns pushing the electromagnetic train. Students are encouraged to experiment with different variations and test their hypotheses, for example, how to make the train go faster, or why its orientation matters.

HINT!

If the battery-magnet system gets stuck in the coil, try giving the coil a gentle shake.

If the system won't move, flip it around and try again. Ask students to think about why the train only works in one direction. Encourage them to consider the magnetic field of the magnets and how it interacts with the current in this orientation.

The train will only work with a coil made from an electrically conductive material like copper. Copper works well with a small battery because it is highly conductive. Most other metals won't work for this setup, except for silver.

Using more magnets increases the strength of the magnetic field and makes the train move faster.

Take it further!

For high school students, consider introducing the right-hand rule to find the direction of the magnetic field around a wire with current. Ask students to draw a diagram showing what's happening in the electromagnetic train, including the direction of current and the shape of the magnetic fields involved. This will require some inductive reasoning!

MAGNETISM

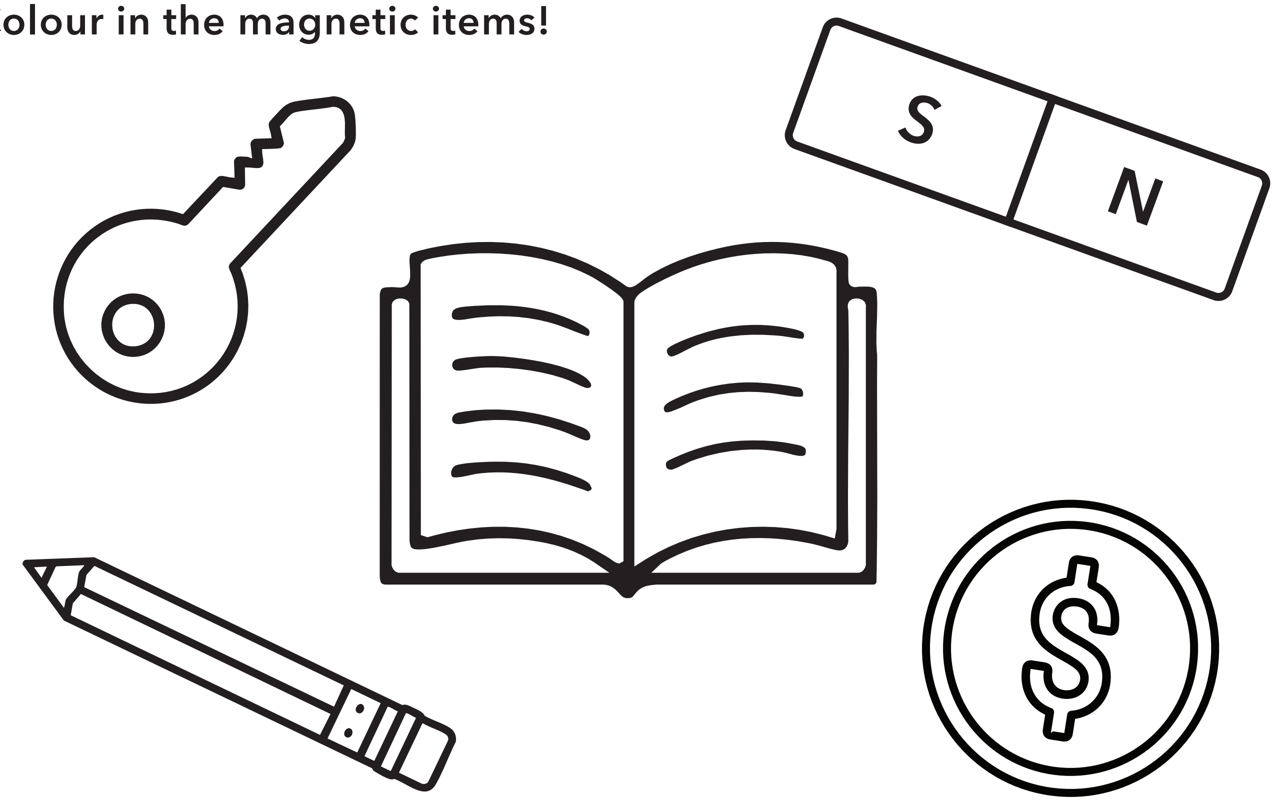
STUDENT HANDOUTS AND ACTIVITY SHEETS

Complementary and optional activities for your learners!

Kindergarten – Grade 3

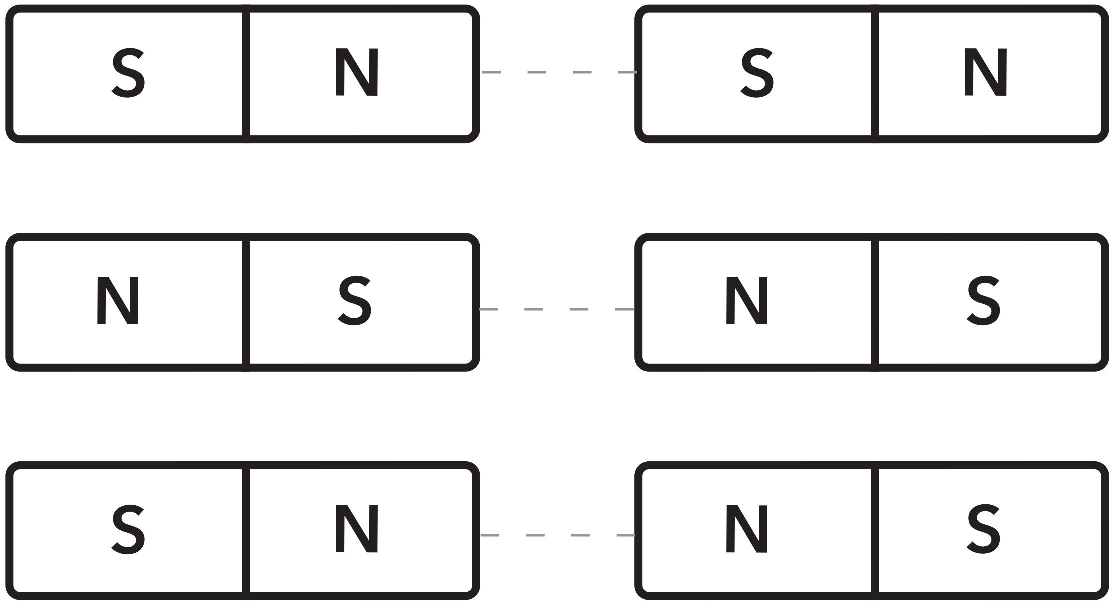
Draw 1 or 2 things you found that were magnetic!

Colour in the magnetic items!



