# Rainbow Magic

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**Field(s) of Interest:** Optics, Physics, Art

**Brief Overview:**
In this lesson, mentees will learn about properties of light, especially with mirrors: how light can be split into the colors of the rainbow, how we can guide it in certain directions, and how this can be put together for fun practical applications.

**Agenda:**

- Introduction (5 min)
- Module 1: Folsom Prism Blues (10-15 min)
- Module 2: aMAZing Mirrors (10-15 min)
- Module 3: Disco Elysium (15-20 min)
- Conclusion (5 min)

**Main Teaching Goals/Key Terms:**

- visible light spectrum
  - wavelength
- prism
- refraction
  - dispersion
- beam
- direction and angle
- reflection
  - wave
- scattering
- conservation of energy
- symmetry
- mirror image
- pattern

## Background for Mentors

**Module 1**

- visible light spectrum
  - wavelength
- prism
- refraction
  - dispersion

Light is crucial to many parts of our life. In previous lessons this semester, students have explored waves. Light behaves as a wave. Like other waves, light has a **wavelength**, defined as the distance between two consecutive peaks of a wave. Different wavelengths of light correspond to different colors, and the range of wavelengths that humans can perceive is known as the **visible light spectrum**.

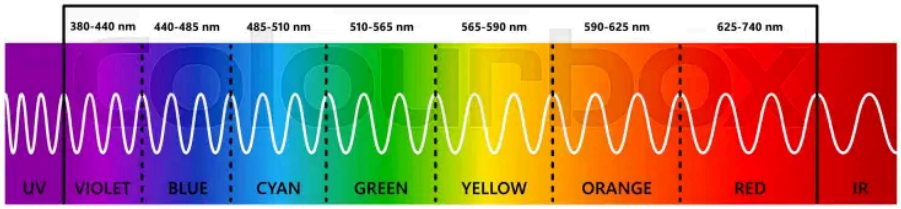



**Figure 1:** Visible Light Spectrum

The visible light spectrum ranges from approximately 380 to 700 nanometers (nm), with violet light having the shortest wavelength and red light having the longest. The sequence of colors is red, orange, yellow, green, blue, indigo, and violet, although the spectrum is continuous rather than divided into seven distinct colors. Visible light is only a small portion of the electromagnetic spectrum, which also includes forms of electromagnetic radiation that humans cannot see. For example, ultraviolet (UV) light and X-rays have shorter wavelengths than visible light, while infrared light, microwaves, and radio waves have longer wavelengths.

Although sunlight and many artificial light sources appear white, white light contains a mixture of wavelengths spanning the visible light spectrum. When these wavelengths reach our eyes together in appropriate proportions, we perceive them as white. However, the different wavelengths can be separated, allowing us to observe the individual colors that make up white light. This is called dispersion.

One way to produce this effect is through a **prism**, typically a transparent object made of glass or plastic with flat, angled surfaces. When light enters a prism, it undergoes **refraction**, meaning it changes direction as it passes from one material into another.



**Figure 2:** Light is refracted through a prism, causing dispersion.

This occurs because light travels at different speeds in different materials. Importantly, the speed of light within a material also depends slightly on its wavelength. **Dispersion** is a wavelength-dependent form of refraction.

As a result, different colors of light refract by different amounts. In a typical glass prism, violet light bends more than red light, causing the initially combined wavelengths to spread apart into a visible spectrum. The angled surfaces of the prism help direct the different colors along separate paths, making the separation easier to observe.

A mirror in water can produce a similar effect to a ‘DIY prism’ because water also refracts light, with different wavelengths bending by slightly different amounts. When light passes between air and water at an angle, the change in speed causes it to change direction. A mirror can reflect the light, redirecting it through the water and toward another water-air boundary. While the mirror itself does not separate the colors, its reflection can position the light so that refraction and dispersion produce a visible rainbow. This is how natural rainbows are formed too, with the back of a water droplet in the sky acting as a mirror.

