Unit Overview

Major Concepts

Major concepts of the unit are to investigate color through science and art. The unit integrates learning of waves and wave properties, the electromagnetic spectrum, light properties, the chemistry of color through natural and synthetic dye, chromatography, and color systems. Students will investigate physical and chemical properties of color. They will also have the opportunity connect the science of color with the art of color through STEAM activities.

Lesson 1: Wave and Wave Properties

Lesson 2: Exploring the Electromagnetic Spectrum

Lesson 3: Make Your Own Dyes and Markers

Lesson 4: Be a Color Detective (Chromatography)

Lesson 5: Light Properties

Lesson 6: Color Systems: RGB, RYB, CMYK

Lesson 7: Color Matters

Lesson 8: Light Painting

Resources from Class

Resources from the Chemistry in STEM course integrated in unit plan are the PhET website that teachers can utilize with their students to engage in digital simulations to grasp concepts related to light, electromagnetic activity, and molecules. Another resource, although it doesn't seem to have as much pertaining to light and the electromagnetic spectrum is the Concord Consortium (2020). There is one activity that requires a sensor to use it, if the sensor software is downloaded on the technology students are using the site could help to expand students' understanding of the electromagnetic spectrum and light. I have also incorporated a link to Ck-12 Exploration Series Chemistry Simulations on Neon Lights as a homework activity. I originally took out the Light Painting (STEAM) activity to balance the level of physics, chemistry and STEAM lessons in the unit, but I put it back in because I felt that it would connect well with the Neon Lights simulation.

Benefits to Students

The resources that I used were shared from various colleagues in the Chemistry in STEM course, specifically from our spectroscopy discussion boards. I explored the resources shared to see how the sources would integrate into this unit. The benefit of utilizing these resources is that students have yet another way of experiencing the STEAM of color and how deeply integrated color is in the world they experience. When students learn and experience content that is integrated in nature it provides them real-world application of their learning. The National Research Council desires for students to experiences science learning not just learn about science.

> As in all inquiry-based approaches to science teaching, our expectation is that students will themselves engage in the practices and not merely learn about them secondhand. Students cannot comprehend scientific practices, nor fully appreciate the nature of scientific knowledge itself, without directly experiencing those practices for themselves. (NRC, 2012, p. 30)

The benefit of tying in the color systems (Lesson 6:RGB, RYB, and CMYK) and the cultural connections (Lesson 7: Color Matters) to color bring the scientific learning of color full-circle for students. The light painting lesson (Lesson 8) utilizes students' knowledge of light and color through an artmaking process.

Unit: The STEAM of Color

<table>
<tr><td colspan="2">Lesson 1: Waves and Wave Properties

This lesson is from:

TeachEngineering. (2019, Nov 21). Lesson: Waves and wave properties (Zielinsky, E., Faber, C., & Forbes, M.H., Contributors). University of Colorado Boulder. Retrieved from https://www.teachengineering.org/lessons/view/clem_waves_lesson02</td><td rowspan="2">Time Frame: 2-3 x 40 minute class periods</td></tr>
<tr><td colspan="2">Grade Level: 6-8th Grade</td></tr>
<tr><td colspan="3">Brief Description of Lesson: Students learn wave types and properties of waves, how they change directions, wavelength, frequency, amplitude and speed. During the presentation students will take notes using the handout. Students will label the parts of a wave on a diagram and draw their own waves with specified properties. They will also make observations about the waves they drew to determine which has the highest and lowest frequency.</td></tr>
<tr><td colspan="3">Specific Learning Outcomes:
Students should be able to understand waves and are a step closer to understanding how humans see color
Students should be able to explain that waves transfer energy, not matter.
Students should be able to distinguish between mechanical and electromagnetic waves.
Students should be able to summarize the major properties and behavior of waves, including (but not limited to) wavelength, frequency, amplitude, speed, refraction, reflection, and diffraction.</td></tr>
<tr><td colspan="3">Narrative/Background Information: Students will have begun to investigate how we see color through the “Three color mystery” lesson. Students will likely not have an understanding of the unseen to the naked eye parts of science like waves and wave properties.</td></tr>
<tr><td colspan="3">Vocabulary:
Amplitude, compression, compressional (longitudinal) wave, crest, diffraction, electromagnetic wave, energy, frequency, mechanical wave, rarefaction, reflection, refraction, transverse wave, trough, wave, wavelength.</td></tr>
<tr><td>Science & Engineering Practices:
Developing and Using Models</td><td>Disciplinary Core Ideas:

PS4.A: Wave Properties
A simple wave has a</td><td>Crosscutting Concepts:
Pattern
Graphs and charts can be used to</td></tr>
</table>

Modeling in 6–8 builds on K–5 and progresses to developing, using, and revising models to describe, test, and predict more abstract phenomena and design systems. ● Develop and use a model to describe phenomena. (MS-PS4-2) Using Mathematics and Computational Thinking Mathematical and computational thinking at the 6–8 level builds on K–5 and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments. ● Use mathematical representations to describe and/or support scientific conclusions and design solutions. (MS-PS4-1) Obtaining, Evaluating, and Communicating Information Obtaining, evaluating, and communicating information in 6-8 builds on K-5 and progresses to evaluating the merit and validity of ideas and methods. ● Integrate qualitative scientific and technical information in written text with that contained in media and visual displays to clarify claims and findings. (MS-PS4-3)	repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-1) ● A sound wave needs a medium through which it is transmitted. (MS-PS4-2)	identify patterns in data. (MS-PS4-1 Structure and Function Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (MS-PS4-2) ● Structures can be designed to serve particular functions. (MS-PS4-3) Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering, and Technology on Society and the Natural World ● Technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations. (MS-PS4-3) Connections to Nature of Science Science is a Human Endeavor ● Advances in technology influence the progress of science and science has influenced advances in technology. (MS-PS4-3)

Connections to Nature of Science Scientific Knowledge is Based on Empirical Evidence ● Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS4-1)		

Possible Preconceptions/Misconceptions: The nature of color is that it is there, but may not be able to explain why or how we see color, other than when the sun is up and lights are on, we can see. When the sun is down or lights or off, we can't see well.

NGSS Science and Engineering Standards:

MS-PS4-1 Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.

MS-PS4.2 Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials**.**

CCSS ELA and Math Standards:
RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts. (MS-PS4-3)

RST.6-8.2 Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. (MS-PS4-3)

RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-PS4-3)

WHST.6-8.9 Draw evidence from informational texts to support analysis, reflection, and research. (MS-PS4-3)

SL.8.5 Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (MS-PS4-1),(MS-PS4-2)

MP.2 Reason abstractly and quantitatively. (MS-PS4-1)

MP.4 Model with mathematics. (MS-PS4-1)

6.RP.A.1 Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. (MS-PS4-1)

7.RP.A.2 Recognize and represent proportional relationships between quantities. (MS-PS4-1)

5E Model Lesson 1: Wave and Wave Properties

In advance make copies of the All About Waves-Notes Outline (Appendix A) and Anatomy of a Wave Worksheet (Appendix A). One per student, and have graph paper available). Also prepare the slide show Waves and Wave Properties Presentation (Appendix A) to accompany the lesson introduction (optional).

Engage: Returning to our three color-mystery, today we are going to develop an understanding of the fundamental concepts of waves. What we learn will move us one step closer to reaching our goal of creating a solution to our engineering challenge that we conducted yesterday.

Questions:

Let’s start with what we already know. Why are we able to see? (Because there is light). What is light? (It is a wave). So, what is a wave? Well, we will learn the answer to that question today.

(pass out the outline that will help students track the important concepts explained as discussion takes place about waves and wave properties and present the slide show presentation)

(then divide the class into groups of 2 students each, hand out copies of the worksheet and blank paper)

Explore/Explain: Who has ever sunburned your skin? Who has used a microwave to make popcorn? Or had an x-ray taken? Or listen to the radio? What do these activities have in common? (Listen to student answers) All of these require waves.

One difference between the waves that pop popcorn and the waves that tan your skin is wave frequency. As we have learned, the frequency of a wave is defined as the number of cycles that pass a single point in a given time.

In the first of the worksheet, label the parts of a wave using the definitions given. Then, draw four different waves based on the information given about the waves’ properties. Of these four waves, your challenge is to identify the ones with the highest and lowest frequencies.

Legacy Cycle Information: This lesson falls into the research and revise phase of the legacy cycle. During the phase, students begin to learn the basic concepts required to design solutions to engineering challenge presented in lesson 1 of this unit. After lesson 2, students should be able revise their initial thoughts, forming new ones that will help solve the engineering challenge question.

Waves and Wave Properties

(The following lecture materials aligns with slides.)

A wave is a disturbance that carries energy from one place to another. Matter is NOT carried with the wave. A wave can move through matter (called a "medium"), but some waves do not need a medium to be able to move. If a wave needs a medium, we call it mechanical wave. If a wave can travel without a medium, (for example, through space), we call it an electromagnetic wave.

Wave Types
1. Transverse waves: Waves in which the medium moves at right angles to the direction of the wave. Think about a "stadium wave:" the people are moving up and down, but the wave is going around the stadium.
Parts of transverse waves:

a. Crest: the highest point of the wave
b. Trough: the lowest point of the wave

2. Compressional (longitudinal) waves: Waves in which the medium moves back and forth in the same direction as the wave. Parts of compressional waves:

a. Compression: where the particles are close together
b. Rarefaction: where the particles are spread apart

Wave properties depend on what (type of energy) makes the wave. For example, you splashing in the ocean or an earthquakes creating a tsunami. Descriptive wave properties include:

1. Wavelength: The distance between one point on a wave and the exact same place on the next wave.

2. Frequency: How many waves go past a point in one second. The unit of measurement is hertz (Hz). The higher the frequency, the more energy in the wave.
   a. If 10 waves go past in 1 second, it is 10 Hz
   b. If 1,000 waves go past in 1 second, it is 1,000Hz
   c. If 1,000,000 waves go past, it is 1,000,000 Hz

3. Amplitude: How far the medium (crests and troughs, or compressions and rarefactions) moves from rest position (the place the medium is when not moving).