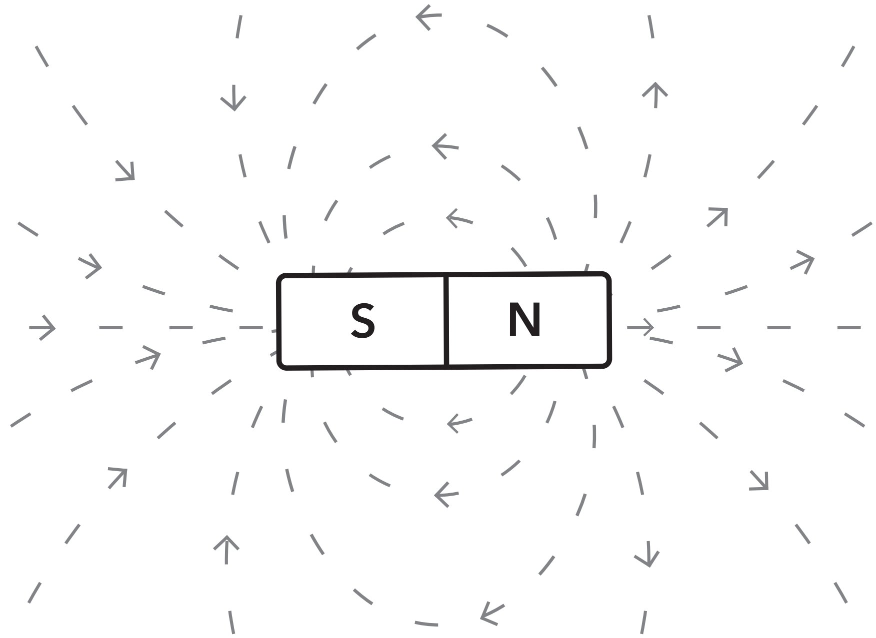
ACTIVITY 2: MAGNETIC ATTRACTION AND REPULSION

Colour the magnets: the N side is red, the S side is blue.
Connect the magnets: Green for attraction and purple for repulsion.

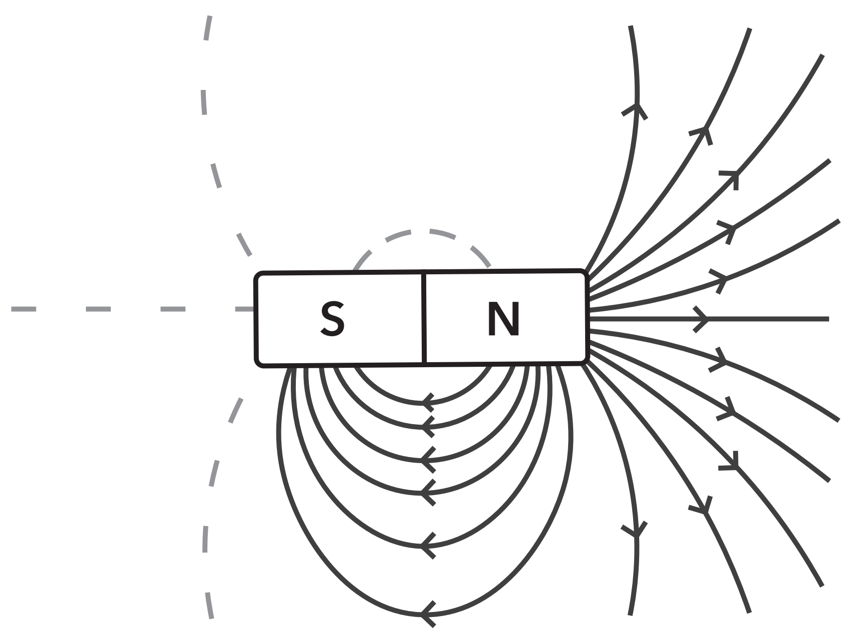


Draw something you noticed while experimenting with the magnets!

Trace the lines to discover the magnetic field!

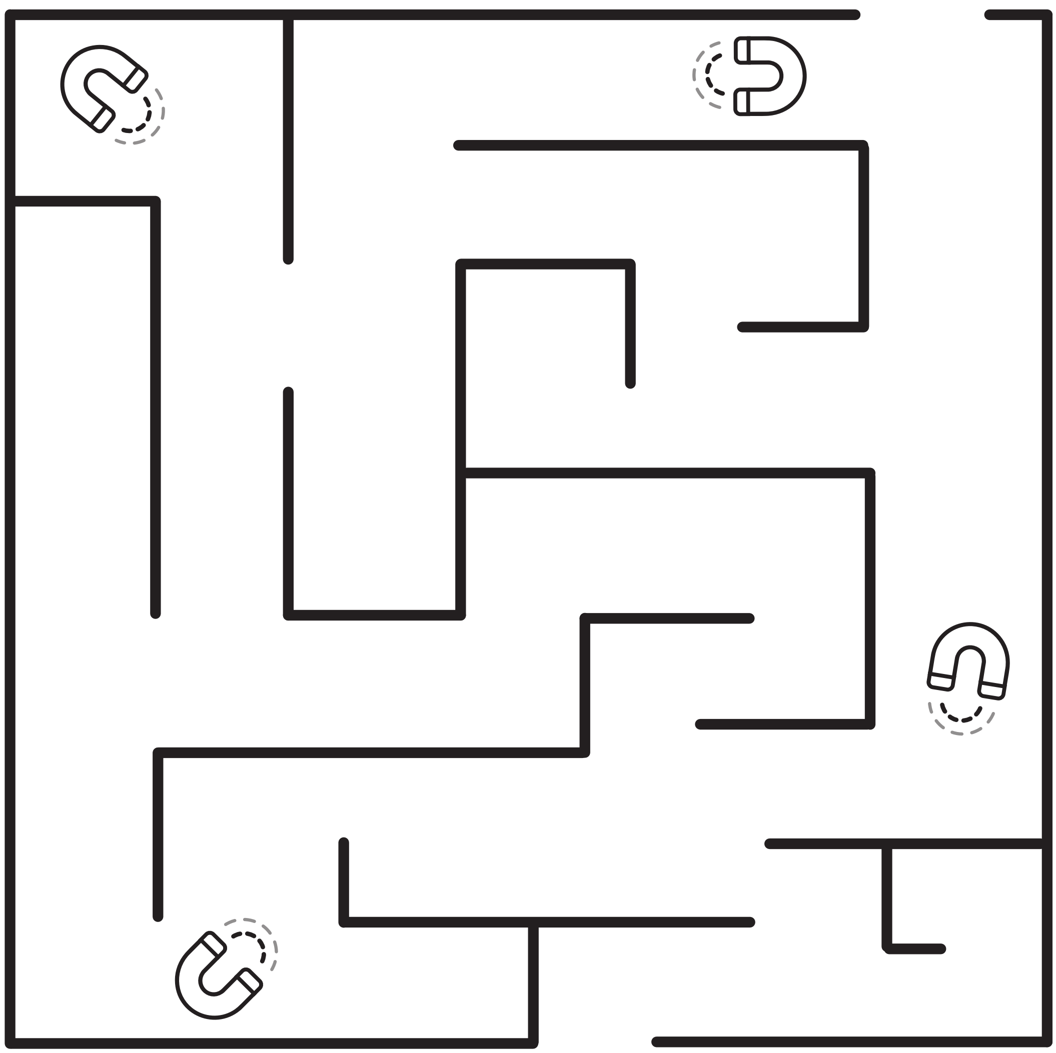


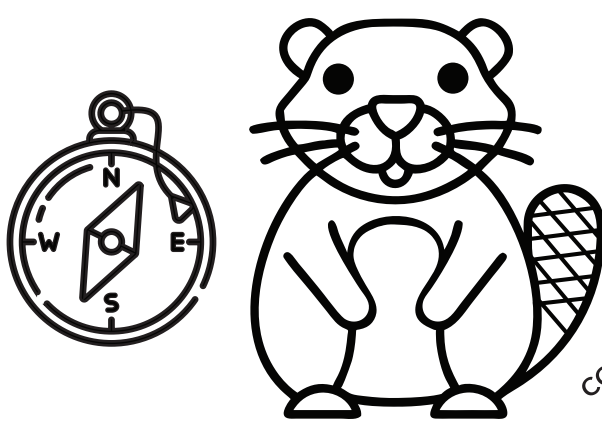
Colour the N side red and the S side blue then finish the magnetic field by drawing the missing lines. Make the arrows go the right way (north to south).