Refraction describes the bending of light (the mechanism), while dispersion describes the separation of light into different wavelengths (the result). A prism produces dispersion because different wavelengths undergo different amounts of refraction. (Mentees do not need to understand the process of refraction in detail.)

**Module 2**

- beam
- direction and angle
- reflection
  - wave
- scattering
- conservation of energy

As students have explored in previous lessons, light behaves as a wave. More specifically, light is an electromagnetic wave, consisting of oscillating electric and magnetic fields that carry energy through space. Light waves can travel together to form a **beam**, which is a concentrated stream of light traveling primarily in a particular direction. For example, a flashlight produces a beam that directs much of its light forward, rather than distributing it equally in every direction. The **direction** of a beam describes where it is traveling, while its **angle** describes its orientation relative to a reference line or surface. These concepts help us understand how light moves and how we can redirect it.

When light encounters a surface, some of its energy may bounce back in a process called **reflection**. Reflection occurs on many everyday surfaces, including mirrors, aluminum foil, CDs, and other shiny objects. However, the smoothness of a surface influences how light is reflected. Smooth surfaces, such as mirrors, produce *specular reflection*, in which incoming light rays are reflected in predictable directions, allowing clear images to form. Rough surfaces produce *diffuse reflection*, in which light is redirected in many directions because different parts of the surface are oriented differently.

Reflection follows a fundamental principle known as the *law of reflection:* the *angle of incidence* (the angle at which light strikes a surface) equals the *angle of reflection* (the angle at which light bounces away). Both angles are measured relative to an imaginary line perpendicular to the surface, called the *normal*. This principle allows us to predict the path of reflected light and understand how multiple reflective surfaces can redirect a beam.

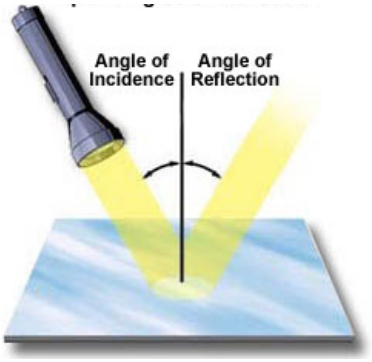



**Figure 1:** The law of reflection.

Although light can travel long distances and be reflected from surfaces, a flashlight beam becomes less intense as it travels farther away. One reason is that light beams spread out over distance, distributing their energy across

a larger area. Another contributing process is **scattering**, which occurs when light interacts with small particles or molecules in a medium, such as dust, water droplets, or molecules in the atmosphere. These interactions redirect some of the light in different directions, reducing the amount that continues along the original path. Scattering also explains familiar phenomena such as the blue appearance of the sky, where shorter wavelengths of sunlight are scattered more strongly by molecules in the atmosphere.

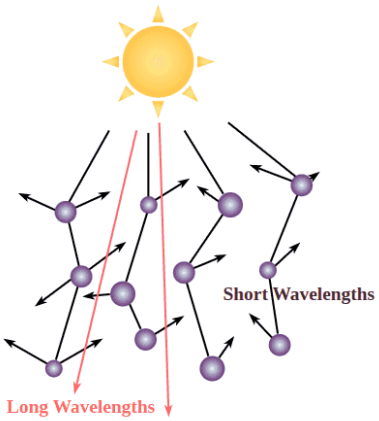



**Figure 2:** Scattering of light, which allows the sky to appear blue (relatively short wavelengths).

Both these processes connect to the **law of conservation of energy**, which states that energy cannot be created or destroyed, only transferred or transformed. Light carries energy, and when it reflects or scatters, that energy is redirected rather than disappearing. Some light energy may also be absorbed by materials and converted into other forms, such as thermal energy (heat). Therefore, even when a beam becomes too faint to see, its original energy has not simply vanished. Instead, the energy has been distributed over a larger area, redirected, or transformed into other forms.