The more energy a wave carries, the larger its amplitude.

a. The energy of a wave can be expressed by the equation E = CA2, where E is energy, C is a constant dependent upon the medium, and A is the amplitude.

2. Wave speed: Depends on the medium in which the wave is traveling. It varies in solids, liquids and gases.
    a. A mathematical way to calculate wave speed is: wave speed = wavelength (in m) x frequency (in Hz). Or, $v = f \times \lambda$. So, if a wave has a wavelength of 2 m and a frequency of 500 Hz, what is its speed? (Answer: wave speed = 2 m x 500Hz = 1000 m/s)

Changing Wave Direction

A demonstration of refraction.

1. Reflection: When waves bounce off a surface. If the surface is flat, the angle at which the wave hits the surface will be the same as the angle that the wave leaves the surface. In other words, the angle in equals the angle out. This is the law of reflection. (For example, when a pool ball strikes the side of a pool table, the angle at which it hits the bumper is the same angle at which it bounces off the bumper.)
2. Refraction: Waves can bend. This happens when a wave enters a new medium and its speed changes. The amount of bending depends on the medium it is entering. (optional: To explain this phenomenon in more detail, search the Internet to find an interactive tutorial that shows light being bent as it travels through a medium.)
3. Diffraction: The bending of waves around an object. The amount of bending depends on the size of the obstacle and the size of the waves. (optional: To explain this phenomenon in more detail, search the Internet to find an interactive tutorial that shows the diffraction of monochromatic light through slits of varying widths.)

a. Large obstacle, small wavelength = low diffraction (bending)
b. Small obstacle, large wavelength = large diffraction (bending)

Elaborate (Applications and Extensions):

Closure:

Now that you're all experts in understanding the different types of waves, how they move and change direction, and how to describe their characteristics, tell me, what are some of the ways that you see waves used in your everyday lives? (Listen to student ideas.) Those are great examples. What about microwave ovens, medical and dental x-ray machines, eyeglasses and speakers? These are common examples in which engineers apply their knowledge of waves to design all types of useful products and tools that are evident in our everyday lives. To design these products, engineers must be well versed in all the properties of waves and how waves can differ from one another. For example, the waves emitted from a microwave are very different than those emitted from an x-ray machine that creates images of bones or teeth. Engineers need a complete understanding of wave properties in order to design safe and effective products!

But that's not all—engineers work to protect people and predict how tsunamis will travel after an earthquake in the ocean by using wave properties. To successfully predict where a tsunami will travel, engineers must understand how waves move and the properties associated with waves.

Another example of engineers using wave properties is when electrical engineers separate different types of waves so that the radio you are using tunes in to the right station, or your cell phone only picks up the calls that you want. If it were not for these engineers, you would constantly be getting calls from people you didn't know. To accomplish this, they must have a clear understanding of wave properties and know how to separate different types of waves. Before designing and creating a solution to a challenge, engineers conduct research and gather information, just like you did today. This step is a crucial part of the engineering design process.

Evaluate:

Formative Monitoring (Questioning/Discussion):
Note Taking: During the lecture, have students complete the All About Waves—Notes Outline (Appendix A) and refer to it for visuals that supplement the lecture material. Then, with the notes turned over on their desks, ask students various questions that were covered in the lecture material. Evaluate students' answers to gauge their mastery of the subject.

After the lecture, have students complete the Anatomy of a Wave Worksheet (Appendix A) to see how well they apply what they learned.

Summative Assessment (Quiz/Project/Report):

Trade-n-Test: To conclude, have each student make up his/her own wave properties (that is, trough and crest height and wavelength) and write it down. Then have students trade the "invented properties" papers with other students and draw the new waves based on the given properties.

<table>
<tr><td>Lesson 2: Exploring the Electromagnetic Spectrum

This lesson is from:

TeachEngineering. (2019, Dec 4). Lesson: Exploring the electromagnetic spectrum (Zielinsky, E. & Faber, C., Contributors). University of Colorado Boulder. Retrieved from https://www.teachengineering.org/lessons/view/clem_waves_lesson04</td><td colspan="2" rowspan="2">Time Frame: 1 x 40 minute lesson</td></tr>
<tr><td>Grade Level: 6-8th Grade</td></tr>
<tr><td colspan="3">Brief Description of Lesson: Students will learn the electromagnetic spectrum and how various waves are related in wavelength and energy. Students will be introduced to radio waves, ultraviolet waves, visible light and infrared waves.</td></tr>
<tr><td colspan="3">Specific Learning Outcomes:
Students should be able to explain the relationship between the size of a wave and frequency. Students should be able to explain the relationship between a wave’s energy and wavelength.</td></tr>
<tr><td colspan="3">Narrative/Background Information: Students will have an understanding of waves and wavelengths, and light properties. Legacy Cycle Information: This lesson falls into the research and revise phase of the legacy cycle. During this phase, students begin to learn the basic concepts required to design solutions to the engineering challenge presented in lesson 1 of this unit. After, this lesson on the Electromagnetic Spectrum students, should be able to revise their initial thoughts, forming new ones that will help solve the engineering challenge.</td></tr>
<tr><td colspan="3">Vocabulary:
Radio waves, Infrared waves, Visible light, Ultraviolet, X-rays, Gamma rays, electromagnetic radiation, electromagnetic spectrum</td></tr>
<tr><td>Science & Engineering Practices:</td><td>Disciplinary Core Ideas:</td><td>Crosscutting Concepts:</td></tr>
</table>

<table>
<tr>
<td>• Developing and Using Models
• Using Mathematics and Computational Thinking
• Planning and Carrying Out Investigations
• Obtaining, Evaluating, and Communicating Information

Connection to Nature of Science:

Scientific knowledge is based on empirical evidence</td>
<td>PS4.A. Wave Properties
PS4.B. Electromagnetic Radiation

Connections to other DCIs in this grade band: MS.LS1-D</td>
<td>• Patterns
• Structure and Function

Connections to Engineering, Technology and Applications of Science
• Influence of science, engineering, and technology on society and the natural world. Connections to Nature of Science:

Science is a human endeavor
• Advances in technology influence the progress of science and science has influenced advances in technology.</td>
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<td colspan="3">Possible Preconceptions/Misconceptions: Students may believe that white light is just white and not understand that white light is made up of all wavelengths. Students may also only know one of the multiple color systems: RGB, RYB, and CMYK.</td>
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MS-PS4.2 Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.</td>
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<td colspan="3">CCSS ELA and Math Standards:

ELA/Literacy -
RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts. (MS-PS4-3)
RST.6-8.2 Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. (MS-PS4-3)
RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-PS4-3)</td>
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WHST.6-8.9	Draw evidence from informational texts to support analysis, reflection, and research. (MS-PS4-3)
SL.8.5	Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (MS-PS4-1), (MS-PS4-2)
Mathematics -	
MP.2	Reason abstractly and quantitatively. (MS-PS4-1)
MP.4	Model with mathematics. (MS-PS4-1)
6.RP.A.1	Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. (MS-PS4-1)
6.RP.A.3	Use ratio and rate reasoning to solve real-world and mathematical problems. (MS-PS4-1)
7.RP.A.2	Recognize and represent proportional relationships between quantities. (MS-PS4-1)f
8.F.A.3	Interpret the equation y = mx + b as defining a linear function, whose graph is a straight line; give examples of functions that are not linear. (MS-PS4-1)

5E Model Lesson 2: Exploring the Electromagnetic Spectrum

(In advance make copies of the All About EM-Notes Outline, one per student. Prepare to show the Electromagnetic Spectrum Presentation to students)

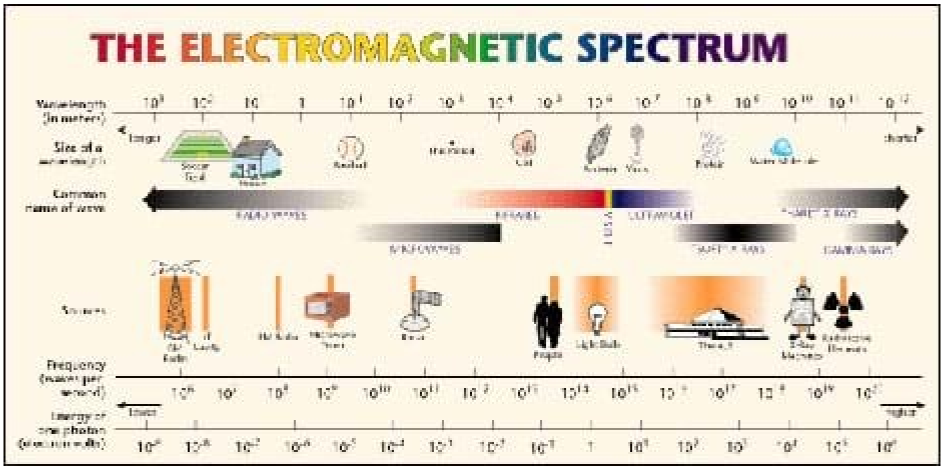
Engage: Students go to https://phet.colorado.edu/en/simulation/molecules-and-light **to experience molecules and light.**

We have already learned about the properties of light and how light interacts with objects. Today, we are going to move on and begin talking about the electromagnetic spectrum.

The only type of electromagnetic radiation we see is visible light, which makes up only a fraction of the spectrum. We will begin by introducing you all the EM spectrum and how it is organized and then we will look at the different types of waves that can be found in this spectrum, many may be familiar.

Questions: What is the electromagnetic spectrum? Why is only white light visible? How do we get all the other colors of light?

