RET Classroom Application 2020

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Introduction

The interaction of light with matter has a massive impact on our daily lives. Darkness, color, and reflection are aspects of light/matter interaction that are obvious to everyone, but other aspects, such as absorption and emission might not be so clear. These two lab activities will help you see some of the ways that light interacts with matter on a microscopic level, and how that helps the light behave on the macroscopic level.

In the first activity, you will make a hypothesis of how **white light** interacts through different color filters. You will test your hypothesis with different colored filters absorbing and transmitting different colored lights. Next, you will see the world as if it were only colored by one color of light, and how that impacts how we view objects.

In the second activity, you will explore the phenomenon of **fluorescence**, or how some chemicals can give off one kind of light when exposed to another kind of light. You may be familiar with some examples, such as glow-in-the-dark toys and the glow of white clothing under blacklights at dance parties or bowling alleys. You will explore how, using this same principle, water can be made safe to drink and secret messages can be written.

In your lab journal, you will record your observations, and will **explain and communicate** that information. Look for patterns and cause-and-effect in the observations you make.

Activity #1—Playing with Color

Introduction

Color is such an integral, important part of our lives, that we take it for granted. But what is color? How do the objects around us get the colors they have? In this activity, we will explore how light can travel, and how different objects can absorb, transmit, and reflect light.

Recall that light travels incredibly quickly and in a straight line. Some objects, such as clean windows, are **transparent** to visible light and allow the light to pass through. These objects are said to **transmit** light. Air is another example—clean air transmits light. A frosted window will transmit some light but will **absorb** or **reflect** some light. These objects are referred to as **translucent,** only allowing some light through. Closing a shutter or blinds will prevent any light from transmitting. The blinds are said to be **opaque** and reflect or absorb all light. So how do we know how much is absorbed or reflected?

Figure 1 The red skin of the apple absorbs purple and green light and reflects red light, making the apple appear red.

When we look at a shiny red apple sitting on a table, we know through experience that the apple is not transparent or translucent—we cannot see the table behind the apple, after all. The apple is not transmitting any light from the table. All the light is either being absorbed or reflected by the apple.

The skin of the apple is a deep red because it **reflects to our eyes** light with a wavelength that falls into the “red light” area of the electromagnetic spectrum. Cells in our eyes pick up these wavelengths and tell our brains, “that apple is red.” The apple absorbs all light that that is not red—specifically blue and green light. Since no blue or green light is reflected to our eyes, our brains do not see those colors.

In this activity, we are going to use different **translucent** filters to see what colors are absorbed, transmitted, and reflected by different objects.

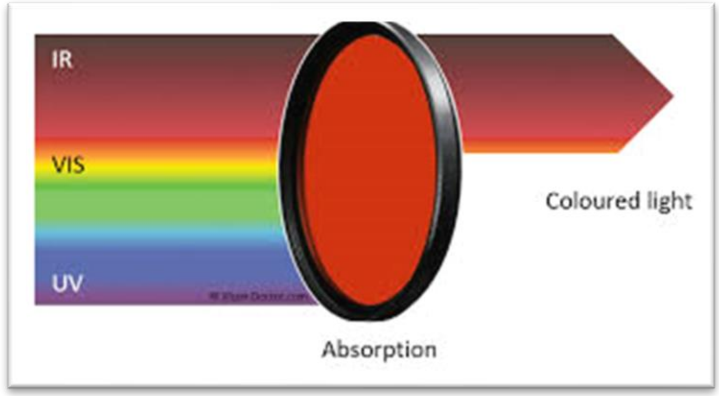

Figure 2 LED photography lights can provide clean blue, green, or red light to a dark lab or classroom; Color filters can absorb or stop different color lights, allowing only specific colors through.