ACTIVITY 4: MAKING A COMPASS

Help Maple the Beaver find her way through the maze. Use her compass, but be careful! Magnets can make it point the wrong way.





COLOUR MAPLE IN!

GRADE K-3 ANSWER KEY

Activity 1

The key, coin, and magnet bar are magnetic.

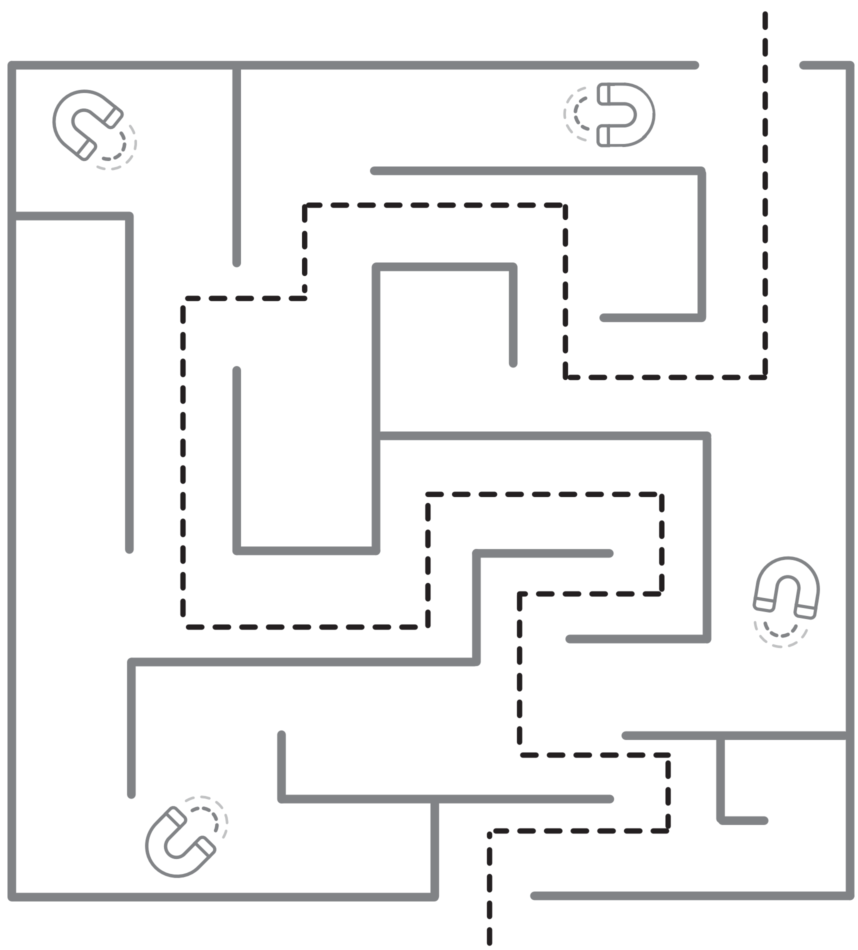
Activity 2

Green lines should connect N to S, and purple lines should connect N to N or S to S. So, in order: Green line, green line, purple line.

Activity 3

Watch for symmetry and completion. Arrows should always point away from north and toward south.

Activity 4



MAGNETISM

STUDENT HANDOUTS AND ACTIVITY SHEETS

Complementary and optional activities for your learners!

Grade 4 – 6

List items you tested in the correct column.

Magnetic	Not Magnetic

Circle the correct answer.

A. Only some metals are magnetic.	TRUE	FALSE
B. You can pick up a paperclip with a magnet.	TRUE	FALSE
C. Copper wire is magnetic.	TRUE	FALSE
D. A magnet can attract an object even if it's not touching it.	TRUE	FALSE
E. If something sticks to a magnet, it must be metal.	TRUE	FALSE
F. Magnets can push and pull.	TRUE	FALSE
G. Magnets can still work through plastic.	TRUE	FALSE
H. Magnets always attract each other.	TRUE	FALSE

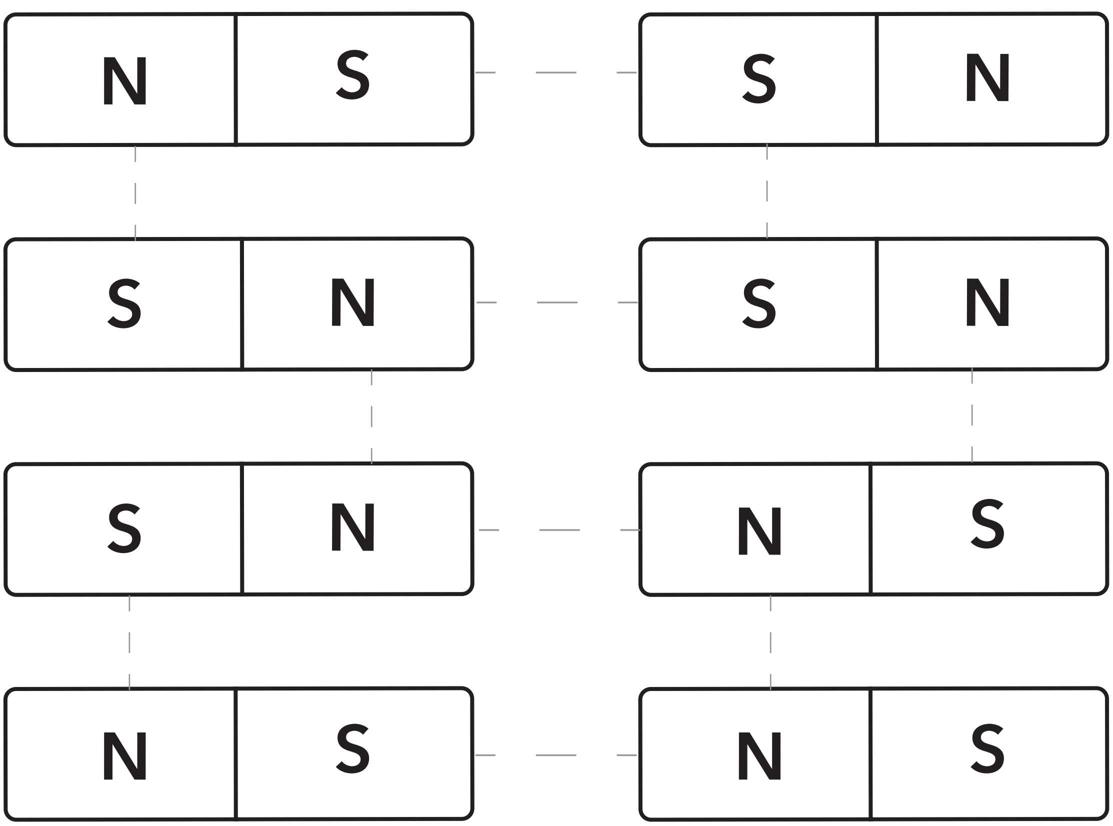
ACTIVITY 2: MAGNETIC ATTRACTION AND REPULSION

Fill in the Blanks!