Explore/Explain #1: (The following lecture material aligns with the slides.)
The EM Spectrum is the complete (entire) range of EM waves in order of increasing frequency and decreasing wavelength. This means as you look from left to right on a diagram of the spectrum, the wavelengths get smaller and the frequency gets larger. An inverse relationship exists between size of the wave and frequency. Remember: all EM waves travel at the same speed: 300,000 km/s. If you remember the formula for speed, it is the wavelength times the frequency. For the answer to always be 300,000 km/s, as one number goes up, the other must go down. All EM waves are radiation. It is just that the longer wavelengths do not carry enough energy in them to damage cells. Remember: the higher the frequency, the more energy in the wave!



A diagram of the electromagnetic spectrum. Copyright (https://www2.lbl.gov/MicroWorlds/ALSTool/EMSpec/EMSpec2.html)

As we continue to gather information—an important step of the engineering design process—we now know a lot about the electromagnetic spectrum. Tell me what you know. (Listen to student responses, adding and correcting as necessary.) What is the relationship between the size of a wave and frequency? And what about the relationship between a wave's energy and wavelength?

What do you think that engineers have done with their understanding of EM? (Listen to student ideas.) Well, engineers have designed many devices and instruments that use various types of waves found in the electromagnetic spectrum. Some examples are: radios, x-ray instruments, CT scanners and sterilization techniques. These devices use electromagnetic waves in different ways. And since, as we have learned, some waves can be powerful and dangerous, engineers must understand every aspect of the electromagnetic spectrum to make the instruments and tools safe for people to use.

Explore/Explain #2: Show the electromagnetic spectrum video from:

Khan Academy. (n.d.). *The electromagnetic spectrum*. [Video File]. Retrieved from https://www.khanacademy.org/partner-content/nova/sunandsolar/v/electromagneticspectrum

Elaborate (Applications and Extensions): Have the students stand up with their feet close together. As they oscillate side to side have them take small steps sideways so that they stand wider. They will not be able to sway side to side as fast, as their stance gets wider. This can help relate wave size and frequency. Show the following equation on the board:

$v = \lambda * f$

Where:

v = speed of wave (distance/time)

λ = wavelength (distance)

f = frequency of wave (1/time)

The speed of a wave depends on the material it is traveling through. The speed of an electromagnetic wave (including light) through a vacuum is always the same (300,000,000 meters per second...or 670,000,000 miles per hour! This is represented by c). Through other materials the speed varies! To find the speed of an electromagnetic wave, you only have to divide c (speed through vacuum) by the "refractive index" shown in Table 1.

material	*n*	material	*n*
Vacuum	1	Crown Glass	1.52
Air	1.0003	Salt	1.54
Water	1.33	Asphalt	1.635
Ethyl Alcohol	1.36	Heavy Flint Glass	1.65
Fused Quartz	1.4585	Diamond	2.42
Whale Oil	1.460	Lead	2.6

Table 1. Refractive Index (n) for Variety of Materials
Hand out the attached Math Worksheet (Appendix A).

Evaluate:
Formative Monitoring (Questioning/Discussion): Note taking and class discussion.

Summative Assessment (Quiz/Project/Report): Electromagnetic Quiz (Appendix A)

Lesson 3: Make Your Own Dyes and Markers

Agee, S., & De Brabandere, S. (2020, January 12). *Make Your Own Markers.* Retrieved from https://www.sciencebuddies.org/science-fair-projects/project-ideas/Chem_p014/chemistry/make-your-own-markers.

Time Frame: Two- 40 minute lessons

Grade Level: 6-8th Grade

Brief Description of Lesson: Students will make plant-based natural dye and make their own markers.

Specific Learning Outcomes:
Students will investigate making plant-based natural dye.
Students will compare natural and synthetic dyes.
Students will create their own marker

Narrative/Background Information: Students will use markers made in this lesson for the lab

in lesson four.		
Vocabulary: Synthetic Natural		
Science & Engineering Practices: **Developing and Using Models** Develop a model to describe unobservable mechanisms. (MS-PS1-5) **Analyzing and Interpreting Data** Analyze and interpret data to determine similarities and differences in findings. (MS-PS1-2) **Scientific Knowledge is Based on Empirical Evidence** Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS1-2) **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** Laws are regularities or mathematical descriptions of natural phenomena. (MS-PS1-5)	**Disciplinary Core Ideas:** PS1.A: Structure and Properties of Matter PS1.B: Chemical Reactions	**Crosscutting Concepts:** **Patterns** Macroscopic patterns are related to the nature of microscopic and atomic-level structure. (MS-PS1-2) **Energy and Matter** Matter is conserved because atoms are conserved in physical and chemical processes. (MS-PS1-5) The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-PS1-6) **Scale, Proportion, Quantity** Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-PS1-1) **Structure and Function** ▪ Structures can be designed to serve particular functions by taking into account properties of different materials, and how materials can be shaped and used. (MS-PS1-3)
Possible Preconceptions/Misconceptions: Students may believe that white light is just white		

and not understand that white light is made up of all wavelengths. Students may also only know one of the multiple color systems: RGB, RYB, and CMYK.
NGSS Science and Engineering Standards: MS-PS4-1 Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. MS-PS4.2 Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.
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5E Model Lesson 3: Make Your Own Dyes and Markers
Materials: - A colorful spice, tea, plant, fruit, or vegetable (rich in color and not limited to blueberries, cranberries, beets, yellow onion, red onion, turmeric, black tea, coffee) Enough to cover a sauce pain.

- Cutting board (if you need to chop your plant source into small pieces)
- Knife
- Saucepan
- Stove/Hot plate
- Water
- Bowl
- Strainer
- Ruler
- Scissors
- Pencil
- Plate
- Lab Notebook

For Marker Making:
-Crayola Marker Refill Pack (Available on Amazon.com)
- Drinking glass
-Tweezers
- Hammer
- Newspaper

Engage: (will happen along with explore and explain)

Questions: *How do artists get color in paints, markers, crayons? How do ancient civilizations get color in their work?*

Explore/Explain:

1. Students should get into lab groups with their science notebooks.
2. Pick out a plant source to extract your dye from. Make sure there is enough to cover the bottom of a sauce pan. (One color per group0
3. If the plant source is large, finely chop it into pieces using a knife and cutting board(teacher could prepare this in advance instead of letting the kids chop)(Enlist the Family and Consumer Science teacher or parent volunteers to assist in this lab if needed). If color of the plant source is concentrated in the skin, peel of skin and only use the skin.
4. Add the plant material to the saucepan and add just enough water to cover the plant. If you selected tea or a spice, add enough water so that it is floating or mixed into the liquid and not just absorbing the water or turning into a paste.
5. Bring the mixture to a boil and simmer covered on the stove approximately 10-15 minutes. The pigment from the plant material will slowly begin to color the water in your saucepan.
   Safety notes: Do not leave the plant-water mixture unattended on the stove. Remain

nearby to make sure it does not burn. It is good to be in a well-ventilated area or have a stove fan running. Cooking plants may have bad smelling fumes.

6. If the color of your water is too faint, you may want to concentrate the color by removing the lid of the saucepan and continue boiling until enough liquid has evaporated, leaving behind a darker liquid.
7. When the color of the water is rich in color, remove from saucepan from the heat, turn off heat source and allow the dye to cool. If there are pieces of material in your dye, use a strainer or slotted spoon to remove the pieces, pour liquid into a separate bowl through a strainer. If the material dissolved into the water just power the liquid into a bowl and set aside.
8. Watch the video while liquid is cooling.

Engage: The Chemistry of Color: https://youtu.be/CtiKkJrB-ag

9. Now that you have your homemade dye, you are ready to make your dye into a marker.
10. Pour some of your dye into a glass until the dye reaches about 1 cm up the glass.
11. Gather all the materials for the marker. (Hammer, tweezers, core, tip, plug, barrel, cap)
12. Start by pressing one tip into the narrow side of the marker barrel.
13. Place a marker core into the glass filled with about 1 cm of dye and watch how it soaks up the dye.
14. Place the tip into the empty marker barrel.
15. Once the core is completely soaked, use your tweezers to press the core into the barrel.
16. Snap on the plug and cap.
17. Place marker cap over the tip and then place cap down on a hard surface.
18. Use a hammer and tap on the plug with the hammer. Watch your fingers.
19. If you see the tip soaked up the dye, you know everything snapped together well. The marker is finished.
20. Label your marker. Give your color a unique name. Test it out!
    Compare group markers/natural material choices. Which natural material made the richest dye?

Clean up lab.

Extra time: Explore careers like a chemical engineer, chemist, and chemical technician and their roles in creating products that we use on an everyday basis.

Elaborate (Applications and Extensions):

a. Make more markers by using other materials to get different colors. Compare and contrast which materials may the best colors.
b. Use Kool-Aid as a source of pigment with chromatography. Do some of the different

flavors use some of the same coloring agents? Which flavors contain a mix of different-colored molecules?

c. Some plant pigments change color when they are mixed with an acid (vinegar) or a base (baking soda). Conduct an experiment on different plant dyes to see which one have this amazing color changing ability.
d. Candy Chromatography Kit from Science Buddies.

Evaluate:

Formative Monitoring (Questioning/Discussion): Teacher questioning and discussion as students conduct the lab. Homework students explore this site: https://interactives.ck12.org/simulations/chemistry/bohr-model-of-electron/app/index.html?lang=en&referrer=ck12Launcher&backUrl=https://interactives.ck12.org/simulations/chemistry.html&_ga=2.246041922.776173425.1582986640-1044991653.1582212235 and write a one paragraph summary of what they learned.

Summative Assessment (Quiz/Project/Report):.): Combined and completed lab report for lessons 3 and 4.. Guidelines in Appendix A.

Lesson 4: Be a Color Detective Science Buddies. (2015, May 14). *Chromatography: Be a color detective*. Retrieved from https://www.scientificamerican.com/article/chromatography-be-a-color-detective/	**Time Frame:** One 40-minute class period
Grade Level: 6-8th Grade	

Brief Description of Lesson: Ink and paint are created by colored molecules. Students will investigate the differences in natural and synthetic dyes. In a marker, while one color is visible to our eyes, the actual color might be made up of one type of color molecule or a blend of color molecules. This science lab will discover the hidden colors in water-soluble markers.