Activity

1. Before you start collecting data with the filters, make predictions of what color the objects will appear. In your lab notebook, or on your Lab Worksheet, complete Data Table 1 on how you predict different objects will appear when viewed through different filters. It may help to imagine you are looking at the world through colored sunglasses. What color would a red object appear if you viewed it through blue sunglasses, for example.
2. Discuss with your lab group or your teacher your predictions. **Why** did you predict the way you did?
3. Take a blue, red, yellow, green, and purple filter and look through them at the different objects (this works best in a very well-lit area. You may want to go outside if your teacher allows you to.) Record in Data Table 2 the colors that those objects appear. Remember, you can include black and white in your observations.
4. Once you have completed these tables, you are prepared to answer **discussion questions 1 and 3.** Answer those questions in your lab notebook or on your Lab Worksheet.

Next, we will explore a similar phenomenon. How does the color of light that shines on an object affect its color?

5. Return to the classroom, and your teacher will introduce special lights that provide only a certain color of light. They might shine blue light, red light, green light, or any combination of those lights on an object. How will the light be reflected or absorbed by those objects? Once again, work with your lab group and make predictions on Data Table 3. The columns of Data Table 3 represent the color of light shining on the objects, and the rows represent the color of the object under normal circumstances.
6. Once you are ready, your teacher will turn off the classroom lights and use the special lights to shine light on the objects. Working with your group, record your observations on Data Table 4. What colors do the objects appear under those colors?
   With that data table complete, you are prepared to answer **discussion questions 2, 4, and 5.** Working with your group, answer those discussion questions in your lab notebook or on the Lab Worksheet.

Discussion

1. What patterns are present with white objects and black objects in Data Tables 1 and 2?
2. Does this pattern continue with different colored light in Data Tables 3 and 4?
3. What filters could I use to view a purple object and not have it appear black?
4. Children often draw a picture of the sun as yellow with yellow light rays coming from it. What color is the light from the sun? What colors would we **not** be able to see if the sun's light really were only yellow?
5. If I shine blue light on a yellow object, what color does the yellow object appear?

Activity #2—Playing with Fluorescence

Introduction

What is fluorescence? When most people hear the word, they usually think of the long, cylindrical light bulbs that require opening the windows if they break. While this is a common use of fluorescence, it is certainly not comprehensive. All sorts of matter demonstrate fluorescence under certain circumstances. For instance, look at Figure 3. The medication quinine, which is dissolved with the carbon dioxide and sugar in tonic water, and what gives tonic water its bitter taste, can fluoresce when under a certain wavelength of light.

Figure 1: Tonic water, often mixed in cocktails and other drinks, contains a chemical that fluoresces.

Perhaps you have also done “blacklight bowling” or gone to a party with a blacklight and seen how white socks and shoes glow a deep blue, while other colors remain dark. How does this work?

A blacklight is not “black” light—as we learned above, “black” is the absence of light, so “black light” is somewhat oxymoronic. The word “blacklight” is used to mean a lightbulb that emits ultraviolet, or UV, light. Most ultraviolet light from a blacklight is invisible—we cannot see it because its waves are so short. But some we can see as purple or blue light.

Fluorescent materials can absorb energetic light, like UV light. This causes an electron in the materials’ atoms to jump to another energy level. When those electrons return to the original, or ground, state they release that light as another wavelength of light. This corresponds to the color of light that is emitted. For example, in the example of Figure 4, the atoms in the girl’s face paint absorb high energy UV light. The electrons in those atoms jump from a lower energy state to a higher energy state. When those electrons return to the ground state, that energy is released as light energy. In this case, that light energy has a wavelength that corresponds to yellow light.

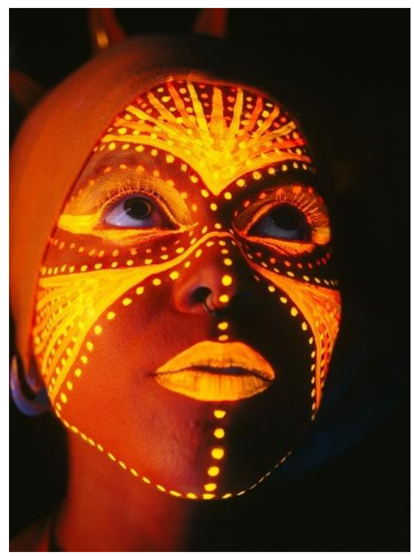

Figure 2 This girl has face paint that glows under a black light. The black light is ultraviolet light.

