# Light and Color:

## Laboratory for Primary Level Students

*Student Manual*

WOMEN SUPPORTING
WOMEN IN THE SCIENCES

Meet a Scientist

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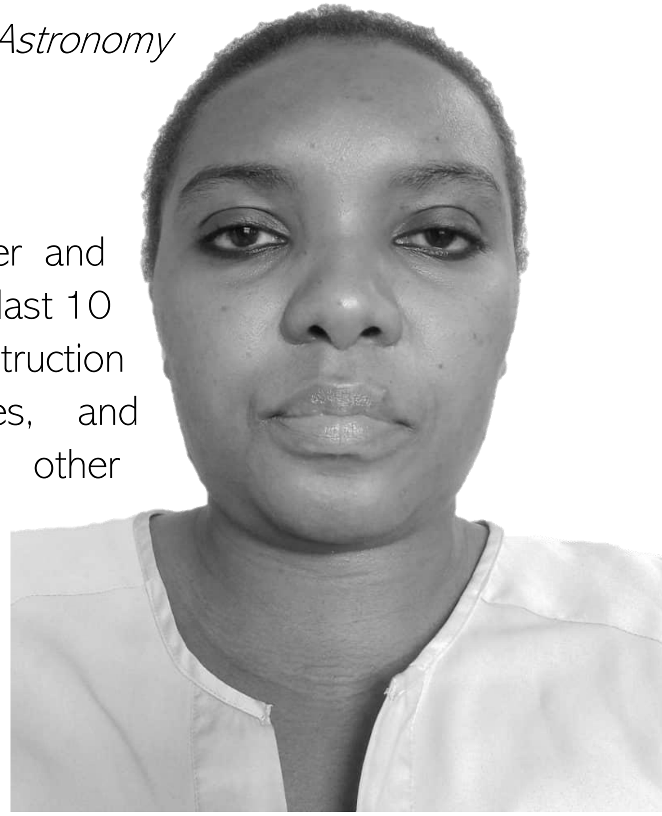


## About me:

I am a civil and structural engineer and professional project manager. In the last 10 years, I have worked in the construction industry, taught applied sciences, and completed research, among other experiences. I am a holder of Master of Science in Civil Engineering from the University of Nottingham. I am motivated, work well under pressure, and I know well how to balance both family and career.

## My advice for students interested in science:

They should explore the world around them, not only sticking to what they learn in books.

## Why should you study science?

Science is challenging, and it arouses the interest to dig deeper. Science is not a subject that stops. Science provides a deeper and more fulfilling way to appreciate the world we live in.

# Mission Statement

This laboratory will teach light and color concepts to a target audience of elementary/primary-aged students (ages ~6-12) through experiments related to how light travels and how light is absorbed, reflected, and transmitted.

# Contents

# 1. Introduction to WS2 Laboratories

## 1.1. Information about WS2

Women Supporting Women in the Sciences (WS2), an international organization unifying and supporting graduate and professional-level women and allies in science, technology, engineering, and mathematics (STEM), was awarded an American Physical Society (APS) Innovation Fund in 2020 to form international teams to design and distribute low-cost physics and materials science lab kits to 5000 primary and secondary school students, predominantly in eastern Africa. The lab kits are intended to utilize local resources and include topics that are especially relevant to young girls in order to spur their interest in STEM subjects. The international teams, which designed the content found in these laboratory manuals, worked with WS2 Partners in eastern Africa in order to successfully deliver and teach the science lab kits to their local communities through 2022. WS2 gratefully acknowledges the hard work of the teams in the creation of this lab kit content. For more information about WS2, please visit our website at ws2global.org.