Specific Learning Outcomes:

Students will investigate color molecules.
Students will compare and contrast color molecules that create different colors in water-soluble markers.

Narrative/Background Information: How we see light will be investigated in future lessons within this unit. Paper chromatography is used by chemists to separate out parts of a solution. The components of a solution start out in one place on a piece of paper. A solvent, like water or isopropyl alcohol, is allowed to absorb up the paper. Different parts of the mixture absorb with

the solution at different rates up the paper. The components of the solution separate in this process and visible on the piece of chromatography paper.
Vocabulary: Chromatography Molecules Solutions Primary Colors Colors Solutions Secondary Colors

Science & Engineering Practices:	Disciplinary Core Ideas:	Crosscutting Concepts:
Developing and Using Models Develop a model to describe unobservable mechanisms. (MS-PS1-5) **Analyzing and Interpreting Data** Analyze and interpret data to determine similarities and differences in findings. (MS-PS1-2) **Scientific Knowledge is Based on Empirical Evidence** Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS1-2) **Science Models, Laws, Mechanisms, and Theories Explain Natural Phenomena** Laws are regularities or	PS1.A: Structure and Properties of Matter PS1.B: Chemical Reactions	**Patterns** Macroscopic patterns are related to the nature of microscopic and atomic-level structure. (MS-PS1-2) **Energy and Matter** Matter is conserved because atoms are conserved in physical and chemical processes. (MS-PS1-5) The transfer of energy can be tracked as energy flows through a designed or natural system. (MS-PS1-6) **Scale, Proportion, Quantity** Time, space, and energy phenomena can be observed at various scales using models to study systems that are too large or too small. (MS-PS1-1) **Structure and Function** ▪ Structures can be designed to serve particular functions by

mathematical descriptions of natural phenomena. (MS-PS1-5)		taking into account properties of different materials, and how materials can be shaped and used. (MS-PS1-3)

Possible Preconceptions/Misconceptions: The only one color molecule makes up each marker color.

NGSS Science and Engineering Standards:

MS-PS1-2. Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred.

MS-PS1-5. Develop and use a model to describe how the total number of atoms does not change in a chemical reaction and thus mass is conserved.

MS-PS1-6. Undertake a design project to construct, test, and modify a device that either releases or absorbs thermal energy by chemical processes.

MS-PS1-3. Gather and make sense of information to describe that synthetic materials come from natural resources and impact society.

CCSS ELA and Math Standards:
RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts. (MS-PS4-3)

RST.6-8.2 Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. (MS-PS4-3)

RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-PS4-3)

WHST.6-8.9 Draw evidence from informational texts to support analysis, reflection, and research. (MS-PS4-3)

SL.8.5 Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (MS-PS4-1),(MS-PS4-2)

MP.2 Reason abstractly and quantitatively. (MS-PS4-1)

MP.4 Model with mathematics. (MS-PS4-1)

6.RP.A.1 Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. (MS-PS4-1)

7.RP.A.2 Recognize and represent proportional relationships between quantities. (MS-PS4-1)

5E Model Lesson 4: Be a Color Detective

Materials:
White coffee filters (cut into 1 inch by 4 inch strips)
Scissors
Rulers
Drawing markers (not-permanent, water -based): brown, yellow, and any other colors
Popsicle sticks (one for each color to be tested)
Beakers or glasses 4 inches or taller (one for each color to be tested)
Water
Binder clips or clothespins
Drying rack or two additional water glasses (one for each color being tested)
Science notebooks/lab packet
Pencils for notetaking
Homemade markers made from lesson 2

Preparation:
1. Carefully cut the coffee filters into strips about 1 inch wide and 3 inches long.
2. Cut at least three strips, one to test brown, one to test yellow, and one to test the homemade marker. Cut more if planning to test additional colors.

Questions:
Will your marker show different colors as you put it to the test?
How do you expect each of the different colors to behave when you test it with paper strips?

Engage/Explain:

1. Students will move into lab groups (self-chosen or teacher-chosen).
2. Instruct students to look at materials list for the lab and make sure they have the materials needed for the lab.
3. Draw a pencil line across the width of each paper strip, about one centimeter from the bottom end.
4. Take the brown marker and paper strip and draw a short line (about one centimeter) on the middle section of the pencil line. Your marker line should not touch the sides of your strip.
5. Use a pencil to write the color of the marker you just used on the top end of the strip. Note: Do not use the marker or any other maker or pen to write on the strips, the color or ink will run/bleed during the test. Answer in notebook: *Why do you think is this a problem?*

6. Repeat steps 3-5 for the yellow marker and any additional colors to be tested.
7. Hold a paper strip next to one of the tall glasses (on the outside of it), aligning the top of the strip with the rim of the glass, then slowly add water to the glass until the level just reaches the bottom of the paper strip. Repeat with the other glass(es). **Keep the strips out of the glasses and away from the water at this time.** Answer in notebook: *What role do you think the water will play?*
8. Fasten the top of the strip (side farthest from the marker line) to the popsicle stick with a binder clip or clothespin.
   Answer in notebook: *Do you expect this color to be the result of a mixture of colors or the result of one color molecule?*
9. Hang the strip in one of the glasses that is partially filled with water by letting the pencil rest on the glass rim. The bottom end of the strip should just touch the water level. If needed, add water to the glass until it is just touching the paper. Note: It is important that the water level stays below the marker line on the strip.
10. Leave the first strip in the glass as you repeat steps 8 and 9 for the remaining colors.
11. Observe, and record observations in notebook, as the water rises up the strips.
    Reflect/Observe: *What happens to the colored lies on the strips? Does the color run up as well? Do you see any color separation?*
12. When the water level reaches about one centimeter from the top (this may take about 10 minutes), remove the sticks with the strips attached from the glasses. If you let the strips run too long, the water can reach the top of the strips and distort your results.
13. Write down your observations. *Did the colors run? Did they separate in different colors? Which colors can you detect? Which colors are on the top (ran quickly) and which are on the bottom (ran slowly)?*
14. Hang strips in empty, dry cups or on a drying rack. Some colors might keep running from the water. You might need longer strips to see the full spectrum of colors.
15. Look at your strips. Answer in notebook:
    How many color components does each marker color have? Can you identify which colors are the result of a mixture of color components and which ones are a result of one hue of color molecule? Are individual color components brightly colored or dull in color? How many different colors can you detect in total?

Explain/Elaborate:

1. Ask students to share their observations with the class. *What were your predictions about brown, yellow, and the other colors you tested? Did the experiment confirm or challenge your predictions?*

Marker companies combine a small subset of color molecules to make a wide range of colors, much like you can mix paints to make different colors. Nature provides a wide range of colors too. Natural yellow in turmeric is the result of several curcuminoid molecules. The brown pigment umber (obtained from dark brown clay; clay comes from the ground) is caused by the combination of two color molecules: iron oxides (rusty-brown color) and manganese oxides (darker black-brown color).

Closure:
In this activity you investigated the color components using coffee filters as chromatography paper. Your color bands might be quite wide and artistic, whereas scientific chromatography paper would yield narrow bands and precise results.

Cleanup lab and materials.

Extend:

a. Test permanent markers using isopropyl rubbing alcohol as a solvent. Do you think similar combinations of color molecules are used to color similar-colored permanent markers?
b. Investigate other art supplies like paint, pastels, inks in a similar way. Be sure to choose a solvent that will dissolve the material for the chromatography test. Isopropyl rubbing alcohol, vegetable oil, and salt water are some examples.

Evaluate:

Formative Monitoring (Questioning/Discussion): Teacher questioning and discussion with groups as they are conducting the lab.

Summative Assessment (Quiz/Project/Report): Combined and completed lab report for lessons 2 and 3. Guidelines in Appendix A

Lesson 5: Light Properties This lesson is from: TeachEngineering. (2019, Feb 28). *Lesson: Three color mystery* (Zielinsky, E. & Faber, C., & Forbes, M.H., Contributors). University of Colorado Boulder. Retrieved from https://www.teachengineering.org/lessons/view/clem_waves_lesson03	**Time Frame: 3-4 x 40 minute class periods**
Grade Level: 6- 8th Grade	
Specific Learning Outcomes:	

<table>
<tr><td colspan="3">Students will be able to explain how objects appear to be a certain color.
Students will be able to explain how monitors and TVs display color.
Students will be able to describe opaque, translucent, and transparent objects.
Students will be able to identify additive and subtractive color phenomena.
Students will be able to explain the difference between additive and subtractive color.</td></tr>
<tr><td colspan="3">Narrative/Background Information:</td></tr>
<tr><td colspan="3">Prior Student Knowledge: Understanding of wave and wave properties and light properties.</td></tr>
<tr><td colspan="3">NGSS Science and Engineering Standards:

MS-PS4-1 Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.

MS-PS4.2 Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.</td></tr>
<tr><td>Science & Engineering Practices:

● Developing and Using Models
● Using Mathematics and Computational Thinking
● Planning and Carrying Out Investigations
● Obtaining, Evaluating, and Communicating Information

Connection to Nature of Science:

Scientific knowledge is based on empirical evidence</td><td>Disciplinary Core Ideas:

PS4.A. Wave Properties
PS4.B. Electromagnetic Radiation

Connections to other DCIs in this grade band: MS.LS1-D</td><td>Crosscutting Concepts:

● Patterns
● Structure and Function

Connections to Engineering, Technology and Applications of Science
● Influence of science, engineering, and technology on society and the natural world.
Connections to Nature of Science:

Science is a human endeavor
● Advances in technology influence the progress of science and science has influenced</td></tr>
</table>

		advances in technology.