Another application of UV light is its effects on living organisms. Many of us have felt the sting—literally—of forgetting to apply sunscreen and getting a sunburn. Some of us enjoy using tanning beds to achieve a golden tan. Both applications deal with the interaction of UV sunlight on our skin cells. Another application is using a UV light sterilization pen. These devices clean water by using a UV Lamp to disrupt the DNA of harmful microbes in water, making the microbes unable to reproduce and making the water safe to drink. In the activity, students will read about how these devices work.

Activity

1. Begin with a reading activity from the blog “How Stuff Works” about the UV light water sanitation device shown in Figure 5. There are many such devices on the market, but the blog mentions the brand name SteriPen, by Swiss water purification company Katadyn. Your teacher will provide you a link to the reading, or a printed handout.
2. As your group finishes reading, discuss with yourselves the following questions:
    - The article mentions some negative and positive aspects of ultraviolet light. What are some negative aspects? What are some positive aspects?

- How does a SteriPen work to remove the trillions and trillions of harmful microbes from a liter of water?
- If UV light is enough to destroy these microbes, why doesn't sunlight shining on a mountain stream kill all the microbes in the stream? What benefit does the SteriPen provide?

3. Another interesting application of UV light is their use with fluorescent inks and dyes. In this activity, your group will use a fluorescent ink to write a secret message to another group.
4. Using a small piece of plastic or an index card, write a short, fun message to another group. The yellow ink of the highlighter will be difficult to see in normal light, but if you shine the blacklight on the message, it will pop brightly.
5. With your teacher's permission, you can use the yellow highlighters on your skin. Yellow marker on skin is even more inconspicuous than on plastic or paper and makes for fascinating colors under black light. Only write short messages and be considerate of future classes.
6. If writing on plastic, a wet rag or paper towel should erase the message easily for the next group.
7. Your teacher should provide your group with a blacklight. Shine it on the messages to reveal them. Also, test the blacklight on other things. White clothing, dollar bills, your driver's license, explore the lights and see what you can find!
8. Once you are finished exploring, return the plastic, highlighter, and blacklight to your teacher and answer the discussion questions below in your lab notebook or on your Lab Worksheet.

Figure 3 An ultraviolet light water sterilization pen and an ultraviolet light tanning bed both use invisible ultraviolet light to interact with the DNA of living cells.

Discussion Questions

1. **Construct an explanation** for what is happening as the blacklight is striking the ink. Why does the ink glow when the rest of the plastic (or paper or skin) does not?
2. Draw or explain how electron jumps from different energy levels. What provides the electron with the energy to do that jump?
3. What is the wavelength of the light that is **absorbed** by the ink, and what is the wavelength of the light that is **emitted** by the ink?
4. Which light (absorbed or emitted) is higher in energy? Check the EM Spectrum if you are not sure!
5. What are two uses for fluorescent light besides SteriPens and body art? Can you think of other places these lights are used?

Name & Class Period:

Lab Worksheet

Activity #1

Data Table 1 –Predictions of How Objects Will Appear					
	Blue Filter	Red Filter	Yellow Filter	Green Filter	Purple/Magenta Filter
Blue Object					
Red Object					
Yellow Object					
Green Object					
Black Object					
White Object					

Data Table 2 –Observations of How Objects Appear					
	Blue Filter	Red Filter	Yellow Filter	Green Filter	Purple/Magenta Filter
Blue Object					
Red Object					
Yellow Object					
Green Object					
Black Object					
White Object					

What colors do objects appear under different colors of light?

Data Table 3 –Predictions of How Objects Will Appear Under Colored Light					
	White Light	Red Light	Blue Light	Green Light	Yellow Light
Blue Object					
Red Object					
Yellow Object					
Green Object					
Black Object					
White Object					

Activity #1 Lab Worksheet

Data Table 4 – Observations of How Objects Appear Under Colored Lights					
	White Light	Red Light	Blue Light	Green Light	Yellow Light
Blue Object					
Red Object					
Yellow Object					
Green Object					
Black Object					
White Object					

Discussion

1. What patterns are present with white objects and black objects in Data Tables 1 and 2?

2. Does this pattern continue with different colored light in Data Tables 3 and 4?

3. What filters could I use to view a purple object and not have it appear black?

4. Children often draw a picture of the sun as yellow with yellow light rays coming from it. What color is the light from the sun? What colors would we **not** be able to see if the sun's light really were only yellow?