**Module 3**

- symmetry
- mirror image
- pattern

**Symmetry** is a mathematical concept that describes how the parts of an object or shape correspond to one another in a balanced, organized way. One common type is *reflectional symmetry,* in which an object can be divided into two halves that are mirror images of each other. The imaginary line dividing these halves is called the *line of symmetry.* For example, a square has four lines of symmetry, while a rectangle has two. Symmetry is also common in nature, appearing in butterfly wings, leaves, flowers, snowflakes, and even human faces. Although natural objects are rarely perfectly symmetrical, many have structures that are approximately the same on either side. (Another form of symmetry is *rotational symmetry*.)



**Figure 1:** Line of reflectional symmetry in a flower..

A **mirror image** is a reflected version of an object that appears flipped across the plane of the mirror. This is why words can be difficult to read in a mirror: letters and their arrangement appear reversed relative to how we normally view them.

An interesting application of mirror images appears in **chemistry**, particularly in the study of *enantiomers*. Enantiomers are molecules that are mirror images of one another but cannot be perfectly superimposed, meaning they cannot be aligned exactly in three-dimensional space. Our hands provide a useful analogy: the left and right hands are mirror images, but no matter how we rotate them, they cannot be perfectly aligned with the palms facing the same direction. This property is called *chirality*, and it is especially important in biology and medicine because two enantiomers of the same molecule can interact differently with proteins and other structures in the body. As a result, they may produce different biological effects.

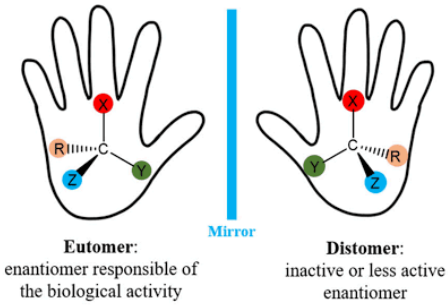



**Figure 2:** Enantiomers in biochemistry.

Symmetry also plays an important role in creating **patterns**. A pattern is an arrangement of shapes, colors, or objects that repeats in a recognizable or predictable way. Patterns can be created through repetition, reflection, rotation, or a combination of these transformations. For example, a checkerboard repeats alternating colors, while a snowflake displays a repeating arrangement of shapes around its center. Patterns are found throughout nature, art, architecture, and mathematics, often incorporating multiple forms of symmetry.

A *kaleidoscope* combines these concepts by using mirrors to produce repeated reflections of objects and colors. When mirrors are arranged at angles to one another, they can reflect images back and forth, creating multiple copies that appear in symmetrical arrangements. These repeated mirror images form intricate geometric patterns, functioning as an *optic toy*.



**Figure 3:** An example of the symmetry through a traditional intricate kaleidoscope.

## Introduction

Light is almost everywhere, and it impacts almost every aspect of our lives. In this lesson, mentees will explore the “fun” of light, splitting it up into different colors and harnessing it to move in certain directions. The goal is to demystify common processes, like how a mirror flips images, why we can see objects from multiple angles, and how rainbows form!

**Concepts to Introduce**

- Reflections are everywhere, not just in household mirrors but also eyes, windows, shiny objects, etc.
- Each object absorbs certain wavelengths of light and reflects certain wavelengths back, causing it to appear a certain color.
    - For example, leaves change color in the fall because trees stop producing a pigment called chlorophyll, and the remaining pigments are better at absorbing green and reflecting back orange.

**Questions to Pique Interest**

- Why are some objects reflective while others aren’t?
- When do you see rainbows? How might they be formed?
- Why is the sky blue?
- Why does the moon glow?

**Scientists, Current and Past Events**

- Isaac Newton demonstrated that a glass prism simply bends and separates the colors of white light with a second inverted prism to recombine the colors back into white light.
- Generally, we know that light affects sleep, but it can also affect mood, cognitive function, and behavior.
    - Blue light is especially effective at suppressing melatonin, the chemical that helps you sleep.
- Physicist Sarah Bohndiek is improving photoacoustic imaging, a technique for imaging using light and sound.
    - She demonstrated how melanin can physically induce image distortion by acting as an optic absorber. Accounting for this is necessary to build medical technology for all skin tones.