WS2 is sponsored by the APS Innovation Fund, Northwestern University Materials Research Science and Engineering Center, and Northwestern University Multicultural Student Affairs. WS2 Partners receiving lab kits are representatives from Makerere University (Uganda), Masinde Muliro University of Science and Technology (Kenya), Mbeya University of Science and Technology (Tanzania), Mkwawa University College of Education (Tanzania), Nelson Mandela African Institution for Science and Technology (Tanzania), University of Dar es Salaam (Tanzania), University of Dodoma (Tanzania), and University of Rwanda (Rwanda). The APS, Materials World Modules, SciBridge, and Projekt Inspire have provided valuable input on WS2 lab kit design. WS2 especially thanks WS2 Partner representatives (John Bakayana, Pendo Bigambo, Daudi Mazengo, Lawrence Robert Msalilwa, Celine Omondi, Marcellin Rutegwa), Tom Coon and students of Haile-Manas Academy (Debre Birhan, Ethiopia), and Carla Johnston and students of Frank Bergman Elementary School (Manhattan, KS, USA) for piloting the lab kits with small focus groups in late 2021. WS2 also tremendously thanks the virtual lab kit design team that created the content for this lab manual.

## 1.2. Key Vocabulary

- <u>Light:</u> A type of energy that helps us see (the Sun is an important source of light!); this type of energy can travel in waves ("<u>light waves</u>")
- <u>Transmission:</u> When light travels through an object
- <u>Reflection:</u> When light bounces off an object
- <u>Light Absorption:</u> When light is taken in by objects and converted into energy
- <u>Transparent:</u> See-through; describes an object that lets light pass through so that objects behind it can be distinctly seen
- <u>Opaque:</u> Not see-through; not transparent; describes an object that does not let light pass through so that objects behind it cannot be distinctly seen

## 1.3. Key Questions

- What happens when light is blocked? What are some examples of light being blocked in your life? How do you change this so that light can instead pass through?

- Why are many plants and leaves green? Why are some flowers red, yellow or orange?

## 1.4. Purpose

In this lab, students will learn what light is and how it travels. Light is important because it helps us to see and is responsible for the different colors we see. Light, mostly from the Sun, is also the main source of energy for most living things.

# 2. Background on Main Topics

## 2.1. Light and Color

Humans have always needed light. Our ancestors, who survived by foraging, hunting, and farming for their food, scheduled their days around the Sun. Back then, without light from the Sun, they could not see anything! Our dependence on light has led to the discovery of light sources other than the Sun. This began when we created light by making fire from wood, oil, and gas. As time went on, other light sources such as incandescent light bulbs, neon lights, lasers, and more complicated lights, like light-emitting diodes, were invented. With the invention of artificial (this means made by humans) light sources, humans could extend our days into the night. Besides humans needing light to see, plants need light because light is their energy source for something called photosynthesis, which is the way plants produce their own energy or "food". Plants are very important, because they also produce the oxygen that we need to breathe. Humans and plants live in a shared world that depends on both living and nonliving things. The shared world is also called an ecosystem.

Light is essential for our lives, so it is important for us to understand the basics of how we see light and color! <u>Light</u> is a type of energy that is made up of different lengths of light waves. These <u>light waves</u> travel through space to get to us. Certain light waves are called visible light waves and humans can see them with their eyes. Colors, like red, orange, and green, that we see come from visible light.

When visible light waves hit an object, they are either transmitted through, absorbed by, or reflected off the object. Transmission means that light can travel through an object, like in Figure 1 (right). Reflection means that light bounces off an object and sometimes hits our eye, helping us to see an object and its color like in Figure 1 (left). Light absorption means light is taken in by objects and is converted into energy like in Figure 1 (middle). Depending on which of these happen when light hits an object will change what we see, including colors we see! You can see examples of these processes in the picture below. If an object allows light to pass through it easily so that you can see through it, this object is transparent. If an object cannot be seen through, this object is opaque, and light cannot easily pass through it.