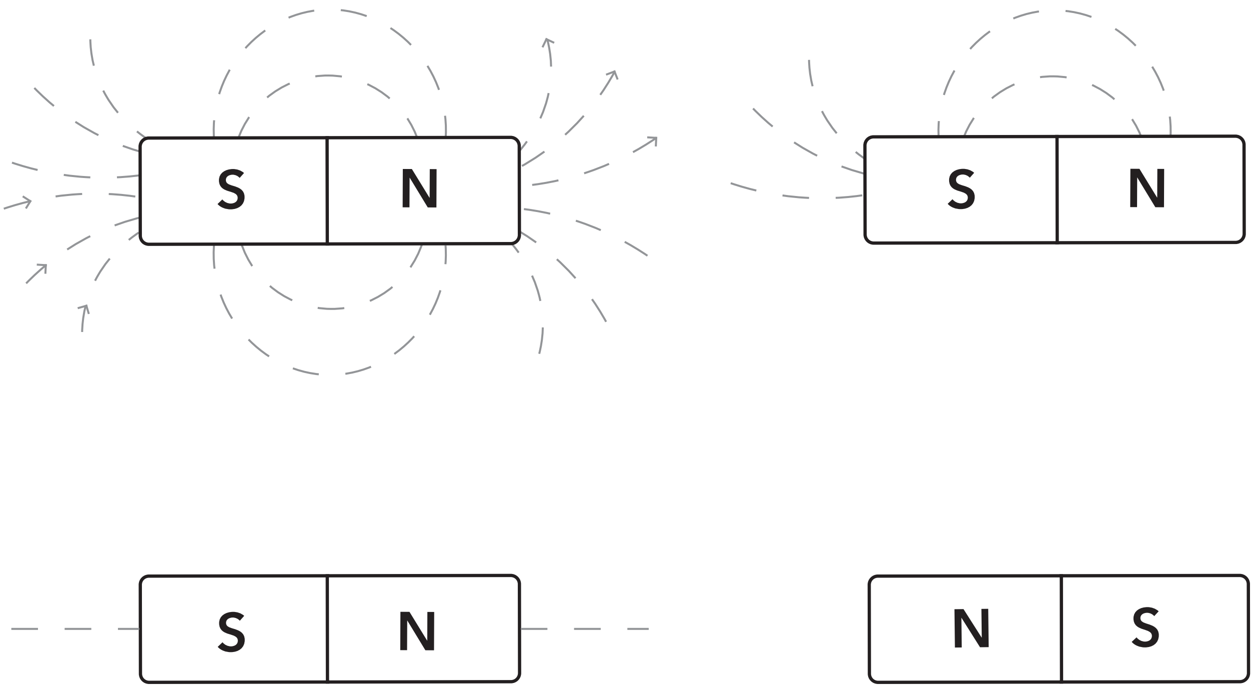
Magnets have two ends called the __________ and __________ poles. Opposite poles __________ each other, and identical poles __________ each other. The invisible area around a magnet where magnetic forces can be felt is called the magnetic __________. Some common metals that magnets attract are __________, __________, and nickel. Magnet can attract objects even if there is space between them

KEYWORDS: iron • repel • steel • north • south• copper • field • space • attract

Here's a set of magnets. Colour them in: S = Blue (south), N = red (north).
Look at the magnets both across and up and down. Trace the lines between poles: green for attraction, and purple for repulsion.



Fill in the Magnetic Field lines and make sure the arrows point the right way!

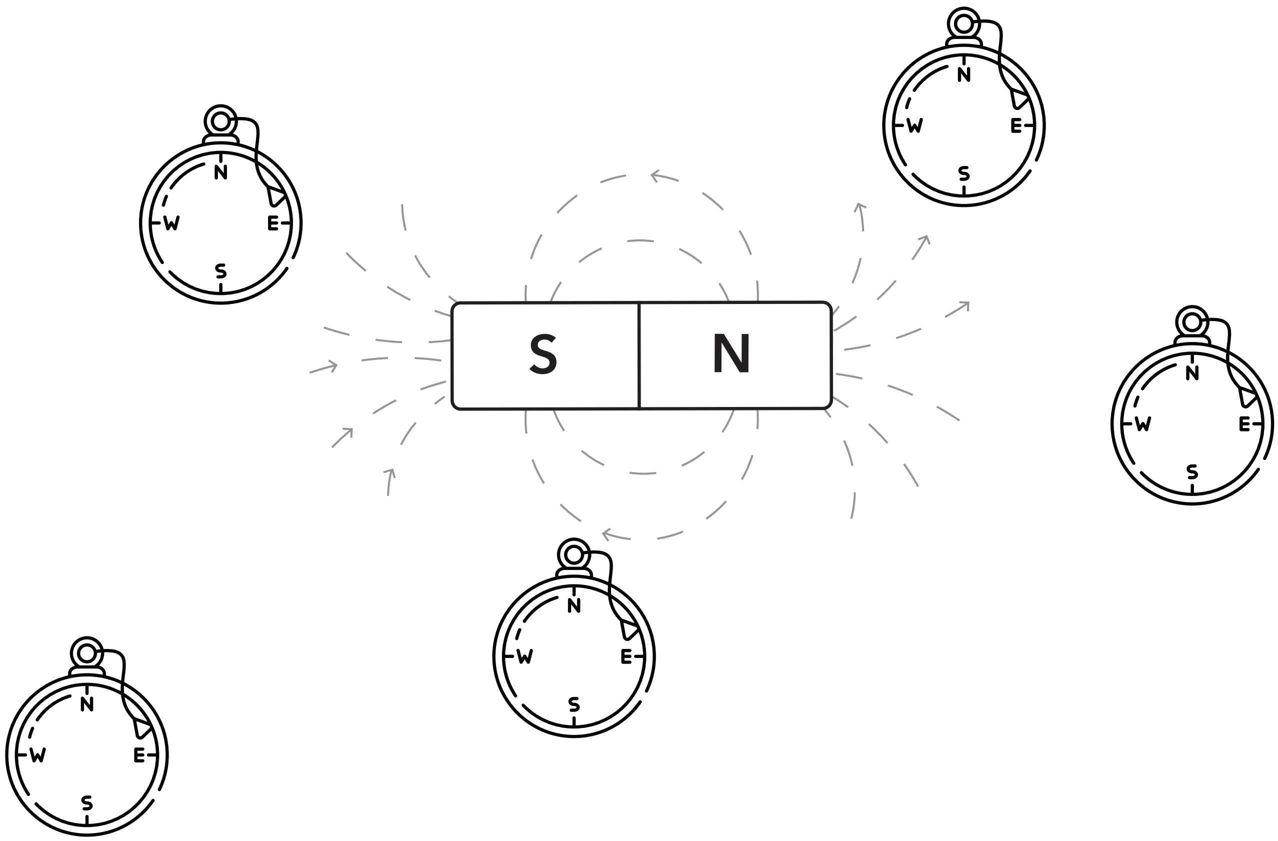


Circle the correct answer.

A. Magnetic field lines go from the north pole of a magnet to the south pole.	TRUE	FALSE
B. The magnetic field is strongest in the middle of a bar magnet.	TRUE	FALSE
C. Opposite poles attract, and identical poles repel.	TRUE	FALSE
D. You can see the shape of a magnetic field by using iron filings.	TRUE	FALSE
E. The magnetic field exists even if nothing is touching the magnet.	TRUE	FALSE

ACTIVITY 4: MAKING A COMPASS

These compasses are missing their arrows! Draw them in so that they're pointing the right way. *Hint: Pay attention to the magnetic field they're near!*



Fill in the Blanks!