Possible Preconceptions/Misconceptions: Students may only know one color system, such as subtractive as it is taught in traditional visual arts programs. Or if they have never had an art class, they may only know color systems as it pertains to RGB and CMYK color properties. Color can often be taught in isolated contexts instead of the integrative nature of color across multiple content areas (science and art). Colors can have emotional and cultural implications as well. This could tie in history and social/emotional impacts of color for a fully integrated learning.

Students may not grasp the concept that white light equals the total of all spectrum colors where in painting in art (brown is the total sum of all colors). Black and white in visual art are neutrals (technically not a color). Black in terms of light is the absence of color. The way color interacts is dependent on the medium in which color is being used.

Connection to Engineering:

Development and use of computer monitors, TV screens, lasers to fiber optics, medical devices.

- Fiber optic cables give us the ability to communicate and transmit data over long distances at high rates by guiding light through refraction.

- Portable glucose monitors are one example of medical devices that use color change as a way to detect body chemicals. Diabetes patients can monitor their glucose levels and increase their quality of life. Interior designers and digital designers use color interactions to create harmonious schemes used in advertisements or to create aesthetically pleasing rooms/environments**.**

- The name Blu-ray Disc derives from the blue-violet laser used to read the disc. While a standard DVD uses a 650 nanometer red laser, Blu-ray uses a shorter wavelength, a 405 nm blue-violet laser, and allows for almost ten times more data storage than a DVD. The first lasers to read media were red lasers.

CCSS ELA and Math Standards:
Common Core State Standards Connections:
ELA/Literacy -

RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts. (MS-PS4-3)

RST.6-8.2 Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions. (MS-PS4-3)

RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-PS4-3)

WHST.6-8.9	Draw evidence from informational texts to support analysis, reflection, and research. (MS-PS4-3)
SL.8.5	Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (MS-PS4-1), (MS-PS4-2)
Mathematics -	
MP.2	Reason abstractly and quantitatively. (MS-PS4-1)
MP.4	Model with mathematics. (MS-PS4-1)
6.RP.A.1	Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. (MS-PS4-1)
6.RP.A.3	Use ratio and rate reasoning to solve real-world and mathematical problems. (MS-PS4-1)
7.RP.A.2	Recognize and represent proportional relationships between quantities. (MS-PS4-1)f
8.F.A.3	Interpret the equation y = mx + b as defining a linear function, whose graph is a straight line; give examples of functions that are not linear. (MS-PS4-1)

(https://www.nextgenscience.org/topic-arrangement/mswaves-and-electromagnetic-radiation)

National Core Visual Arts Anchor Standards:

Anchor Standard 1: Generate and conceptualize artistic ideas and work.
Anchor Standard 2: Organize and develop artistic ideas and work.
Anchor Standard 3: Refine and complete artistic work.
Anchor Standard 4: Select, analyze, and, interpret artistic work for presentation.
Anchor Standard 5: Develop and refine artistic techniques and work for presentation.
Anchor Standard 6: Convey meaning through the presentation of artistic work.
Anchor Standard 7: Perceive and analyze artistic work.
Anchor Standard 8: Interpret intent and meaning in artistic work
Anchor Standard 9: Apply criteria to evaluate artistic work.
Anchor Standard 10: Synthesize and relate knowledge and personal experiences to make art.
Anchor Standard 11: Relate artistic ideas and works with societal, cultural, and historical content to deepen understanding.

Vocabulary:
additive color system, concave or negative lens, convex or positive lens, cyan, laser, opaque, prism, translucent, transparent

5E Model Lesson 5: Light Properties

Lesson 5 Day 1

Preparation (before lesson):

1. Prepare red cabbage extract by shredding some cabbage into a bowl and pour in enough boiling water to cover the cabbage.

2. Let it sit for 10 minutes or longer (the longer it sits the better.
3. Strain out the cabbage and keep the liquid.

Engage: Watch clip from Brain Games, Season 3 Episode In Living Color (stop at 3:33) Available for purchase on YouTube

We will investigate more about color that will help us understand why the black and white image turned to color.

Questions:

a. How would you explain this phenomenon?
b. What do you think is happening?

(students will discover over the next couple of lessons progresses what is happening)

Explore/Explain:

Before Class Starts: Make sure all the supplies are prepared and organized.

1. Hand out Color Magic Demo Worksheet to each student for the demonstrations.
2. For the three color magic demonstrations, write down your initial observations, your predictions about what you think will happen and your final observations.
3. Make sure to note which demonstrations represented the additive and subtractive color systems.

Demonstrate #1 pH Change and Color-Red Cabbage Indicator Demo (subtractive color system)

Materials:

- half-filled glass of water
- half-filled glass of vinegar
- half-filled glass of general cleaning ammonia (available at most grocery stores)
- red cabbage extract (see preparation instructions)

Demonstration with Students: Color Indicator

1. Ask students to make predictions on their worksheets about what they think will happen when you pour the cabbage extract into each cup. Ask for volunteers to share their predictions with the class.
2. Pour some cabbage extract into the first cup (water)
3. Ask students to record their observations and explanations for what happens.
4. Pour some of the extract into the second cup (vinegar).
5. Ask students to record their observations and explanations for what happens.
6. Ask students if they would like to change their original prediction about what will happen when the extract is poured into the third cup.
7. Pour some of the extract into the third cup (ammonia).
8. Have students record their observations and explanations for what happens.
9. As a class, have students share their explanations for what happened. What is the difference between the liquid in the three cups? (As for volunteers to come up and smell (by wafting) the three liquids to figure out why the color changes occurred).

(Vinegar contains acetic acid and turns reddish when cabbage extract is added)
(Ammonia is a base and turns greenish when cabbage extract is added)

(Likely the end of day 1) Have students complete exit slip.

Lesson 5 Day 2

Preparation Before Class Starts: Make sure all the supplies are prepared and organized for demonstration #2 and #3. Write a message on the goldenrod paper using wax (such as paraffin)

Demonstration #3 Preparation (before class session):

- Mix 0.23g luminol in 500 ml 0.1M sodium hydroxide (NaOH)
- Make either of the following two solutions and set aside 100 ml of it.
    1. bleach solution: 50 ml bleach to 500 ml water OR
    2. hydrogen peroxide solution: 25 ml 3% hydrogen peroxide in 50 ml water
- Put 100 ml of the luminol solution in a 400 ml beaker.

Explore/Explain:

Beginning of Class Reminders:

1. Students need to have their worksheets to continue to record predictions, observations and explanations.
2. For the three color magic demonstrations, write down your initial observations, your predictions about what you think will happen and your final observations.
3. Make sure to note which demonstrations represented the additive and subtractive color systems.

Materials:

- sheet of goldenrod paper
- wax
- spray bottle of window cleaner containing ammonia

Demonstration #2 with students: Goldenrod Paper

1. Position the goldenrod paper so that the entire class can see it.
2. Have students record on their worksheet their original observations and predictions about what will happen when the paper is sprayed.
3. Spray some of the window cleaner on the paper.
4. Ask students to record on their worksheets their final observations and explanations about what happens.
5. Engage the class in a discussion about the demonstration they just saw.

(The paper changes to a red color because the dye in the paper is sensitive to bases)

Demonstration #3: Luminol Demo

Materials:

- 0.23g luminol (available at any chemistry supply store)
- 500 ml 0.1M sodium hydroxide (available at any chemistry supply store)
- 50 ml bleach in 500 ml water or 25 ml of 3% hydrogen peroxide in 50ml water
- 400 ml beaker

Demonstration #3 with students:

1. Have students record on their worksheets their initial observations about the beaker of liquid.
2. Take the 400 ml beaker containing the luminol solution.
3. Darken the room and add 100 ml of the bleach or peroxide solution
4. Ask the students to record their observations and explanations for what happens.
5. Engage the class in a discussion they just saw.

Conclude by asking students which demonstrations they thought represented additive and subtractive color phenomena. Ask other questions, as provided in the assessment section and lesson closure.

Who can tell me the difference between opaque, translucent and transparent objects? What are the differences between additive and subtractive color systems?
Now that you are an expert in understanding objects and colors, tell me, what are some ways this might be applied in your everyday lives? (Listen to ides) What about computer monitors, TV screens, fiber optic cables, medical tests, print or digital advertisements? These are all common examples in which engineers, designers and artists apply their understanding of light and color to design all types of useful products and tools for us to use.

Lesson 5 Day 3

Explore/Explain:

1. Hand out “All About Light- Notes Outline (Appendix A).
2. Complete lecture using presentation on the properties of light (Appendix A).
3. Students need to complete handout while listening to the lecture
4. Once lecture completed, have students in groups of 3-4 and have them compare notes and fill in any gaps of things they may have missed.

Elaborate (Applications and Extensions): None for this lesson.

Evaluate:

Formative Monitoring (Questioning/Discussion): During the lecture, have students complete the All About Light-Notes Outline (Appendix A) and refer to it for visuals that supplement the lecture material. Then gauge understanding by having students flip their notes upside down (blank side up). Ask questions about the material on the notes sheet.

Summative Assessment (Quiz/Project/Report): After the lecture, conduct the three demos.

Have students complete the Color Magic Demos Worksheet (Appendix A), including all questions. Evaluate students answers to see how well they applied what they have learned. Students will also create a light painting project in groups to use light to create art. After the demos, lead a class discussion to see how well students predicted the results and asking them which demos they thought represented additive and subtractive color phenomenon. (Figure 5 on https://www.teachengineering.org/lessons/view/clem_waves_lesson03) Additive colors can be seen in the dark because light is emitted directly from the source. Subtractive color needs external light to be seen. Then proceed into the light painting projects.