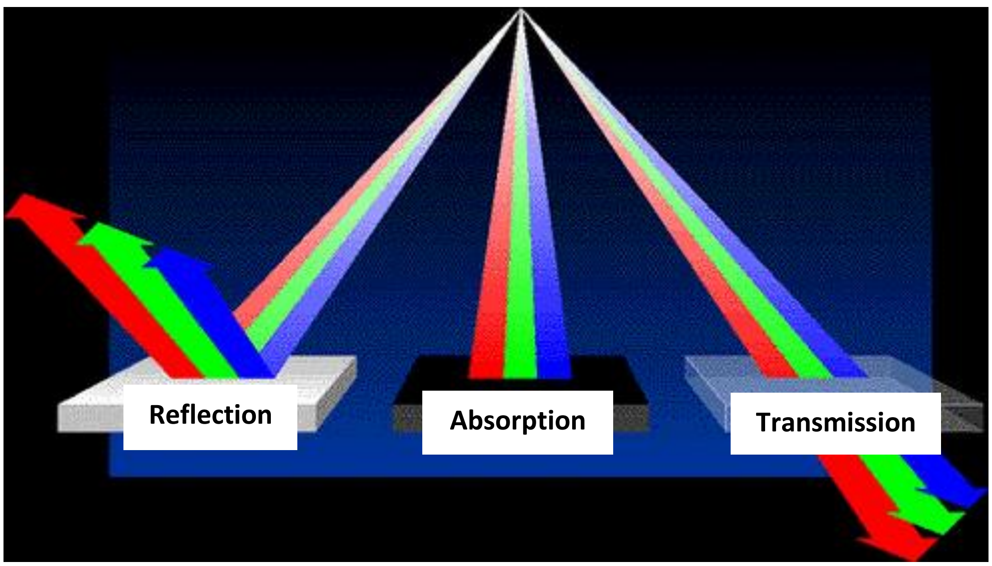



Figure 1. Examples of reflection (left), absorption (middle), and transmission (right) of light waves. The direction of the light is represented by the blue, green, and red arrows. Source: maggiesscienceconnection.weebly.com

## 2.2. Supplies List

- Light sources (sunlight, fluorescent bulbs, candles, etc.)
- Straws or hollow tubes of any kind or color
- Thread or string
- Cardboard
- Clear plastic (binder sheet or other piece of plastic)
- Pencil
- Scissors
- Water

- Spray bottle
- Fabric of various colors (T-shirts or other fabric): white, black, blue, red, yellow
- Ruler (optional)
- Flashlight (optional)

## 2.3. Safety Information

Before the students begin the laboratory, please take into consideration the following safety concerns:

- Students should never look directly at the Sun. This can permanently damage their eyes. If you are using the Sun as a light source, have the students look at a sunny spot on the ground or at the horizon away from the direction of the Sun.
- The students need to be careful when working with candles. Since they are a fire hazard, the table should be cleared of all objects when performing the experiment.

# 3. Experiments

## 3.1. Part I. Propagation of Light

### 3.1.1. *Pre-Experiment Questions*

1. What are some examples of light sources?

2. How does light travel?

3. What parts of life need light? How can you tell those things need light?

## 3.1.2. *Materials*

- Straws or tubes
- Source of light (indirect sunlight, lamp)

## 3.1.3. *Procedure*

1. Take one straw or tube and hold it up to your eye. **Do not point the straw directly at the Sun!! This will damage your eyes.**
2. Look through the straw at objects around you.
3. Record with words or drawings what you see.
4. Bend the straw once.
5. Repeat steps 2. and 3.
6. Bend the straw once more so that the straw is now bent twice.
7. Repeat steps 2. and 3.

## 3.1.4. *Results*

| What I see through the straw | What I see through the straw bent once | What I see through the straw bent twice |
|---|---|---|
| | | |

## 3.1.5. *Post-Experiment Questions*

1. When you first looked through the unbent straw, could you see objects and light? What does this mean?

2. When you bent the straw once, could you see objects and light? What about when you bent the straw twice? Compare the objects and light you saw before and after bending the straw.

3. What does this experiment show you about how light travels?

4. Can you guess how can plants adapt to low light conditions?

5. Extension: Plants are amazing! Have you ever noticed the behavior of clovers? They actually "open up" so more of their leaves can reach the light. Other plants actually can tilt and bend towards the light to get more sunlight. This behavior is called tropism. Tropism is a change in the direction of a plant's

growth in response to something outside the plant, like sunlight or water. Phototropism is when the plant growth changes direction due to light, usually from the Sun. There is a picture of phototropism in a houseplant (called the false shamrock) below in Figure 2! Look at how the leaves change between day and night. Can you guess how the false shamrock's leaves would change if the day was sunny? What if the day was rainy and cloudy?


Figure 2. The false shamrock during the day (left) and at night (right). See how the shape of the leaves change?

