**Physics 246 Laboratory**
**George Mason University**

**Ray Tracing and Light[1]**

**Learning Goals:**

- Learn to differentiate convergent and divergent light rays
- Determine what kind of lens and mirrors produce convergent and divergent light rays through direct experimentation.
- Determine how colored light affects our ability to interpret colored writing. Hypothesize why this is the case.
- Determine how colored light combines and white light separates into constituent parts.

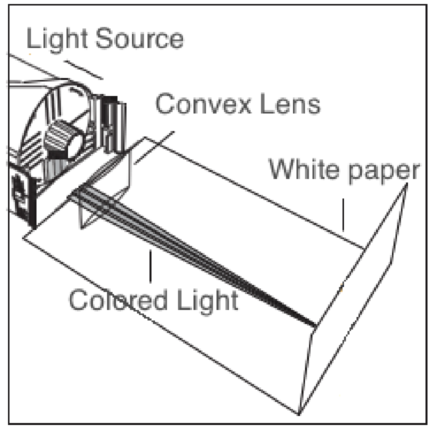
**Motivation:**
All branches of science depend upon the understanding of light in many ways. Of particular interest to those using microscopes or telescopes of varying types is the understanding of geometric ray tracing. Ray tracing visualizes light as rays traveling outward from a source in straight lines as shown in the sky image above. Ray tracing is also used to determine how rays travel through different materials and reflect off of surfaces.
Also of interest to scientist when viewing light is knowledge about how the eye interprets colored light, what does it mean for an object to be a specific color? What is true about our ability to discern colored images using various collected light? Of particular interest then, is an understanding about how colored light combines into new colors, and how white light is broken down into constituent parts. Also, how light reflects off of surfaces and to our eyes.
This laboratory is a discovery lab and therefore no predictive equations are provided, instead students will be asked to complete particular mini-labs and report on the group's findings. Hypotheses will be made by the group about the phenomena examined and these results and hypotheses turned in as a group at the end of the lab session. If any topic is researched online – this should be done AFTER hypotheses and comments made about whether the original hypotheses demonstrated accepting understanding of the concept.

## <u>Experiment 1: Colored Light Mixing</u>

In this mini-experiment groups will discover how light mixes and the basic use of a convex lens.

[1] This lab, both written and visual content is adapted from the Pasco manual on Geometric Optics. Sun image above came from: gswumc.com

1. Turn the wheel on the light source to select the red, green, and blue color bars. Fold a blank, white sheet of paper, as shown in right hand figure. Lay the paper on a flat surface and put the light source on it so that the colored rays are projected along the horizontal part of the paper and onto the vertical part.




2. Place the convex lens near the ray box so it focuses the rays and causes them to cross at the vertical part of the paper.

*Note: The lens has one flat edge. Place the flat edge on the paper so the lens stands stably without rocking.*

3. What is the resulting color where the three colors come together? Record your observation in a table as shown.

4. Now block the green ray with a pencil. What color results from adding red and blue light? Record the result.

**Table 1.1: Combination of colors**

| Colors Added | Resulting Color |
|---|---|
| red + blue + green | |
| red + blue | |
| red + green | |
| green + blue | |

5. Block each color in succession to see the addition of the other two colors and complete the table above

6. Did you find that mixing colored light is the same as mixing colored paint? Why or why not? Explain.

7. White light is said to be the mixture of all colors. In this experiment, did mixing red, green, and blue light result in white? Explain.

## Experiment 2: Observing Colored Ink Under Colored Light

Setup the experiment before starting so that all group members help. Cover the red and green light bars so the only light is the *blue* light. (This can be done by taking a small piece of folded paper and putting it up against the desired blocked colors, if needed a small bit of tape can be used.)

While you look away, have a group member draw two lines—one red and one black—on a sheet of white paper. One of the lines should be labeled A, and the other B, but <u>you should not know which is which</u>. Once this is done – have the room lights turned OFF , turn off the computer monitor at your station, and cover the white light coming from the top of the light source before allowing your group member/s to view the paper.

Now the group member/s that had their eyes covered, look at the paper that has been placed in front of the colored light.

1. What colors do the two lines appear to be?

2. Do they appear to be different colors? Record your observations in Table 1.2.

3. Finally, observe the lines under white light and record their actual colors in Table 1.2.

4. Repeat the observation, but this time have your partner draw lines using blue and black ink (labeled C and D), and observe them under *red* light. Answer questions on the following page about the *red* light.

5. Finally, switch roles and repeat observations 1 and 2 with your partner observing lines that you have drawn. Record the results in Table 1.2. (For this trial, you may try to trick your partner by drawing both lines the same color—both red or both black, for instance.)

**Table 1.2: Colored Ink Observed Under Colored Light**

**Trial 1:** Name of observer: ________________________________

| Color of Light | Line | Apparent Color of Ink | Do they look different? | Actual Color of Ink |
|---|---|---|---|---|
| Blue Light | A | | | |
| | B | | | |
| Red Light | C | | | |
| | D | | | |

**Trial 2:** Name of observer: ________________________________

| Color of Light | Line | Apparent Color of Ink | Do they look different? | Actual Color of Ink |
|---|---|---|---|---|
| Blue Light | A | | | |
| | B | | | |
| Red Light | C | | | |
| | D | | | |

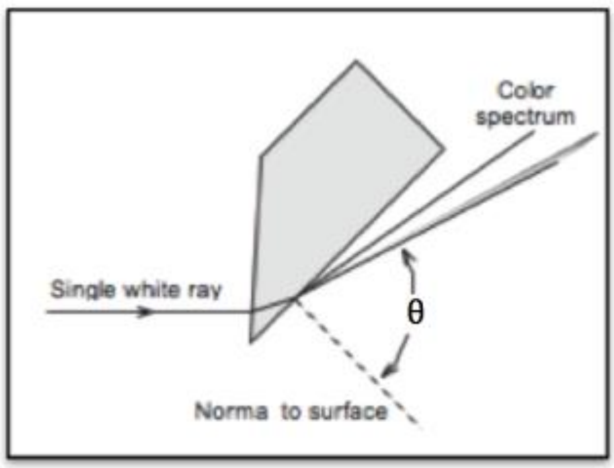
**1.** Look at red and black lines under red light. Which line is easier to see?