Lesson 6: Color Systems: RGB, RYB, and CYMK		**Time Frame: 2-3 x 40 minute periods**
Grade Level: 6-8th Grade		
Brief Description of Lesson: In this lesson students are exploring the three color systems, their similarities, and their differences through three hands-on experiences. This lesson is a merging of physical science with art through color.		
Specific Learning Outcomes: Students will be able to identify a RYB color system and its applications/uses. Students will be able to identify an RGB color system and its applications/uses. Students will be able to identify a CMYK color system and its applications/uses. Students will be able to distinguish the difference between an additive and subtractive color system.		
Narrative/Background Information: This could be used to kick-off a study of waves and electromagnetic radiation or be a lab at the culmination of a unit or a lab somewhere in the middle. Students may need an understanding of Wave & Wave Properties, Light Properties, and the Electromagnetic Spectrum prior to this lab.		
Prior Student Knowledge: Based on students' previous learning experiences they may only know of one out of the three color systems.		
Science & Engineering Practices: • Developing and Using Models • Planning and Carrying Out Investigations • Obtaining, Evaluating, and Communicating	**Disciplinary Core Ideas:** PS4.A. Wave Properties PS4.B. Electromagnetic Radiation PS4.C Information Technologies and Instrumentation	**Crosscutting Concepts:** • Patterns • Structure and Function • Cause and Effect Connections to Engineering, Technology, and Applications of Science:

Information Connection to Nature of Science. Scientific knowledge is based on empirical evidence.		● Modern civilization depends on major technological systems. ● Engineers continuously modify these technological systems by applying scientific knowledge and engineering design practices to increase benefits while decreasing costs and risks. The interdependence of Science, Engineering, and Technology: ● Science and engineering complement each other in the cycle known as research and development
Possible Preconceptions/Misconceptions: They may also believe that only one system is the “right” system of color.		
NGSS Science and Engineering Standards: MS-PS4-1 Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave. MS-PS4.2 Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.		
CCSS ELA and Math Standards: ELA RST.6-8-1 Cite specific textual evidence to support analysis of science and technical subjects. (MS-PS4-3) RST.6-8.2 Determine the central ideas or conclusion; provide an accurate summary of the text distinct from prior knowledge or opinions. (MS-PS4-3) RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-PS4-3) WHST.6-8.9 Draw evidence from informational texts to support analysis, reflection, and		

research. (MS-PS4-3)
SL.8.5 Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (MS-PS4-1) (MS-PS4-2)

Math

MP.2 Reason abstractly and quantitatively. (MS-PS4-1)
MP.4 Model with mathematics. (MS-PS4-1)
6.RP.A.1 Understand the concept of a ration and use ration language to describe a ration relationship between two quantities (MS-PS4-1)
6.RP.A.3 Use ratio and rate reasoning to solve real-world and mathematical problems. (MS-PS4-1)
7.RP.A.2 Recognize and represent proportional relationships between quantities. (MS-PS4-1)

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5E Model Lesson 6: Day 1 Red Yellow Blue (RYB) Lab

Engage:

Lesson 6 Day 1: Watch YouTube Clips: Ok Go-The One Moment (2016) https://youtu.be/QvW61K2s0tA**.** The band OK GO is very unique in the music videos they create. Their work is a great example of science, technology, engineering, math, and art merging together. This video involves using color/paint and fun to watch. Another video that is more elementary level but could be used by OK GO is Sesame Street-Ok Go-Three Primary Colors (2012) https://youtu.be/yu44JRTIxSQ.

Before starting: Have students make a prediction about color and color mixing in light, paint, and ink in their lab packet.

Questions:

How many color systems are there? (1, 2, 3, more than three?) What are these color systems called? What color inks are used in a color printer? What are the primary colors used in painting a picture? How is color created on a TV or computer screen? (The purpose of these questions are to draw attention to the idea that there are different uses, applications, and systems of color).

Optional: Watch Video

VolkArt. (2015, Nov 3). *Color and light 101: CMYK and subtractive color systems*. [Video File]. Retrieved from https://www.youtube.com/watch?v=mqXyjOsq2Ck&feature=youtu.be

Lesson 6 Day 1 Explore/Explain:

Before Class Starts:
Prepare and set up the lab for the day. Prepare enough materials for students to work in groups of 3-4.

Divide the class into groups of three to four students.

Materials for Lab 1:
Worksheets
Paint Brushes
Aprons
Water Cups
Paper Towel
Paint trays/Palettes
Red Paint
Blue Paint
Yellow Paint
Green Paint

Lesson 6 Day 1 Lab: Red Yellow Blue Paint (this also works similarly to cyan magenta and yellow):

Part = One small scoop or dip of brush into the paint. (working on more ratio than exactness)

1. Have students mix one part of red to two parts of yellow. Paint color on the worksheet
2. Have students mix one part of blue to two parts of red paint. Paint color on the worksheet.
3. Have students mix one part of blue into two parts of yellow paint. Paint color on the worksheet.
4. Mix one part green and one part red together. Paint a swatch and write down in your packet what you observed.
5. Mix one part yellow, one part blue, and one part of red together. Paint a swatch and write down what you observed.

Allow approximately 10 minutes for the cleaning up of materials (brushes, palettes, and workstations).

If students are done early with clean up, they can explore this Scratch program. https://scratch.mit.edu/projects/296441748/ (Ossey, 2019-b)

Elaborate (Applications and Extensions): Hang large white roll paper on the wall. Draw a large grid on it. After students complete the lab activity, they can investigate inventing colors, paint the swatch in the grid square and give their invented color a name. What would happen if they took 3 dabs of blue and mixed it with one dab of green or three dabs of green with one dab of blue? Same color or different? Put out black and white paint for this activity.

Evaluate:

Formative Monitoring (Questioning/Discussion):
Day 1: Teacher observations of student participation, discussions with groups and individual students as they work on the lab, Note Taking/Reflection of Lab in the packet (Appendix A). Students can also explore this site: http://web.mst.edu/~gbert/color/colorimetry.html?843#top

Summative Assessment (Quiz/Project/Report):
After the three labs are completed students will complete a formal lab report for summative assessment. Instructions are in Appendix A.

Rubric for the lab report in Appendix A.

5E Model Lesson 6: Day 2 RGB and CMYK Labs

Engage:

Lesson 6 Day 2: Watch video on Additive Color Systems

VolkArt. (2015, July 15). *Color and light 101: RGB and additive color systems*. [Video File]. Retrieved from https://youtu.be/WF_YHumMiRU.

Divide the class into groups of three to four students.

Lesson 6 Day 2 Explore/Explain:

Lesson 6 Day 2 Lab 2:

Materials:
- Red LED (brighter the better)
- Blue LED (brighter the better)

- Green LED (brighter the better)
- Watch Battery (x3)
- Electrical Tape

Or

- Red LED (brighter the better)
- Blue LED (brighter the better)
- Green LED (brighter the better)
- 9V battery (x3)
- Resistor 470 W (x3)
- Switch (x3)
- White Wall Space/White Paper to Shine Lights on it

Directions:

1. Have the students put the LED lights over each battery and wrapped in electrical tape. (Positive prong of LED light to the positive side of the battery).
   (half-dim the lights if needed to create a semi-dark environment)
   
2. Shine LEDs on a white wall or white paper in combinations according to the instructions in the lab packet.
3. Have the students investigate to try and create the different combinations of LEDs to produce the three secondary colors. (magenta, yellow, cyan)
4. Combine all three and see what color is created.
5. Change the amount of illumination of each of the LEDs by varying the distance to see if other colors can be created. For example, red and green in equal parts produce yellow. What is necessary in order to produce orange?
6. Students will then go to https://phet.colorado.edu/sims/html/color-vision/latest/color-vision_en.html and explore the simulator.

   Students will record observations in science notebooks.

Lesson 6 Day 2 Lab 3:

The Day 2 Lab 3 is from:

Exploratorium Teacher Institute. (n.d.). *Science snacks. The three little pigments.* Retrieved from https://www.exploratorium.edu/snacks/three-little-pigments.

Materials Needed:

Click on each link below and print a copy of each picture on a separate sheet of transparent acetate. (Note: you'll probably have to insert the acetate sheets into your printer manually.) If your printer cannot print on acetate, your local copy center may be able to help transfer these images onto transparencies.

1 set per group (Exploratorium Teacher Institute, n.d.):

- Cyan acetate
- Yellow acetate
- Magenta acetate
- Black acetate
- Full-color acetate

Optional: You can print a classroom set of images (multiple images on the same sheet) by going to the Exploratorium website.

1. Align the cyan, yellow, magenta, and black acetates and hold them up to your light source. (Be sure not to look directly at the sun!) What do you see?
2. Align various combinations of acetates. Now, what do you see? Compare your stack of four colored acetates to the full-color acetate.

Interactive RGB Color Experience:
https://www.khanacademy.org/partner-content/pixar/color/color-101/e/rgb-color

Elaborate (Applications and Extensions): Create artworks using paint (RYB) or through Photoshop (CMYK or RGB). Or they could investigate "time arts" using light, light painting, and videography. This lesson could tie in the use of Green Screen technology.

Evaluate:
Formative Monitoring (Questioning/Discussion):
Day 2: Teacher observations of student participation, discussions with groups and individual students as they work on the lab, Note Taking/Reflection of Lab in the packet (Appendix A)

Exit Ticket: Students will take a three-question quiz using a Scratch Quiz on color. The link is here: https://scratch.mit.edu/projects/281762318/ (Ossey, 2019-a)

When students complete the quiz, they will take a screenshot of their final score and email the screenshot to the teacher. This screenshot could also be used as an exit ticket as the students leave.

Summative Assessment (Quiz/Project/Report):
After the three labs are completed students will complete a formal lab report for summative assessment. Instructions are in Appendix A.

Rubric for the lab report in Appendix A.

Lesson 7: Color Matters	**Time Frame: 1 x 40 minute class period**
Grade Level: 6-8th Grade	

Brief Description of Lesson: This lesson could be modified in a variety of ways to address other aspects of color using colormatters.com and https://education.seattlepi.com/not-list-black-white-colors-physics-3426.html. This website addresses the cultural, psychological, and biological aspects of color. If time is running short to accomplish lessons 1-6 in this unit, this lesson could be left out or it could be used with students who are advanced in their learning as an extension of the unit.

https://colormatters.com/color-and-design/are-black-and-white-colors

https://colormatters.com/color-and-design/are-black-and-white-colors/more-about-black-white

https://education.seattlepi.com/not-list-black-white-colors-physics-3426.html

http://www.tkbridalatlanta.com/7-different-wedding-dress-color-from-around-the-world/

Specific Learning Outcomes:
Students will be able to identify the theories behind black and white color.
Students will be able to make a claim and support their claim with evidence.
Students will be able to identify the role of colors in different cultures.