5. If I shine blue light on a yellow object, what color does the yellow object appear?

Lab Worksheet

Activity #2

Discussion Questions

1. **Construct an explanation** for what is happening as the blacklight is striking the ink. Why does the ink glow when the rest of the plastic (or paper or skin) does not?

2. Draw or explain how electron jumps from different energy levels. What provides the electron with the energy to do that jump?

3. What is the wavelength of the light that is **absorbed** by the ink, and what is the wavelength of the light that is **emitted** by the ink?

4. Which light (absorbed or emitted) is higher in energy? Check the EM Spectrum if you are not sure!

5. What are two uses for fluorescent light besides SteriPens and body art? Can you think of other places these lights are used

Teacher Guide

Utah SEEd Standards

Chem 4.2	Construct an explanation of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. Emphasize a qualitative understanding. Examples could include that low energy electromagnetic radiation can increase molecular rotation and bond vibration, visible light can cause electronic transitions, and high energy electromagnetic radiation can result in ionization and bond breaking.
Phys 4.5	Obtain, evaluate, and communicate information about how devices use the principles of electromagnetic radiation and their interactions with matter to transmit and capture information and energy. Emphasize the ways in which devices leverage the wave particle duality of electromagnetic radiation. Examples could include solar cells, medical imaging devices, or communication technologies.

Activity #1

Possible Answers

Here are possible answers students may find to the data tables and discussion questions for Activity #1:

	Blue Filter	Red Filter	Yellow Filter	Green Filter	Purple/Magenta Filter
Blue Object	*Blue*	*Black*	*Black*	*Black*	*Blue*
Red Object	*Black*	*Red*	*Red*	*Black*	*Red*
Yellow Object	*Black*	*Red*	*Yellow*	*Green*	*Red*
Green Object	*Black*	*Black*	*Green*	*Green*	*Black*
Black Object	*Black*	*Black*	*Black*	*Black*	*Black*
White Object	*Blue*	*Red*	*Yellow*	*Green*	*Purple*

	White Light	Red Light	Blue Light	Green Light	Yellow Light
Blue Object	*Blue*	*Black*	*Blue*	*Black*	*Green*
Red Object	*Red*	*Red*	*Black*	*Black*	*Red*
Yellow Object	*Yellow*	*Red*	*Black*	*Green*	*Yellow*
Green Object	*Green*	*Black*	*Black*	*Green*	*Green*
Black Object	*Black*	*Black*	*Black*	*Black*	*Black*
White Object	*White*	*Red*	*Blue*	*Green*	*Yellow*

1. What patterns are present with white objects and black objects in Data Table 1 and 2? (*Black objects do not reflect any light, so they will always absorb all colors and appear black. White objects reflect all colors, so all colors will be absorbed by the filter except one color.)*
2. Does this pattern continue with different colored light in Data Table 2 and 3? (*Yes. Black objects do not reflect any light, so they will always absorb all colors and appear black. White objects reflect all colors, so will reflect whichever color the light is.*)
3. Children often draw a picture of the sun as yellow with yellow light rays coming from it. What color is the light from the sun? What colors would we **not** be able to see if the sun's light really were only yellow? (*The sun, despite appearing yellowish in the sky, emits white light. If the sun only emitted yellow light, we could only see the colors yellow, green, and red, and no blues or purples would be visible.)*
4. What filters could I use to view a purple object and not have it appear black? (*Since purple is a mixture of red and blue light, a red, blue, or yellow filter will make a purple object appear those colors. A green filter would make purple appear black.)*
5. If I shine blue light on a yellow object, what color does the yellow object appear? (*Black. Since yellow light contains red and green light, blue light would be absorbed by the yellow object and no light would be reflected.)*