**Careers and Applications**

- **Optometrist/Ophthalmologists:** use lenses, mirrors, and light to examine eyes, correct vision, and diagnose eye conditions.
- **Optical engineer:** design mirrors, lasers, cameras, microscopes, telescopes, and more, changing how light travels.
- **Photographer/Filmmaker:** use reflections, angles, colors, etc. to create interesting visual effects.
- **Chemist/pharmacologist:** study how mirror-image molecules (enantiomers) behave differently in the body, particularly in medications.
- **Graphic designer:** use color theory and patterns to create visually appealing designs.

## Module 1: Folsom Prism Blues

Show the whole class how a mirror in water can be used to refract white light and show dispersion. This demonstrates the exact way that rainbows are formed naturally: white light enters water droplets in the sky and refracts because its speed changes, it experiences dispersion because different wavelengths (colors) bend different amounts, and the back of each droplet acts as a mirror, reflecting the light back out so we can see it. In the process, encountering the air-water boundary again refracts the light a second time, causing even more dispersion.

| **Teaching Goals** | **Materials** (per class) |
|---|---|
| 1. **visible light spectrum:** All the colors of light that our eyes can see, from red to violet.<br>2. **wavelength:** The distance between two peaks of a wave, varying for each color.<br>3. **prism:** A clear object that can bend light and separate white light into rainbow colors.<br>a. A mirror in water can act as a prism.<br>4. **refraction:** When light bends as it moves from one material to another, like from air into water.<br>5. **dispersion:** the separation of white light into different colors, i.e. the colors of a rainbow. | • 1 mirror<br>• 1 container<br>• Water (half to three-fourths of the container should be full)<br>• Phone flashlight<br>• White paper |

**Different Methods for Teaching**

1. **Wavelength:** Try drawing out a wave on the board and highlighting the difference between its peaks.
    a. Have the mentees visualize the ocean's waves. The distance from the peak of the first wave to the peak of the second wave would be the wavelength.
2. **Dispersion:** Think of holding a stack of 7 cards. Initially, the stack looks like just one card (white light). When you fan them out, you have moved each of them a slightly different amount, causing them all to be visible at the same time (dispersed rainbow).
3. **Refraction**: If mentees have swam in a pool before, have them consider how different someone looks when they're in vs. outside the pool, especially when viewing from the outside.

**Procedure**

1. **Prepare the container.** Fill the container a bit more than halfway. Place it on a stable, flat surface where spills can be easily cleaned up.
2. **Position the mirror.** Place a small mirror inside the container of water, tilting it against the side of the container at an angle. The mirror can be partially or completely submerged. If it is not stably resting, a mentor should hold it from the corner. The rainbow is easiest to see if the mirror is slightly angled towards a wall.
3. **Turn off the lights** and close the blinds if you can, though this will still work with some light (just look closely!)
4. **Shine the phone flashlight.** Have students shine a flashlight toward the submerged portion of the mirror. Angle the flashlight so that the light passes through the water before reaching the mirror.
5. **Find the rainbow.** Hold a sheet of white paper above or in front of the container, where the reflected light can land. Slowly adjust the angle of the flashlight, mirror, or paper until a rainbow appears. Dimming the room lights may make the colors easier to see.
6. **Observe the colors!** See if mentees can observe all the colors of the rainbow.

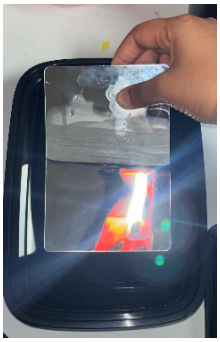


**Figure 1:** *Hold up the mirror in a container more than halfway full of water.*



**Figure 2:** *Check the vicinity for a faint, wavering rainbow (like on the wall).*



**Figure 3:** *Observe the mirror in a dark (left) and bright (right) room.*

**Classroom Notes**

Try this activity with the mirror angled towards a wall, and turn off the lights. If neither are possible, have one mentor hold the mirror all the way in the water, parallel to the desk. When the flashlight shines, the rainbow should reflect directly back up above the container, and can be “caught” with paper. Mentees can crouch down and observe. You can use colored pencils or markers to point out the colors for mentees.