**2.** What makes red ink appear red? When red ink is illumined by blue light, is most of the light absorbed or reflected?

**3.** When illumined with red light, why is red ink on white paper more difficult to see than black ink?

## Experiment 3: Color Separation by a Prism

For this experiment white light will be separated into constituent colors by a prism. Your group must hypothesize why this occurs thinking about what is really changing about the light when it enters the plexiglass trapezoid.




1. Place the light source in ray-box mode on a sheet of blank white paper. Turn the wheel to select a single white ray.

2. Position the trapezoid as shown in the figure. The acute-angled end of the trapezoid is used as a prism in this experiment. Keep the ray near the point of the trapezoid for maximum transmission of the light.

3. Rotate the trapezoid until the angle (θ) of the emerging ray is as large as possible and the ray separates into colors.

   *(a)* What colors do you see? In what order are they?
   *(b)* Mark the exit of RED, GREEN, and BLUE light.

4. Without repositioning the light source or the trapezoid, turn the wheel on the light to select the three primary color rays. The colored rays should enter the trapezoid at the same angle that the white ray did. Do the colored rays emerge from the trapezoid parallel to each other?

5. Do the individual colored light rays exit at the same angle as the white light constituent of the same color did? Comment.

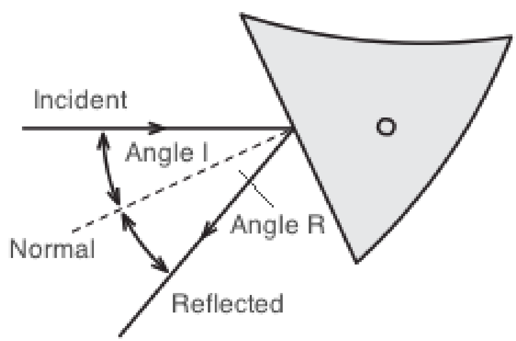
**Experiment 4: Reflection of Light**

1. Turn the wheel of the light box to select a single ray.

2. Place the mirror on the paper. Position the plane (flat) surface of the mirror in the path of the incident ray at an angle that allows you to clearly see the incident and reflected rays.

3. On the paper, trace and label the surface of the plane mirror and the incident and reflected rays. Indicate the incoming and the outgoing rays with arrows in the appropriate directions.

4. Remove the light source and mirror from the paper. On the paper, draw the normal to the surface as shown below.




5. Measure the angle of incidence and the angle of reflection. Measure these angles from the normal. Record the angles in the first row Table below.

6. Repeat steps 1–5 with a different angle of incidence for a total of 3 measurements at 3 different angles.

7. What do you notice about the angles? Explain.

8. Place the light source over the normal of the flat mirror. Describe what happens to the rays. Does this make sense with what you experience with a flat mirror in your everyday life? Comment.

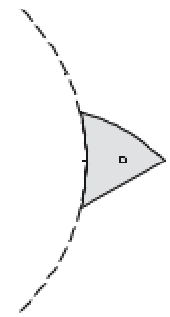
**Plane (Flat) Mirror Results**

| Angle of Incidence | Angle of Reflection |
|---|---|
| | |
| | |
| | |

9. Turn the wheel on the light source to select the three primary color rays. Shine the colored rays at an angle to the plane mirror. Mark the position of the surface of the plane mirror and trace the incident and reflected rays. Indicate the colors of

the incoming and the outgoing rays and mark them with arrows in the appropriate directions.

10. What is the relationship between the angles of incidence and reflection for the colored rays? How do they compare to the white light experiment above? Comment.



11. Are the three colored rays reversed left-to-right by the plane mirror? Does this compare to the prism in some way or not? Explain group hypothesis.

12. Now – turn the mirror to the concave side as shown in the figure. Lay a sheet of paper used to trace out the flat mirror angle tracing.

13. Can you move the concave mirror using a single ray trace such that the angles of incident and reflection are the same as the flat mirror?

14. What is true about the location that the light ray hits the concave mirrored surface?

15. Now, change the light rays from 1 to 3 rays. What happens to the light rays after reflecting off of the mirrored surface? Be clear and comment how the rays appear before and after hitting the mirrored surface.

16. Now, repeat this for the flat-mirrored surface. Can your group hypothesize why a difference in ray tracings exist for these two mirrored surfaces?

17. Finally, repeat 13-16 for the convex side of the mirrored surface and comment on the ray tracings.

## <u>**Experiment 5: Putting Convergent-Divergent Lens/Mirrored Surfaces Together**</u>

18. In many optical devices as you will see in coming labs – multiple mirrors or lenses are used. Have your group try to construct a combination of lenses and mirrored surface that show 3+ light rays undergoing convergent and divergent light.

19. Take a picture with your cell phone and include in your report (you will likely have to upload to Blackboard for your instructor to view). Describe where the light is parallel – where it is convergent – and where it diverges in text within your report.