A _________ is a tool used for finding direction. To make your own compass, you can use a _________ needle. Rubbing the needle with a _________ will make it magnetic. The needle of a compass usually points toward the _________ Pole and the opposite end points toward the _________ Pole. The other two main directions are _________ and _________ . When you bring a magnet close to the compass, the needle will move because of the magnet's _________ .

KEYWORDS: magnet • plastic • metal • pull • push
compass • North • East • West • South

ACTIVITY 5: ELECTROMAGNET TRAIN

Fill in the Blanks!

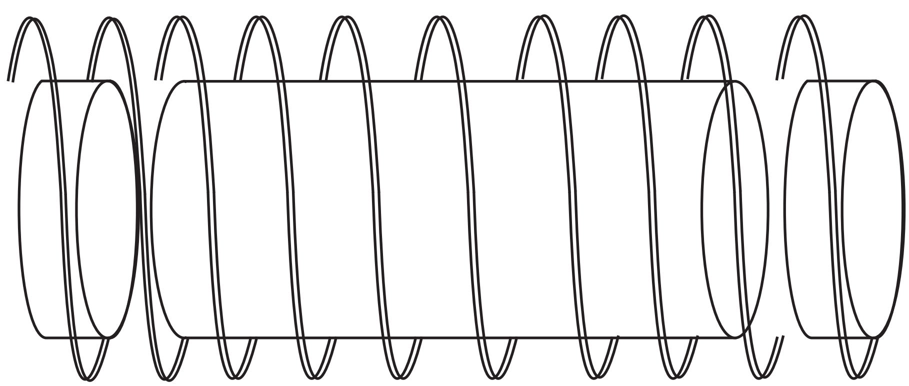
An _________ is a magnet made using electricity. In the electromagnetic train, a battery makes electricity flow through the wire. This electricity creates a _________ field. The magnets on the _________ push and pull against this field, making the battery move through the _________.

KEYWORDS: copper • battery • coil • magnetic • electromagnet

Draw a line to match each action with what happens to the train:

A. Add more magnets	Train does not move
B. Flip the train around	Train goes faster
C. Use a non-metal coil	Train moves in the other direction
D. Make the coil out of copper	Train works normally

Colour the magnets red on their poles. Draw arrows to show which way the train will move in the coil. Label the battery, magnets, and coil.



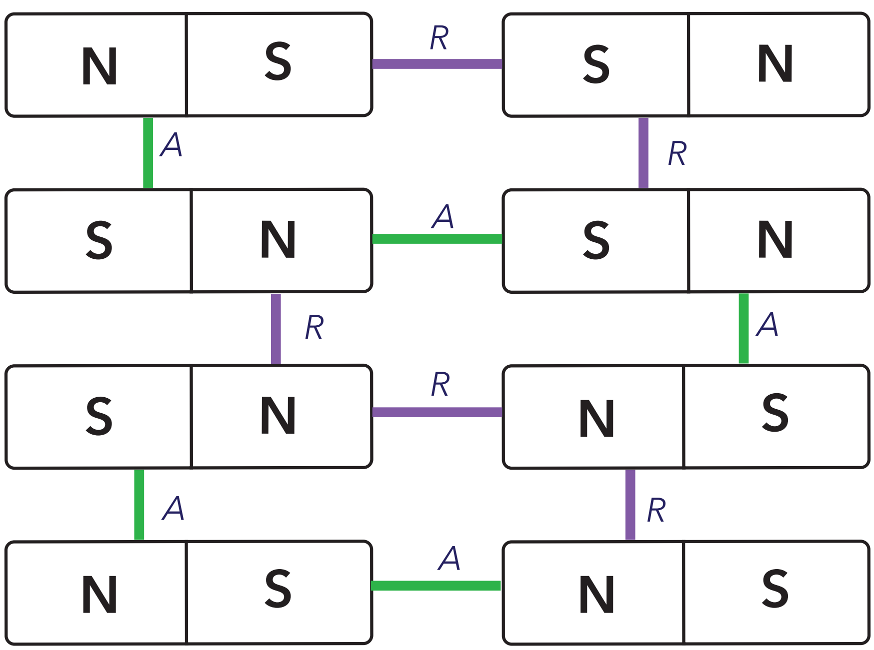
GRADE 4-6 ANSWER KEY

Activity 1

A. Only some metals are magnetic. TRUE
B. You can pick up a paperclip with a magnet. TRUE
C. Copper wire is magnetic. FALSE
D. A magnet can attract an object even if it's not touching it. TRUE
E. If something sticks to a magnet, it must be metal. TRUE
F. Magnets can push and pull. TRUE
G. Magnets can still work through plastic. TRUE
H. Magnets always attract each other. FALSE

Activity 2

Magnets have two ends called the **north** and **south** poles. Opposite poles **attract** each other, and like poles **repel** each other. The invisible area around a magnet where magnetic forces can be felt is called the magnetic **field**. Some common metals that magnets attract are **iron**, **steel**, and nickel. Magnets can attract some objects even if there is **space** between them.

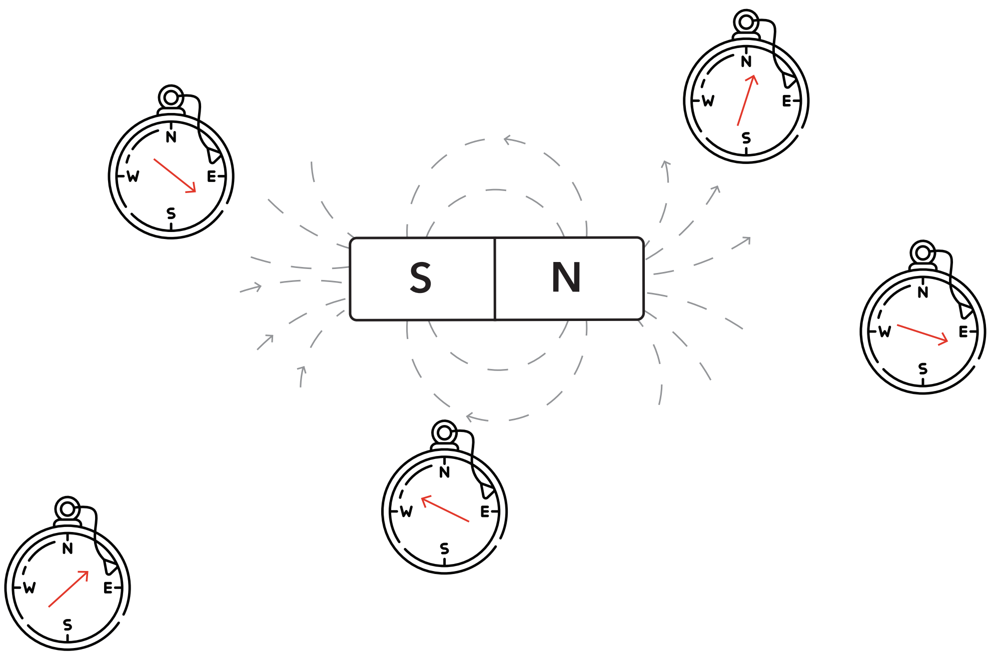


Activity 3

The lines should look like the diagram on page 13 of this guide. But question D is trickier since the magnet is flipped, the arrows should go in the other direction!