Other Information – Activity #1

While there cannot be anything that could replace the experience of seeing colored light through the students' own eyes, this activity can be adapted for online use or homework using a pair of excellent simulations. ThePhysicsClassroom.com hosts online simulations the students can do from Chromebooks, iPads, or other computer devices to complete. The first simulation could allow the students to complete Data Tables 1 and 2, and the second can allow students to complete Data Tables 3 and 4. These would also be useful for reviewing the idea of the lab in class after it is completed. The links are listed below:

- ThePhysicsClassroom.com/Physics Interactives/Light and Color/Filtering Away (https://www.physicsclassroom.com/Physics-Interactives/Light-and-Color/Filtering-Away)
- ThePhysicsClassroom.com/Physics Interactives/Light and Color/Stage Lighting (https://www.physicsclassroom.com/Physics-Interactives/Light-and-Color/Stage-Lighting)

The supplies used for Activity #1 include colored filters, used by photographers or stage lighting, and LED lights to supply one color of light often used for photography. Below are links to Amazon.com that lists some acceptable equipment:

- SAKOLLA 8 Pieces Transparent Color Correction Lighting Gel Filter - Colored Gel Light Filter Plastic Sheet, 8.5 x 11 Inch, 8 Assorted Colors (Probably need a few orders for a class set) https://www.amazon.com/dp/B07PY7NBST/?coliid=I23X2QIFNNADQ3&colid=3VA1IH2K18YLW&psc=1&ref_=lv_ov_lig_dp_it
- Onforu 4 Pack 12W Color LED Flood Lights, IP66 Waterproof RGB Flood Light with Remote Control, Dimmable Color Changing Floodlight, Indoor Wall Washer Light for Party, Stage, Garden, Landscape https://www.amazon.com/dp/B07Q5RFJ8G/ref=dp_cerb_2

Your budget and supplies on hand may provide replacements. There are certainly several alternatives for this equipment.

Activity #2

Possible Answers

I posited some discussion topics during the reading on SteriPens. While the discussion can go in any number of different places, here are the answers to the discussion questions I provided.

- *The article mentions some negative and positive aspects of ultraviolet light. What are some negative aspects? What are some positive aspects?* (The article mentions sunburn as a negative effect of UV light, and water sterilization as a positive aspect.)

- *How does a SteriPen work to remove the trillions and trillions of harmful microbes from a liter of water?* (Technically, the SteriPen is not removing the microbes. Rather, it is disrupting their DNA's ability to copy. If the germs cannot reproduce, they will not be able to infect a healthy individual.)
- *If UV light is enough to destroy these microbes, why doesn't sunlight shining on a mountain stream kill all the microbes in the stream? What benefit does the SteriPen provide?* (While the article does not address this question, students may provide answers based on specific context clues. The most likely answer is that the concentration of UV light in an enclosed bottle is sufficient to kill the microbes, whereas sunlight, even during the sunniest day of the year, cannot achieve enough concentration to kill microbes in a vast lake or stream.)

Here are some possible answers for the Discussion Questions section of the lab:

1. **Construct an explanation** for what is happening as the blacklight is striking the ink. Why does the ink glow when the rest of the plastic (or paper or skin) does not? (*The ink is made of a material that absorbs UV light from the blacklight and emits visible light due to that absorption. Skin, paper, and plastic do not contain those materials.)*
2. Draw or explain how electron jumps from different energy levels. What provides the electron with the energy to do that jump? (*Electrons in the atoms require energy to jump to different energy levels. In the case of our ink, the UV light is energetic enough to absorb that light. After it absorbs high-energy UV light, it emits lower-energy visible light, making the ink appear to glow yellow. See figure 6 below.)*
3. What is the wavelength of the light that is **absorbed** by the ink, and what is the wavelength of the light that is **emitted** by the ink? (*The ink absorbs UV light that is likely near 315-400 nm, and emits visible light that is yellow, 560 nm)*
4. Which light (absorbed or emitted) is higher in energy? Check the EM Spectrum if you are not sure! (*UV Light is higher in energy. It has a higher frequency.)*
5. What are two uses for fluorescent light besides SteriPens and body art? Can you think of other places these lights are used? (*Answers will vary, but some answers may include lightbulbs that fluoresce gasses; crime scene investigations to check for bodily fluid stains; pet owners using UV light to find pet stains; security checks for currency or identification to ensure their authenticity.*)

Other Information—Activity #2

The reading on SteriPens is found at the link below:

- Briggs, Josh. "How the SteriPEN Works." HowStuffWorks, HowStuffWorks, 9 June 2009, electronics.howstuffworks.com/gadgets/travel/steripen.htm.