## 3.2. Part IIa. Opaque Materials

### 3.2.1. *Materials*

- 3 pieces of cardboard (or thick paper or non-transparent plastic that can be cut)
- Pencil
- Thread or string
- Source of light (candle or lamp)
- Scissors
- Ruler (optional)

- Flashlight (optional)

## 3.2.2. *Procedure (work in groups of 3-4)*

1. If not already done, cut your cardboard into three pieces that are the same size.
2. Using a piece of string, measure the length about halfway up the height of the cardboard pieces. This means that the same amount of cardboard is above the length of the string as the distance that the string covers.
3. Next, either make a mark on the string at this distance or cut the string using scissors. You will use this length of string to align the holes you will cut in the cardboard.
4. Use your pencil and string to mark where you will cut a hole on each cardboard piece.
5. Carefully use your scissors to cut 1 small hole in each of the 3 cardboard pieces. The holes should be large enough to see through (~2 cm wide).
6. Arrange the three pieces of cardboard so that all the holes at the center are in a straight line. This can be done by using a piece of string that you may pass straight through the holes of the cardboard pieces. Work with your team to hold up the string or pieces of cardboard.
7. Place a light (candle, lamp, or flashlight) at one end of the set up as shown in the diagram.
8. Look through the holes in the cardboard at the opposite end of the light.
9. Now, move the cardboard pieces slightly to prevent the person looking through the holes from seeing the light.
10. Take turns so that each team member gets to view the light through the cardboard pieces (steps 6-9).

Experimental set-up for Part II is shown in Figure 3.

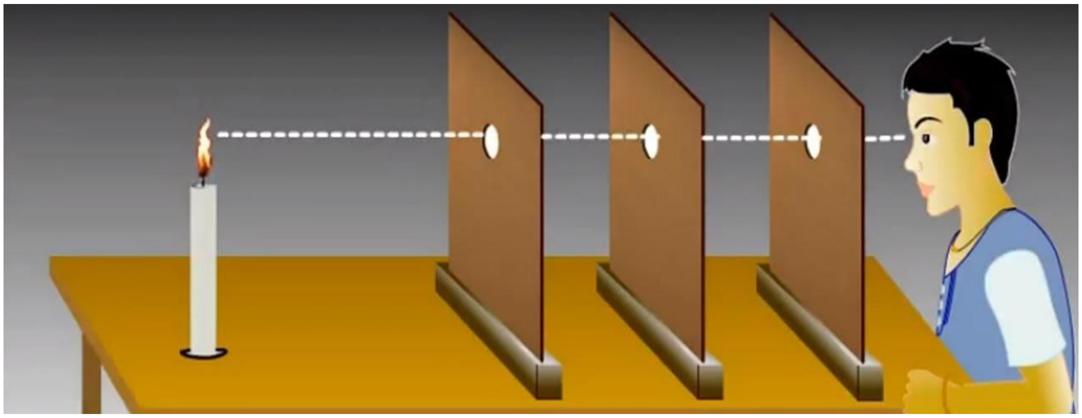


Figure 3. Experimental set-up for Part II. Try to align the holes in your cardboard!

### 3.2.3. *Post-Experiment Questions*

1. What do you see when the holes in the cardboard are aligned?

2. What do you need to do to prevent light from traveling though the holes? How many ways can you set up the cardboard pieces to achieve this?

3. When we can't see light through objects, we call them opaque. What are some uses of opaque materials? What do you use opaque materials for in your life?

# 3.3. Part IIb. Transparent Materials

## 3.3.1. *Materials*

- 3 pieces of clear plastic (binder sheets)
- Pencil
- Thread
- Source of light (flashlight, candle, lamp)

## 3.3.2. *Procedure (work in groups of 3-4)*

1. If not already done, cut your plastic into three pieces that are the same size.
2. Using a piece of string, measure the length about halfway up the height of the plastic sheets. This means that the same amount of plastic sheet is above the length of the string as the distance that the string covers.
3. Next, either make a mark on the string at this distance or cut the string using scissors. You will use this length of string to align the holes you will cut in the sheets.
4. Use your pencil and string to mark where you will cut a hole on each sheet.
5. Carefully use your scissors to cut 1 small hole in each of the 3 plastic sheets. The holes should be large enough to see through (~1-2 cm wide).
6. Arrange the three plastic sheets so that all the holes at the center are in a straight line. This can be done by using a piece of string that you may pass straight through the holes of the sheets. Work with your team to hold up the string or plastic sheets.
7. Place a light (candle, lamp, or flashlight) at one end of the three sheets.
8. Look through the holes in the sheets at the opposite end of the light.
9. Now, move the plastic pieces slightly to prevent the person looking through the holes from seeing the light.
10. Take turns so that each team member gets to view the light through the plastic pieces (steps 6-9).