A. Magnetic field lines go from the north pole of a magnet to the south pole. TRUE
B. The magnetic field is strongest in the middle of a bar magnet. FALSE
C. Opposite poles attract, and identical poles repel. TRUE
D. You can see the shape of a magnetic field by using iron filings. TRUE
E. The magnetic field exists even if nothing is touching the magnet. TRUE

Activity 4



Note: *If the compass has been re-magnetized by being stored near the magnets, the arrow will still line up the same way, but it may point in the opposite direction.*

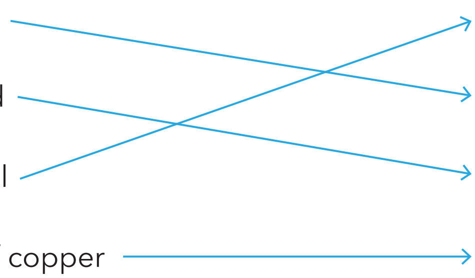
A **compass** is a tool used for finding direction. To make your own compass, you can use a **metal** needle. Rubbing the needle with a **magnet** will make it ferromagnetic. The needle of a compass usually points toward the **North** Pole and the opposite end points toward the **South** Pole. The other two main directions are **east** and **west**. When you bring a **magnet** close to the compass, the needle will move because of the magnet's **pull**.

Activity 5

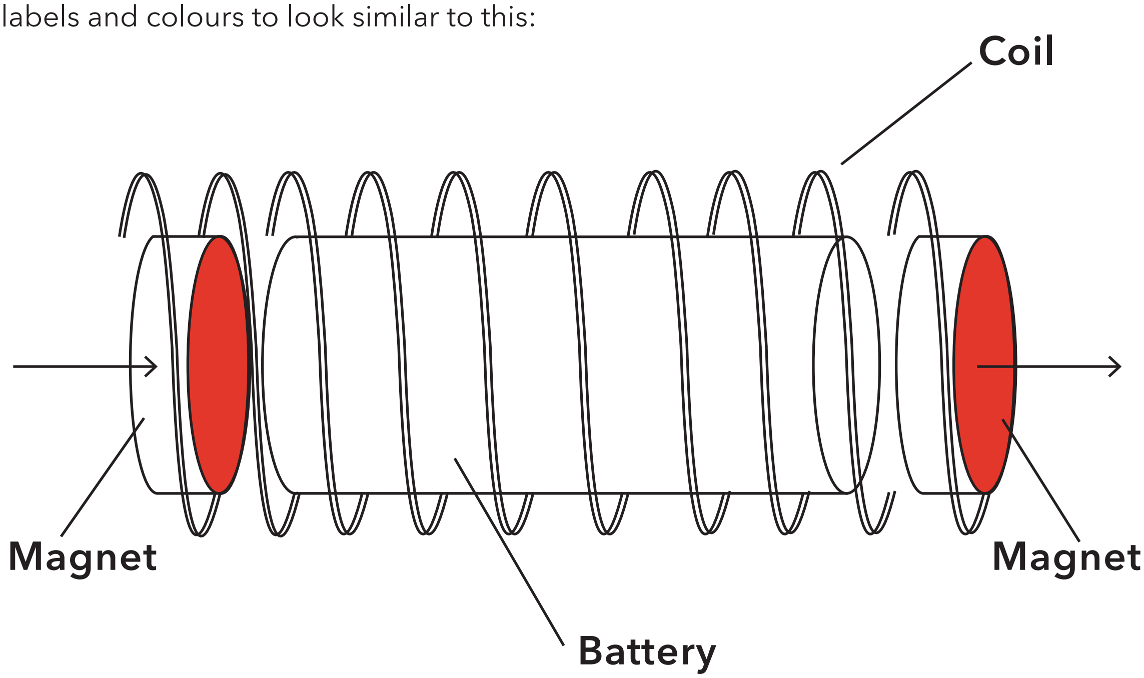
Fill in the Blanks: An **electromagnet** is a magnet made using electricity. In the electromagnetic train, a battery makes electricity flow through the **copper** wire. This electricity creates a **magnetic** field. The magnets on the **battery** push and pull against this field, making the battery move through the **coil**.

Draw a line to match each action with what happens to the train:

A. Add more magnets	Train does not move
B. Flip the train around	Train goes faster
C. Use a non-metal coil	Train moves in the other direction
D. Make the coil out of copper	Train works normally



Expect labels and colours to look similar to this:



MAGNETISM

STUDENT HANDOUTS AND ACTIVITY SHEETS

Complementary and optional activities for your learners!

Grade 7 – 12

ACTIVITY 1: WHAT IS MAGNETIC?

1. **Use the bar and block magnets provided to explore which materials interact with magnets**, then answer the following questions:
    a. What happens when you bring the magnet close to different objects?
    b. Which materials were you able to pick up using a magnet? Do they have anything in common?

2. Some objects that are strongly attracted to a magnet can temporarily become magnets themselves; these are called **ferromagnetic** materials. **Test a paper clip: attach it to a bar magnet, then touch it to another paper clip. Does it stick? How many paper clips can you stack this way?**

3. Objects that show no reaction to a magnet are called **diamagnetic**. **List four objects you found that were diamagnetic. Do you think they can become temporary magnets like paper clips? Why or why not?**

4. **How do magnets react to each other?** Can you pick up a block magnet using a bar magnet from any angle? Why or why not?

5. Cores of planets, like Earth's, can be made of magnetic materials, turning the entire planet into a giant bar magnet. This can reveal a lot about what's happening inside the planet. **If Earth's core is magnetic, should it affect the magnet in your hand? Explain why or why not.**

6. List three examples of magnets or magnetic materials used in everyday life. For each one, explain why magnetism is useful in that object or device.

7. In your own words, define the following magnetic terms:
    a. ferromagnetic:
    b. diamagnetic:
    c. magnetic poles:
    d. paramagnetic:

8. *Challenge*: Devices like metal detectors often use magnets to detect metallic objects.
    a. Are all metals magnetic? Test your bar magnet with the copper coil in your kit and with aluminium foil or a can.
    b. If all metals aren't magnetic, how might a metal detector still find them? Could it have to do with how metals behave in the presence of a magnet? Discuss.

ACTIVITY 2: MAGNETIC ATTRACTION AND REPULSION

1. **Bring two bar magnets close to each other and observe how they interact.**
   a. True or False. All magnets attract each other, no matter the angle you try to connect them. Then explain why or why not.
   b. True or False. The closer two magnets are, the stronger they attract or repel each other. Then explain why or why not.

2. **Use a ruler to measure how far apart two magnets can be before they start to attract or repel each other.** If you have different magnets, compare their strength. *Remember: a stronger magnet's field extends farther, so it will start affecting other magnets at a greater distance.* Repeat your measurements a few times for accuracy.
   a. Which magnets would you call strong?
   b. Which would you call weak?
   c. Compare and discuss your findings with one or more other students.

3. **Place one magnet on top of another of the same kind and note what happens.** Then, flip the top magnet around and observe again.
   a. Which orientation made it easier for the magnets to stick together?
   b. Explain why that happened.

4. Opposite poles of a magnet attract, while identical poles repel. **Choose the correct word for each statement:**
   a. Two north poles of a magnet will (attract/repel) each other.
   b. The north pole of a magnet and south pole of another magnet will (attract/repel) each other.
   c. Two south poles of a magnet will (attract/repel) each other.

5. **If you place a strong magnet near a paperclip without touching it, the paperclip moves toward the magnet.**
   a. Is this an example of attraction or repulsion?
   b. What does this tell you about how magnetic forces can act over a distance?