Narrative/Background Information:

Prior Student Knowledge: Lesson 1-8 of this unit.

Vocabulary:
achromatic: without color. (white, grey and black) have lightness but no hue or saturation.
chroma: the purity of a color, or its freedom from white or gray. Intensity of distinctive hue; saturation of a color.

Science & Engineering Practices:	**Disciplinary Core Ideas:**	**Crosscutting Concepts:**

• Developing and Using Models • Planning and Carrying Out Investigations • Obtaining, Evaluating, and Communicating Information Connection to Nature of Science. Scientific knowledge is based on empirical evidence	PS4.A. Wave Properties PS4.B. Electromagnetic Radiation Connections to other DCIs in this grade band: MS.LS1-D	• Patterns • Structure and Function Connections to Engineering, Technology and Applications of Science • Influence of science, engineering, and technology on society and the natural world. Connections to Nature of Science: Science is a human endeavor • Advances in technology influence the progress of science and science has influenced advances in technology.

Possible Preconceptions/Misconceptions: All cultures wear white wedding dresses or view colors the same way. Colors have different cultural, social and psychological interpretations.

NGSS Science and Engineering Standards:

MS-PS4-1 Use mathematical representations to describe a simple model for waves that includes how the amplitude of a wave is related to the energy in a wave.

MS-PS4.2 Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

CCSS ELA and Math Standards:

RST.6-8.9 Compare and contrast the information gained from experiments, simulations, video, or multimedia sources with that gained from reading a text on the same topic. (MS-PS4-3)

WHST.6-8.9 Draw evidence from informational texts to support analysis, reflection, and research. (MS-PS4-3)

SL.8.5 Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (MS-PS4-1),(MS-PS4-2)

MP.2 Reason abstractly and quantitatively. (MS-PS4-1)

6.RP.A.1 Understand the concept of a ratio and use ratio language to describe a ratio relationship between two quantities. (MS-PS4-1)

7.RP.A.2 Recognize and represent proportional relationships between quantities. (MS-PS4-1)

National Core Visual Arts Anchor Standards:

Anchor Standard 1: Generate and conceptualize artistic ideas and work.
Anchor Standard 2: Organize and develop artistic ideas and work.
Anchor Standard 3: Refine and complete artistic work.
Anchor Standard 4: Select, analyze, and, interpret artistic work for presentation.
Anchor Standard 5: Develop and refine artistic techniques and work for presentation.
Anchor Standard 6: Convey meaning through the presentation of artistic work.
Anchor Standard 7: Perceive and analyze artistic work.
Anchor Standard 8: Interpret intent and meaning in artistic work
Anchor Standard 9: Apply criteria to evaluate artistic work.
Anchor Standard 10: Synthesize and relate knowledge and personal experiences to make art.
Anchor Standard 11: Relate artistic ideas and works with societal, cultural, and historical content to deepen understanding.

Plan 5E Model Lesson 7: Color Matters

Engage/Questions: We spent all this time talking about colors. What about Black & White? Are they colors too? Give a thumbs up/ down if you think black is a color? Ask for volunteers to state why they gave a thumbs up/thumbs down? What about white (repeat thumbs up/thumbs down)? Ask for volunteers to state their reasons for thumbs up/thumbs down.

Explore/Engage:
Now we are going to do some investigations on whether black and white are considered colors? Directions to students: Go to the websites at the top of your “What about Black and White” worksheet and answer the following questions.

1. What do scientists say about black and white as colors? Why do they believe this?
2. What do artists say about black and white as colors? Why do they believe this?
3. What are your own thoughts about black and white? Should they be considered colors?

Why or why not? Give evidence to support your claim from the websites. 4. Typically, in the United States, wedding dresses are white or off-white, do you know why? What countries wear a color besides white? Why is this color valued in that country? Turn in worksheets once completed.
Elaborate (Applications and Extensions): The investigation could include colors like brown and peach which are colors made up of more than 2 colors. Students could investigate classifying colors especially ones with names like Topaz, Opal, Aubergine, Vermillion, etc. The band, Ok Go, uses a lot of STEAM based ideas to engineer unique music videos. Examples are *The One Moment* (Ok Go, 2016) and *Obsession* (Ok Go, 2017) music videos. They also incorporate a lot of color and unique uses of color to create visual effects.
Evaluate: **Formative Monitoring (Questioning/Discussion):** Observations of group discussions. **Summative Assessment (Quiz/Project/Report):** Completed worksheet.

Lesson 8: Painting with Light (Light Painting) Concept Example: LightPaintingPhoto. (2017, Aug 23). *Light painting tutorial: How to paint a spiral*. [Video File]. Retrieved from https://youtu.be/I73pp-6XRMY	**Time Frame:** 3-5 x 40 minute class periods. Can be adjusted based on time available.
Grade Level: 6-8th Grade	
Brief Description of Lesson: In this lesson students will interact with light (flashlights and light wands) to create images using a slow shutter speed on a camera (digital SLR, cell phone or iPad/tablet).	
Specific Learning Outcomes: Students will be able to identify the parts of a camera. Students will be able to identify the role of shutter speed in taking photographs. Students will be able to identify the role of flash and natural light in taking photographs. Students will be able to record and document the path of light through photography.	
Narrative/Background Information: Students have engaged in the lessons: three color mystery, waves and wave properties, and light properties before engaging in lessons	
Prior Student Knowledge: Students rely on their prior knowledge of using a camera (digital,	

<table>
<tr><td colspan="3">iPad, cell phone, etc.). Students will build in prior knowledge to learn about different features of camera settings.

Erinbordeau. (n.d.). Photography. [Quizlet]. Retrieved from https://quizlet.com/215236642/photography-flash-cards/.</td></tr>
<tr><td>Science & Engineering Practices:

● Planning and Carrying Out Investigations
● Obtaining, Evaluating, and Communicating Information</td><td>Disciplinary Core Ideas:

PS4.A. Wave Properties
PS4.B. Electromagnetic Radiation</td><td>Crosscutting Concepts:
● Patterns
● Structure and Function

Connections to Engineering, Technology and Applications of Science
● Influence of science, engineering, and technology on society and the natural world.
Connections to Nature of Science:

Science is a human endeavor
● Advances in technology influence the progress of science and science has influenced advances in technology.</td></tr>
<tr><td colspan="3">Possible Preconceptions/Misconceptions: Possible misconceptions may be that students only see cameras as a point and shoot tool and be unaware that there are settings that can be used to create unique images as well as adjust to the environment where they photo is being taken.</td></tr>
<tr><td colspan="3">National Core Visual Arts Anchor Standards:

Anchor Standard 1: Generate and conceptualize artistic ideas and work.
Anchor Standard 2: Organize and develop artistic ideas and work.
Anchor Standard 3: Refine and complete artistic work.
Anchor Standard 4: Select, analyze, and, interpret artistic work for presentation.
Anchor Standard 5: Develop and refine artistic techniques and work for presentation.
Anchor Standard 6: Convey meaning through the presentation of artistic work.
Anchor Standard 7: Perceive and analyze artistic work.
Anchor Standard 8: Interpret intent and meaning in artistic work
Anchor Standard 9: Apply criteria to evaluate artistic work.
Anchor Standard 10: Synthesize and relate knowledge and personal experiences to make art.</td></tr>
</table>

Anchor Standard 11: Relate artistic ideas and works with societal, cultural, and historical content to deepen understanding.

5E Model Lesson 8: Painting with Light (Light Painting)

Questions: What color light would be the most visible in the dark? How do you think a camera documents the movement of light without a video recording?

Has anyone taken a photo in a dark environment? What happened in the photo? Has anyone taken a photo where the sun or a lamp is behind the subject matter (people, object, landmark etc.) What happened as a result? (wait for student stories)
Show images of backlit photos, low-lighting/night photos, etc.

Light Painting Slide Deck (Appendix A)

Lighting plays a key role in how photographs are taken and impacts the quality of the final image.

Engage: View slideshow of images created as a result of painting with light and/or show you tube clip of light painting.

Explore/Explain: Integrative Learning Experience between Science, Engineering and Art

Materials:
iPads/Cell Phones/ Digital Cameras (need to have the ability to adjust shutter speed)
Flashlights
Light wands (lightpaintingtools.com)
Tripods
Black paper/fabric to block out daylight from the classroom

Day 1

1. Review the parts of the camera from a prior photography lesson.
2. Group students in a minimum of 3 students per group. I'd say a max of 5 is appropriate.
3. May need to move classroom furniture around open up some space.
4. Ask for 2 volunteers to help create a demonstration of how the light painting works.
5. Assign each group equipment (1 flashlight, light wands, camera/ipad, tripod).
6. Allow for the first day in class to be an experimentation of the different ways to use the light with the camera.
7. Distribute exit slips.
8. Clean up about 5 minutes before the end of class. Collect exit slips (Appendix A).
9. Recommend students look up tutorials on YouTube for ideas for homework.

Days 2-5

1. Review troubleshooting issues as a result of issues stated on the exit slips.

2. (Repeat of Day 1: Steps 5-8) Allow groups to gather and begin working on creating three different images.
    a. Words: Create a light painting that displays a positive or motivating word (each student in the group should have an image where they are drawing the word) Or each member in the group can write their name (must be written back words)
    b. Create an image using spirals or swirls of some kind.
    c. Invent your own image/light painting technique.