## Module 2: aMAZing Mirrors

Practice and experiment to see how light can be guided to a target using strategic angles. Understanding how light moves is crucial to harnessing it in the real world.

**Teaching Goals**

1. **beam:** A stream of light traveling in one direction, like the light from a flashlight.
2. **direction and angle:** The way something is moving or pointing.
3. **reflection:** When light bounces off a surface, like a mirror.
    a. A *specular reflection* is one in which incoming light rays are reflected in predictable directions, allowing clear images to form.
4. **wave:** the pattern that light travels in, carrying energy.
5. **scattering:** When light spreads out in many different directions after hitting tiny particles, more intensely with short wavelengths.
6. **conservation of energy:** The rule that energy cannot be created or destroyed, only changed into different forms or moved from one place to another.

**Materials** (per group of 4-6)

- 4 binder clips
- 4 sheets of mirror paper
- 1 piece of paper
- Marker
- phone flashlight

**Different Methods for Teaching**

1. **Reflections:** Have 2 mentees pretend to be a reflective and non-reflective surface each. A mentor pretends to shine a beam of light with their arms, which the reflective mentee reflects right back at the appropriate angle, whereas the non-reflective mentee moves their arms in lots of different directions.
2. **Scattering:** If sites have access to a board, then draw a representation.
    a. If not, have mentees imagine themselves walking down a very crowded hallway, changing direction every time they bump into someone, like how light changes direction when bumping into particles.
3. Conservation of Energy: Have mentees think about when they're on a swing. At the top of the swing's arc, they have the same amount of energy as when they're moving fast throughout it, but the energy is changed from potential to kinetic.
    a.

**Procedure**

1. **Form groups** of 4-6 mentees.
2. **Fold a piece of paper** in half along the long end.
3. **Draw any target on each side**, and prop this paper up as shown in figure 1.
4. **Put one binder clip** on the edge of each of the **4 mirror sheets** and prop them up on the desk. (Have mentees try to hold them if desks are unstable.)
5. **Turn off the lights** and close blinds if possible.
    a. This still works with some lights on, but mentees may have to hold a second paper or their hands over the second target to see if light is truly being reflected onto it.
6. **Shine the phone flashlight** toward one of the targets on the paper.
7. Have mentees work together to **use angles to reflect the light** off the 4 mirrors **onto the target** on the other end of the paper.

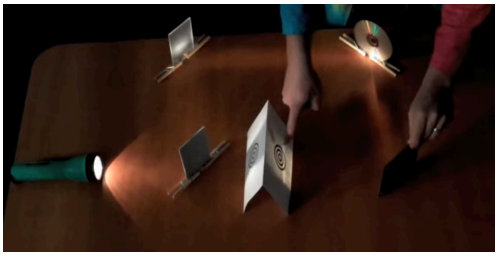


**Figure 1:** *The set-up with mirror paper and binder clips instead of foil and clothespins.*

**Classroom Notes**

If you have more than 5 groups and insufficient flashlights, go around to the groups one by one initially to show them where the light will be coming from, then return only to help them test a hypothesis after they have set up the mirrors.

## Module 3: Disco Elysium

Use what we have learned to create a fun effect with repeating patterns and symmetry, showing the intersection with art.

**Teaching Goals**

1. **symmetry:** When two sides of something match, like the wings of a butterfly. (e.g. faces, shapes)
2. **mirror image:** A reflection of something that looks flipped, like what you see in a mirror.
    a. **e.g. useful vs. unhelpful enantiomers in biochemistry**
3. **pattern:** Something that repeats in a predictable way, like red-blue-red-blue.
    a. e.g. tiling is often filled with patterns.