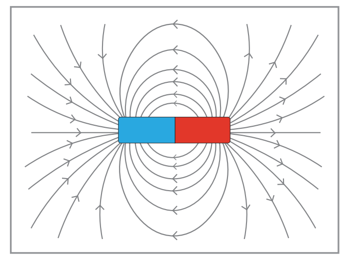
6. *Challenge*: **Magnetic force is responsible for the attraction and repulsion of magnets.**
   a. Can you think of any other examples of forces?
   b. Can these forces pull (attract) or push away (repel) objects like magnets do?
   c. Can these forces act at a distance, like magnets?
   d. Explain your ideas and give examples.

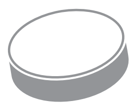
ACTIVITY 3: EXPLORING MAGNETIC FIELD LINES

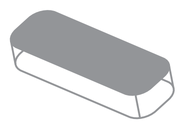
1. **Magnetic field lines help us understand how a magnet will affect magnetic materials, since we can't see the actual pull or push.** Can you think of another force where you can see an object move, but you can't see what's pulling or pushing it?

2. **Circle the correct answer!**
   a. Magnetic field lines start at the north pole and end at the south pole. TRUE FALSE
   b. Earth's magnetic field lines start at the geographic north pole and end at the geographic south pole. TRUE FALSE
   c. Compass needles point towards Earth's north pole because they are reacting to the Earth's magnetic field. TRUE FALSE

3. **The magnetic field in a bar magnet looks like this** ⟶ **the field lines start at one pole and end at the other. Draw or describe** what you think the magnetic field would look like for both of the following magnets:







4. **Place the compass in different locations around the magnet.** How is the compass affected by the magnet? Explain what you're seeing.

5. **Some objects in space have magnetic fields, created when electrically charged material moves around.** We can detect magnetic fields in regions where stars are forming. What could this tell astronomers about stars and star-forming regions:
   a. Material that makes up a star is electrically charged. TRUE FALSE
   b. A star can have magnetic poles like Earth. TRUE FALSE
   c. Material that makes up a star is not magnetized. TRUE FALSE
   d. Material that makes up a star will not affect a compass needle. TRUE FALSE

6. **Planets and moons can have magnetic fields**, created by the movement of ferromagnetic material (like magma) below their surfaces. Planets with this movement are called geologically active.
   a. Our Moon has no magnetic field. What does this suggest about the material below its surface?
   b. Jupiter has a very strong magnetic field. What does this suggest about the material inside Jupiter?
   c. Mars has no magnetic field. What does this suggest about the inside of Mars?

ACTIVITY 4: MAKING A COMPASS

1. **Opposite poles attract.** If a magnet's north pole points toward Earth's geographic North pole, what does this tell you about the type of magnetic pole located at Earth's geographic North?

2. **A compass needle points toward Earth's magnetic north pole, which is not the same as the geographic North Pole**.
   a. Where does your compass needle point when you use it where you are now? Does it help you find geographic North?
   b. Where would a compass needle point if you were standing at the geographic North Pole?
   c. Where would a compass needle point if you were standing at the geographic South Pole?

3. **A compass needle becomes magnetic when it is rubbed on a magnet. This process is called magnetization.** Would a needle that hasn't been magnetized work in a compass? Why or why not?

4. **To make a compass from a magnetized needle, place it on a cardboard or paper strip and let it float in a bowl of water.**
   a. Why does it need to rest on a paper or cardboard strip? Can you replace it with any other material?
   b. Why does the needle need to float freely in water?

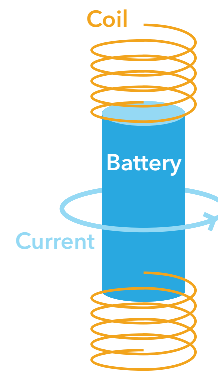
5. **When you bring a magnet close to a floating compass, it changes the direction the needle points.** What does this tell you about the limits of using a compass, and under what conditions can you trust it to point North?

6. **GPS navigation uses satellites, while a compass uses Earth's magnetic field.** Describe a situation where a GPS would be better for finding your way, and a situation where a compass would be better.

7. **The Moon has no global magnetic field, and Mars doesn't have one either** – only some magnetized rocks. Would a standard magnetic compass work on the Moon or Mars? Why or why not?

8. *Challenge*: The magnetic fields of stars and planets can change as material moves inside them. **On Earth, the north and south magnetic poles switch places every several thousand years.** If Earth's magnetic poles flipped, would a compass needle's north still point toward Earth's geographic North? Why or why not?

ACTIVITY 5: ELECTROMAGNETIC TRAIN



1. **Predict which way the train will move!** Curl your right hand in the direction of the arrows labelled "Current" in the diagram and give a thumbs-up – your thumb shows the train's expected direction. This is called the right-hand rule in physics, showing how current and the magnetic field are related. **Test if the magnet train moves in the direction of your thumb.**

2. **If you flip the train and try to put in through the same end,** what happens to the train's movement? What happens if you put the flipped train in the other end? Explain your answer using what you know about current direction and magnetic fields.

3. **The magnet train won't run if the magnets are flipped so their poles face the opposite way.** Explain why it only works when the magnets are oriented the correct way.

4. **The magnet train in this activity runs on a coiled copper wire 'track'.**
   a. Is copper magnetic?
   b. Could the train run on a coil made from a different metal?
   c. Would a plastic slinky work instead? Explain your reasoning.

5. **Why do you think the magnets need to be strong for this experiment to work?** What would happen if you used weaker magnets?

6. **Stacking magnets makes them stronger.** If you add more magnets to the ends of the battery, how would it affect the train's movement? Would it go faster or slower?

7. **This setup uses the battery's energy quickly.** If you make the copper coil track longer (same coil spacing), predict how the train's speed will change from start to finish. Explain your reasoning.

8. **Thicker copper wire can carry more electricity from the battery in this short-circuit setup.** If the coiled track was made with thicker copper wire, what change would you expect in the train's motion? Explain your reasoning using the idea that moving electric charges create the magnetic field.

9. *Challenge:* **A loop of current makes a magnetic field that looks a bit like a bar magnet's field.** Scientists often use coils and electromagnets inside instruments. Explain why a loop is a useful shape when we want a strong, directed magnetic field.

GRADE 7-12 ANSWER KEY

Activity 1

1. a. Look for ... Attracting, no reaction, or repelling depending on what is being tested.
b. Look for... Magnetic items such as paper clips, coins, keys, etc. Students might guess that all these materials are metals. You can encourage them to explore whether all metals are magnetic or not.

2. Expect: A paper clip is ferromagnetic and can be magnetized. Students should be able to make a chain of a few paper clips, but the number will vary with the strength of the magnet used.

3. Expect: Items such as paper, plastic materials, metals such as copper, etc.
Answer: Diamagnetic materials cannot be magnetized like a paper clip because their atoms respond differently than ferromagnets near a magnet.

4. Answer: Magnets can attract or repel each other. A block magnet cannot be picked up from just any angle by a bar magnet. Expect: Only opposite poles of a magnet attract each other.

5. Expect: It will not have any effect on magnets held in-hand because it's too big, but it would affect smaller magnets, such as the ones in a compass.
Look for ... Earth is like a giant magnet, but its magnetic field is very weak and spread out.

6. Look for... Creative and sound answers here. Fridge magnet: Holds notes or pictures in place on a refrigerator door. Speaker: Uses magnets to move a coil and produce sound. Credit/debit card strip: Stores data on a magnetic strip that can be read by a machine. (Other acceptable answers: electric motors, compasses, magnetic clasps, MRI machines, etc.)