### 3.3.3. *Post-Experiment Questions*

1. What do you see when the holes in the plastic sheets are aligned?

2. What do you see when you misalign the holes in the sheets?

3. What is the difference between this experiment with cardboard and plastic sheets?

4. When we can see light through a material, we call it transparent. What is the advantage of transparent materials?

5. What are some examples of what you would use transparent materials for?

## 3.4. Part IIIa. Rainbow in a Bottle

### 3.4.1. *Pre-Demonstration Questions*

1. Does light have color?

2. When have you seen the colors of light?

### 3.4.2. *Materials*

- Sunlight
- Spray bottle
- Water

### 3.4.3. *Procedure (demonstration by teacher)*

1. Fill a spray bottle with water.
2. Find a space outside where you are in direct sunlight.
3. Spray water a few times in the sunlight and watch the sprayed water.

### 3.4.4. *Post-Demonstration Questions*

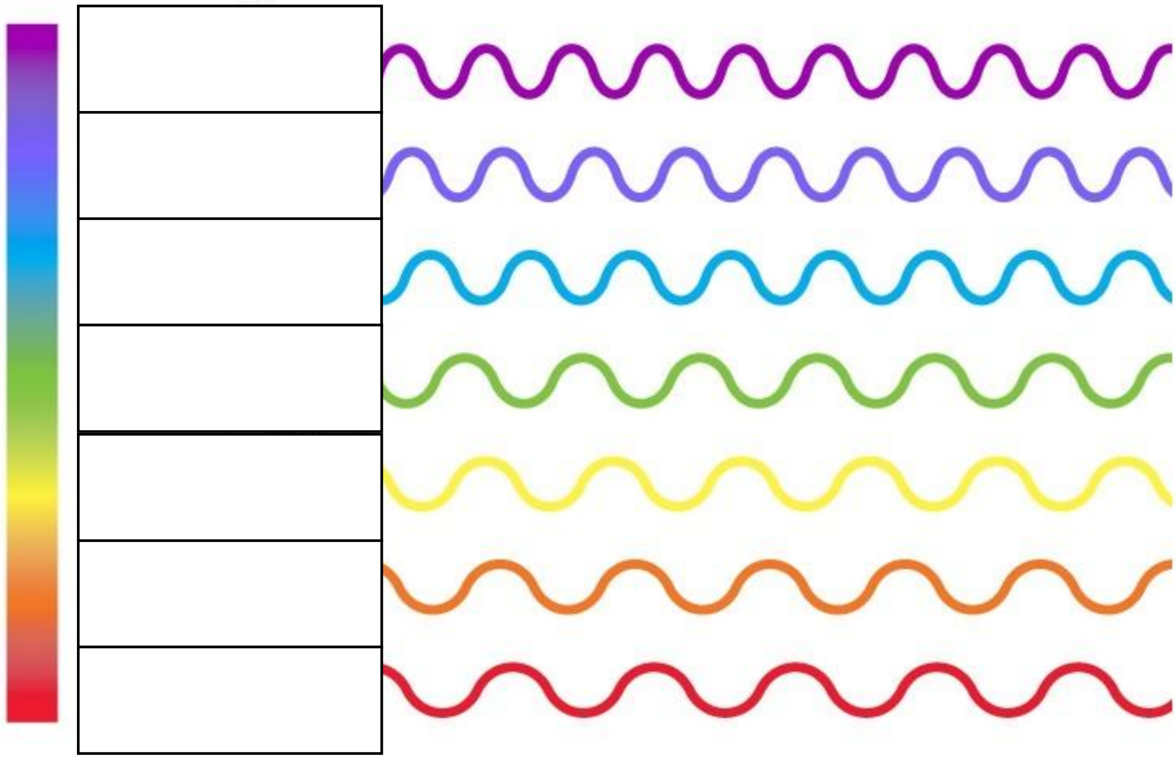
1. When water is sprayed in the sunlight, what do you see?