**Materials** (per mentee)

- 1 bendy straw
- 1 circle of cardstock
- 3 reflective paper strips
- 1 cardboard roll
- Tape
- Markers (to share)

**Different Methods for Teaching**

1. **mirror image:** Have mentees hold up both hands and try to rotate or flip the left hand so it perfectly matches the right. It's impossible because they are mirror images.
    a. You can also use the mirror from module 1 to have volunteers try to read text through the mirror.
2. **symmetry:** Mentors draw half of a picture (e.g. butterfly) on the board or paper. Mentees volunteer to complete the drawing, showing their intuitive understanding of symmetry.

**Procedure**

1. Give each student an **empty toilet paper roll.**
2. Give each mentee **three precut reflective strips** to tape together in a triangular prism.
    a. They are all roughly the same size, but in case one is much bigger, mentors can help cut it down.
3. **Insert the prism** into the cardboard roll. If it is too loose, secure it with a little tape on one of the reflective panels and the end of the cardboard roll.
4. **Cut the top and bottom off of the straw**, retaining the bendy part and a bit of the straight part on either side.
5. **Attach the straw.** Tape the straight segment along the outside of the cardboard tube so

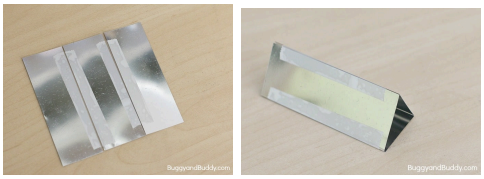


**Figure 1:** Tape together the reflective paper.



**Figure 2:** *Slide it snugly into the roll.*

that the flexible end extends beyond one opening.

6. **Lightly fold the cardstock circle** into fourths and **cut a very small part** of the circle.
    a. If there is a tear or the hole is too big, it can be repaired with tape or held manually outside the kaleidoscope.
7. **Decorate the cardstock circle** with a different design on each fourth. Encourage students to draw colorful shapes, lines, symbols, or other designs on their circle. Ask them to consider how their designs might look when reflected multiple times.
    a. Students can decorate the other side of the circle at the end, if time permits.
8. **Slide the cardstock circle** onto the flexible portion of the straw, with the decorated side facing the inside opening of the kaleidoscope. Make sure the circle is secure but can rotate freely.
    a. If it doesn't work well, the circle can be removed and the mentees should see weird images just viewing the regular world through the kaleidoscopes.
9. **Observe the patterns**. Have students look through the opposite end of the cardboard tube toward the decorated circle in a well-lit area. Encourage them to slowly rotate the circle and observe how the mirrors create repeating, symmetrical patterns.
    a. Positioning the circle so two fourths are partially in view can look cool.
10. If time permits, allow students to decorate the outside of their kaleidoscopes too!




**Figure 3:** Cut the bendy straw.




**Figure 4:** Cut the center of the circle.




.**Figure 5:** Decorate and attach to the kaleidoscope for viewing!



.**Figure 6:** Example of how the pattern may look from the inside.

**Classroom Notes**

Group reflective strips into 3 per mentee in advance. Mentors can help tape them together.

## Conclusion

Light is important in the natural world, but we can also harness it for various purposes. Learning the properties of light and mirrors allow us to build on them and do cool things, like even building solar panels, fiber-optic cables, etc. Science can also be used for fun and art, as shown in the kaleidoscope.

## References


- Lumen Learning Physics Textbook: more on reflections, refraction, and dispersion.
- Optical Toys: This website has more examples of optic toys like kaleidoscopes, combining psychology, light, color, and more.


## Summary Materials Table

| **Material** | **Amount per Site** | **Expected $$** | **Vendor (or online link)** |
|---|---|---|---|
| dishes | 1 per site | $15 | dishes |
| plastic mirrors | 1 per site | $12.49 | mirrors |
| mirror paper | 4 per group | $31.96 | mirror paper |
| binder clips | 4 per group | $12.59 | binder clips |
| toilet paper rolls | 1 per mentee | $95.96 | toilet paper rolls |
| reflective paper strips | 3 per mentee | N/A | cages |
| circle cardstock | 1 per mentee | $39.96 | circle cardstock |
| straws | 1 per mentee | $12.99 | straws |