7. Expected: **Ferromagnetic:** Materials that are strongly attracted to magnets and can become temporary magnets themselves.
Diamagnetic: Materials that are not attracted to magnets.
Magnetic poles: The two ends of a magnet (north and south) where the magnetic force is strongest; opposite poles attract, like poles repel.
Paramagnetic: Materials that are weakly attracted to a magnetic field but do not stay magnetized when the field is removed.

8. a. Answer: All metals are not magnetic. The copper coil is diamagnetic and will not respond to the bar magnet. Aluminum is paramagnetic and may be very weakly attracted to a magnet or not respond to a weak magnet at all.
b. Metal detectors use magnets to produce weak electricity inside metals to detect them. This is definitely an advanced discussion.

Activity 2

1. a. Answer: False.
Look for... Only opposite poles of a magnet attract each other. Joining similar poles of a magnet will cause repulsion and the magnets won't stick.
b. Answer: True.
Look for... A magnet's strength weakens with distance.

2. Expect: Typically, magnets will start affecting each other a few centimetres apart. Students should get a bigger distance for stronger magnets.
a. The neodynium and bar magnets are strong magnets
b. The smaller magnets are weaker
c. Look for... Answers might vary as it is a challenge to make precise measurements before the magnets move.

3. Expect: a. Students may have trouble stacking the magnets together because like poles will repel. The magnets would try to shift around so that opposite poles are sticking together.
b. Look for... explaining the attraction/repulsion of magnet poles in the student's own words.

4. a. Repel, b. Attract, c. Repel.

5. a. Answer: It's attraction.
b. Expect: Shows that magnetic forces can pull on certain objects without touching them. The magnet's field extends through the space (distance) between the magnet and the paperclip, causing it to move.

6. a. Expect: Examples: gravity, electric force, friction, normal/contact force, tension, spring force, air resistance, buoyancy, etc.
b. Answer: Yes. Look for... Gravitational force can act on objects at a distance without any physical contact but can only attract objects. Air resistance: pushes against motion through air. Buoyancy: pushes up in liquids or gases.
c. Answer: Yes. Look for... Gravity and electricity can act at a distance.
d. Look for... Everyday examples like: Gravity attracting an apple. Static making hair stand up. Boats float.

Activity 3

1. Expect: Gravitational force and Electric force. These are non-contact forces like the magnetic force where objects don't need to be touching each other to be influenced by the force.

2. a. Answer: True. Magnetic field lines start at the north pole and end at the south pole.
b. Answer: False. Earth's magnetic poles are misaligned with the geographic poles,
c. Answer: True. North pole of a compass needle points to the south magnetic pole of the Earth (close to geographic North).

3. Field lines would come out of the surface of the magnet and loop around to the other side in both cases as opposed to the bar magnet where they go from end to end.

4. The compass needle always points toward the magnet's south pole. Near the north pole, the arrow points directly away; near the south pole, it points straight toward it. If you draw the arrows in several places and connect them, you'll be tracing the magnetic field lines. **Note**: *if a compass has been re-magnetized by being stored near the magnets in the box, the needle will still line up the same way, but it will point in the opposite direction (from south to north).*

5. Answers: a. True, b. True, c. False, d. False.

6. Expect: a. Lack of a magnetic field implies there is no active movement of material in the Moon's interior. It is geologically dead and cannot have things like volcanic activity or lava.
b. Jupiter has a strong magnetic field because its interior is likely made of ferromagnetic material that is moving around.
c. Like the Earth's moon, Mars is geologically dead

Activity 4

1. The Earth's magnetic pole near its geographic North behaves like a south pole.

2. Expect: a. The needle should still point towards the geographic North Pole, still point roughly towards the geographical North Pole. The closer you are to the poles, the less precise this is.
b. Because the poles are slightly misaligned, being at the true geographical North would point towards the magnetic pole close to it, which behaves like a magnetic south pole. If you were to stand on top of the Earth's magnetic south pole, the compass needle may spin around aimlessly.
c. It would still point at the geographic North Pole. It may once again spin around if you stood right on top of the magnetic pole closest to the Earth's geographic South Pole.

3. Answer: No. A needle needs to be magnetized in order to interact with the Earth's magnetic field and point to the North Pole.

4. Expect: a. The cardboard or paper strip helps it float on water without getting wet. If you were to replace the strip with another material, it should be a diamagnetic material that can float on water so

7-12 ANSWER KEY CONTINUED

that it doesn't interfere between the needle and the Earth's magnetic field.
4. b. The needle needs to be unrestrained so that it can move around and align itself to the geographic north/magnetic south pole.

5. Expect: A compass is only useful if not around any other magnet or magnetic material. It won't point in the right direction if another magnet or magnetic material is brought close to it.

6. Look for... GPS would be better when you need exact locations or maps, like finding a specific place in an unfamiliar city .
A compass would be better when you just need to know direction and don't have satellite service or detailed maps, such as hiking in the wilderness on Earth.

7.Answer: No. A compass needs a global magnetic field to align its needle. Without one, the needle wouldn't point in a consistent direction.

8. If the Earth's magnetic poles flipped, then a compass needle would point to the geographic south pole.

Activity 5

1. Expect: The train should move in the direction your right-hand thumb points (as shown in the diagram). If it doesn't, recheck battery and magnet orientation, and that the coil matches the diagram's current direction.
Look for…
Mentions that curling fingers with current gives the field direction; thumb indicates the train's expected motion; notes about troubleshooting if it doesn't match.

2. Answer: When reversing the train, the current changes direction, which flips the magnetic field direction in the coil, so the train will not go through the same end. Placing in the other end, the train will move the other way.
Look for…
Current direction changes ⟶ field direction changes ⟶ motion reverses, explicit use of the right-hand rule.

3. Answer: The train only works when both magnets have the same pole facing outward. That makes the coil's field and the magnets' field line up to push in one direction. Flipping a magnet reverses its field at that end, so the forces fight or cancel and the train stalls.
Look for…
Forces cancel/misalign if flipped, recognition that magnets also act as the battery–coil contacts.

7-12 ANSWER KEY CONTINUED

4. a) Answer: No. Copper is non-magnetic (diamagnetic).

b) Answer: Ferromagnetic metals won't work because the magnet would then stick to them. Paramagnetic metals may work if they are good conductors of electricity.
Look for… Distinguishes conductor vs. ferromagnetic vs. paramagnetic; examples: aluminium works, iron/steel don't.

c) Answer: No. A plastic slinky cannot conduct electricity. It won't create a circuit with the battery and won't push the train along.
Look for… No circuit = no current = no field = no train.

5. Answer: Stronger magnets give a stronger magnetic field at the battery ends, so the interaction with the coil's field is stronger and the push on the train is larger. Weak magnets don't produce enough force, and the train may not move.

6. Answer: The train would go faster because more magnets would produce a stronger magnetic field which would give a stronger push to the train.

7. Answer: The train will usually slow down over time/distance.
Look for…Mentions quick energy drain; ties reduced current to weaker field and lower force; may note a fresh battery holds speed longer.

8. Answer: Expect the train to move faster/with a stronger push, because more current means a stronger magnetic field in the coil.
Look for… More current = stronger field = greater force

9. Look for… A current loop concentrates and directs the magnetic field through its centre (like a compact bar magnet). It provides a strong, focused magnetic field in a small space, which is useful inside astronomical instruments. With coils, it's easy to adjust the current (using dials, switch, or other inputs) changing the intensity of the magnetic field as needed.