2. If you see colors, how many colors do you see?

3. What are some other examples of when you see a rainbow of light?

4. <u>Extension:</u> The colors of light that you identified in your rainbow are all in visible light from the Sun. These seven colors are sometimes remembered with the letters ROY G BIV, and these colors are often placed on lines or in a circle, sometimes called a color wheel. Now that you know the seven colors in the rainbow, try labelling them on the color wheel and color line below (in the white rectangles).

Source: Pinterest





Source: sciencelearn.org.nz

Remember that light travels in waves? The length of the wave of visible light is specific to the color. See how the red wave looks more stretched out than the purple wave? The color red is a type of light that has a longer wave than purple. If you combine all of the colors on this color line, you end up with white light. Sunlight contains all of the colors of the rainbow!

## 3.5. Part IIIb. Light Absorption

### 3.5.1. *Materials*

- Black fabric (or clothes)
- While fabric (or clothes)
- Other fabric colors (optional)

## 3.5.2. *Procedure (work in groups of 3-4)*

1. Gather black, white, and other colored fabrics. Write the colors of each fabric in the data table found below in Results.
2. Note the temperature of each fabric (hot, cold, warm) by how it feels to your touch in the data table.
3. Make your predictions in the data table for the fabric that will heat up the fastest in the sunlight and the slowest in the sunlight. This guess as to what you think will happen is called your hypothesis!
4. Lay the fabrics out in the sunlight.
5. After ~30 minutes check the temperature of the fabric by touching each with your hands. Record your results in the data table.

## 3.5.3. *Results*

| Material Color | Starting temperature (cold, cool, warm, or hot) | Prediction of how fast each material will heat (fast, medium, or slow) | Ending temperature (cold, cool, warm, hot, super-hot!) |
|---|---|---|---|
| #1 | | | |
| #2 | | | |
| #3 | | | |

| | | | |
|---|---|---|---|
| #4 | | | |
| #5 | | | |

## 3.5.4. *Post-Experiment Questions*

1. Which fabric color became the hottest?

2. Why do you think some fabrics became hotter than others?

3. Do you notice this effect in your everyday life? What are some examples?

4. How could you use this information to decide what to wear on a hot and sunny day?

5. Pick a colored fabric (not black or white). What color is being absorbed and what color is being reflected? Remember what your eye sees is the color that is bouncing off of the fabric.

6. Extension: Can you guess why the sky is blue?

# 4. Design Challenge

The Challenge: It is time to design your future home! Your task now is to pick out the materials you will use for your home. Think about all you have learned about light and color, as well as reflection and absorption, when you answer the following questions. This challenge can either be done by simply thinking about your future home and drawing it or, if you have the supplies nearby, you could actually build a mini model of your future home.

## 4.1 Design Questions

1. If you were going to build a house today, what materials would you use for your windows?

2. Where do you want your windows to be to let in light throughout the day? Will these windows make it hot inside? Will they make it cold? What could you do to help keep the inside of your house comfortable all year?

3. What materials would you use for your walls? Why do you want to use these materials?

4. What materials would you use for the roof? Why do you want to use these materials?

5. Now, there is no electricity in your house and your only source of light is the Sun. But, you have a magic window that can move in any direction throughout the day! Where would you move your window in the house throughout the day? Sketch this idea out.

## 4.2 Design Sketch or Prototype

Try out your design by sketching it on paper and coloring it in with markers, pens, pencils, and crayons. You can also make a small model of your future home using pieces of cardboard and plastic as opaque and transparent materials. Be creative and use what supplies you have!

My future home:

# 5. Sources

Mason, Betsy. A Brief History of Light. Wired, https://www.wired.com/2008/12/gallery-lights/.

Reflection, Absorption & Transmission. Maggie's Science Connection, https://maggiesscienceconnection.weebly.com/reflection-absorption--transmission.html.