Transparency sheets cut into smaller squares works well for the secret message activity. Additionally, the clear plastic cover of CD jewel cases also works well and cleans easily. If using plastic becomes too time or cost restrictive, the students can use 3x5 index cards for permanent messages. It will be easier to read with the yellow highlighter, but it still will be strikingly bright under blacklight.

The supplies for Activity #2 include blacklight flashlights, highlighters, plastic pieces or 3x5 cards for the secret message, and any other objects you have that may fluoresce beautifully. Listed below are links to Amazon.com for the equipment.

- Rarlan Highlighters, Chisel Tip, Fluorescent Yellow, 96 Count Class pack. https://www.amazon.com/dp/B082CXM7PQ/?coliid=I1L5OGNCGECRDJ&colid=3VA1IH2K18YLW&psc=1&ref_=lv_ov_lig_dp_it
- Mopilot Black Light, 4 PCS 12 LEDs 395nm UV Blacklight Flashlights Detector for Pets Urine and Stains. (Pack of 4) https://www.amazon.com/dp/B089GXJJLH/?coliid=I3T39UOJT4UUHQ&colid=3VA1IH2K18YLW&psc=1&ref_=lv_ov_lig_dp_it
- Octago Inkjet Transparency Paper (30 Pack) 100% Clear Transparency Film for Inkjet Printers - Print Color Transparency Sheets for Overhead Projector Transparencies and Screen Prints (8.5x11 Inches).

https://www.amazon.com/Octago-Inkjet-Transparency-Paper-Printers/dp/B07S6Z8DMR/ref=sr_1_4?dchild=1&keywords=plastic+transparency&qid=1596825976&sr=8-4

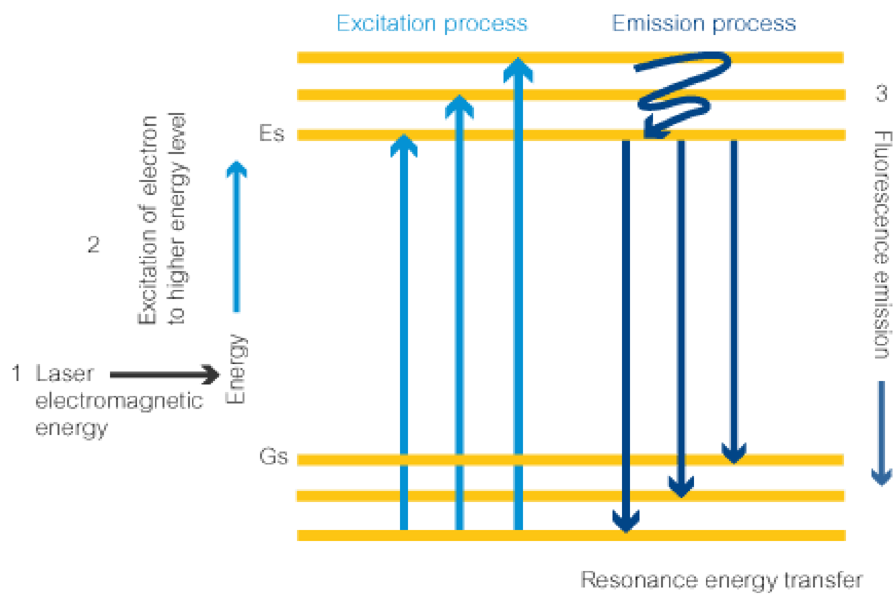

Figure 4 A possible diagram the students could use for #2 on the discussion questions. The light blue lines indicate the electron that absorbs light, and the dark blue line represents the path of the electron as it emits fluorescent light.