3. When completed with all images, students must import the photos from the camera to the Mac Books and place them in the google folder with their group number on it.
4. Allow 5 minutes at the end of each class period for cleaning up of equipment.
5. Once all groups are finished move on to next lesson. If needed, groups that are slow to complete activity may need to come in before school, supervised study, lunch or after school to finish images.

Elaborate (Applications and Extensions): The challenge to this project is that it needs a dark environment. Students could choose to continue to investigate this process at home with their own tools and cameras at night.

Photography in Space can be an extension.

Jarrell, E.M. (2013, August 13). *The science of photography*. NASA's Goddard Space Flight Center. Retrieved from https://www.nasa.gov/content/goddard/the-science-of-photography/.

Evaluate:

Formative Monitoring (Questioning/Discussion): Conferencing with each group as they are working. Exit slips (Appendix A).

Summative Assessment (Quiz/Project/Report): Final Light Painting images shared in Google Folder

References

99 Designs. (n.d.). *The fundamentals of understanding color theory*. Retrieved from https://99designs.com/blog/tips/the-7-step-guide-to-understanding-color-theory/.

Adams, G. (2016, March 30). *Lecture 116 - Color Theory (Spring 2016 - Evening).* [Video File]. Retrieved from https://youtu.be/26pSU2UHznU.

Agee, S., & De Brabandere, S. (2020, January 12). *Make Your Own Markers.* Retrieved from https://www.sciencebuddies.org/science-fair-projects/project-ideas/Chem_p014/chemistry/make-your-own-markers.

Bertrand, G.L. (2008). *Colorimetry*. [Simulation]. Missouri University of Science and Technology. Retrieved from http://web.mst.edu/~gbert/color/colorimetry.html?843#top.

CK-12 Foundation. (2016, March 1). *Neon lights*. [Simulation]. Retrieved from https://interactives.ck12.org/simulations/chemistry/bohr-model-of-electron/app/index.html?lang=en&referrer=ck12Launcher&backUrl=https://interactives.ck12.org/simulations/chemistry.html&_ga=2.246041922.776173425.1582986640-1044991653.1582212235**.**

Color Matters. (2019, April 13). Retrieved from https://colormatters.com/.

The Concord Consortium. (2020). *Spectroscopy.* [Simulation]. Retrieved from https://learn.concord.org/resources/163/spectroscopy.

Delsol, J. (2016, Sep 27). *Munsell Soil Color Chart*. [Video File]. Retrieved from https://youtu.be/826cPcxeULw.

Digiart Tutorials. (2015, November 3). *Color and Light 101: CMYK and subtractive color systems.* [Video File]. Retrieved from https://youtu.be/mqXyjOsq2Ck

Digiart Tutorials. (2015, July 17). *Color and Light 101: RGB and additive color systems.* [Video File]. Retrieved from https://youtu.be/WF_YHumMiRU

Erinbordeau. (n.d.). *Photography*. [Quizlet]. Retrieved from https://quizlet.com/215236642/photography-flash-cards/.

Exploratorium Teacher Institute. (n.d.). *Science snacks. The three little pigments.* Retrieved from https://www.exploratorium.edu/snacks/three-little-pigments

International Society for Technology Education (ISTE). (2016). *ISTE standards for students*. Retrieved from https://www.iste.org/standards.

Jarrell, E.M. (2013, August 13). *The science of photography*. NASA's Goddard Space Flight Center. Retrieved from https://www.nasa.gov/content/goddard/the-science-of-photography/.

Khan Academy. (n.d.-c). *The electromagnetic spectrum*. [Video File]. Retrieved from https://www.khanacademy.org/partner-content/nova/sunandsolar/v/electromagneticspectrum.

Khan Academy. (n.d.-f). *RGB Color Matching*. [Interactive Webtool]. Retrieved from https://www.khanacademy.org/partner-content/pixar/color/color-101/e/rgb-color.

Kingston Technology. (2015, Sep 10). *Light painting tutorial- Camera settings for creative photos - Kingston indieHACK Ep. 4.* [Video File]. Retrieved from https://youtu.be/CFlgMdiZHhc.

LightPaintingPhoto. (2017, Aug 23). *Light painting tutorial: How to paint a spiral*. [Video File]. Retrieved from https://youtu.be/I73pp-6XRMY.

National Coalition for Core Arts Standards. (2014). *National core arts standards*. Dover, DE: State Education Agency Directors of Arts Education. Retrieved from www.nationalcoreartsstandards.org.

National Geographic. (2014, January 14). *In living color.* [Video File]. Retrieved from https://youtu.be/TaOQTtpFOik.

National Geographic India.(2015, March 19). *Colour illusion*. [Video File]. Retrieved from https://youtu.be/QnQg2ij5wM8.

National Governors Association for Best Practices & Council of Chief State School Officers. (2010). C*ommon core state standards*. Washington, DC: National Governors Association Center for Best Practices & Council of Chief State School Officers. Retrieved from www.corestandards.org.

National Research Council (U.S.). Committee on a Conceptual Framework for New K-12 Science Education Standards. (2012). *A framework for k-12 science education : Practices, crosscutting concepts, and core ideas*. Washington, D.C.: National Academies Press. Retrieved from https://www.nap.edu/catalog/13165/a-framework-for-k-12-science-education-practices-crosscutting-concepts.

The Next Generation Science Standards. (n.d). *MS Waves and electromagnetic radiation standards*. Retrieved from https://www.nextgenscience.org/topic-arrangement/mswaves-and-electromagnetic-radiation.

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By State*s. Washington, DC: The National Academies Press. Retrieved from https://www.nextgenscience.org/

Ok Go. (2016, November 14). *The one moment.* [Video File]. Retrieved from https://youtu.be/QvW61K2s0tA.

Ok Go. (2017, November 23). *Obsession*. [Video File]. Retrieved from https://youtu.be/LgmxMuW6Fsc.

Ossey, A.E. (2019, January 23-a). *OsseyQuiz*. [Scratch by MIT program]. Retrieved https://scratch.mit.edu/projects/281762318/

Ossey, A.E. (2019, March 22-b). *OsseyInteractiveColorMixing.* [Scratch by MIT program]. Retrieved from https://scratch.mit.edu/projects/296441748/.

PhET Interactive Simulations. (2020). *Molecules and light*. [Simulation]. University of Colorado Boulder. Retrieved from https://phet.colorado.edu/en/simulation/molecules-and-light

PhET Interactive Simulations. (2020). *Photoelectric effect.* [Simulation]. University of Colorado Boulder. Retrieved from https://phet.colorado.edu/en/simulation/legacy/photoelectric.

PhET Interactive Simulations. (2020). *Color Vision.* [Simulation]. University of Colorado Boulder. Retrieved from https://phet.colorado.edu/sims/html/color-vision/latest/color-vision_en.html.

Professor Ross. (2014, June 18). *Complimentary Afterimage*. [Video File]. Retrieved from https://youtu.be/qIX1ASKKwlM.

Quizlet. (2019, April 12). *Photography* [Quizlet Activities]. Retrieved from https://quizlet.com/215236642/photography-flash-cards/.

Science Buddies. (2015, May 14). *Chromatography: Be a color detective*. Retrieved from https://www.scientificamerican.com/article/chromatography-be-a-color-detective/.

Sesame Street. (2012, January 30). *Sesame street: Ok Go- Three primary colors*. [Video File]. Retrieved from https://youtu.be/yu44JRTIxSQ.

TeachEngineering. (2019, Feb 28). *Lesson: Light properties* (Zielinsky, E., Faber, C., & Forbes, M.H., Contributors). University of Colorado Boulder. Retrieved from https://www.teachengineering.org/lessons/view/clem_waves_lesson03.

TeachEngineering. (2019, Nov 21). *Lesson: Waves and wave properties* (Zielinsky, E., Faber, C., & Forbes, M.H., Contributors). University of Colorado Boulder. Retrieved from https://www.teachengineering.org/lessons/view/clem_waves_lesson02.

TeachEngineering. (2019, Dec 4*). Lesson: Exploring the electromagnetic spectrum* (Zielinsky, E. & Faber, C., Contributors). University of Colorado Boulder. Retrieved from https://www.teachengineering.org/lessons/view/clem_waves_lesson04.

VolkArt. (2015, July 15). *Color and light 101: RGB and additive color systems*. [Video File]. Retrieved from https://youtu.be/WF_YHumMiRU.

VolkArt. (2015, Nov 3). *Color and light 101: CMYK and subtractive color systems*. [Video File]. Retrieved from https://www.youtube.com/watch?v=mqXyjOsq2Ck&feature=youtu.be

Appendix A

Name: Project: Period:

Standard 1: Demonstrates an understanding of how ideas, materials, methods, and approaches, are used to create works of art.		
Creativity and Vision	**Craft and Technique**	**Composition and Design**
Student envisions and expresses their own ideas. Student researches and brainstorms ideas that are original even when inspired by others. The student engages in sketching and developing ideas to improve design choices.	Exhibits care and attention to detail in technique and craftsmanship The student demonstrates the correct techniques and use of materials. The student demonstrates the appropriate elements of art (line, shape, color, value, color, space and texture) pertaining to the project.	Design principles are applied (contrast, pattern, balance, emphasis, movement, unity, variety, rhythm) Design meets project parameters. Students engaged, persisted, stretched and explored through design challenges.

Points	**Proficiency Scale**
10	**Exemplary**: The student independently demonstrated creativity and vision. The student independently went above and beyond the expectations of the assignment. Work is original. The student independently demonstrated consistent care in materials, technique, attention to detail and craft. The student independently went above and beyond the expectations of the assignment in the implementation of the elements of art. The student independently demonstrated consistent design principles with a composition that fills the page. The composition goes above the minimum expectations for the assignment.
9.5	The student is in-between exemplary and secure level work.
9	**Secure**: The student independently demonstrated the expectations of creativity and vision. Work is original. The student independently demonstrates consistent care in the materials, technique, attentional to detail, and craft of the assignment. The student demonstrated the expected elements of art. The student independently demonstrated consistent design principles with a composition that fills the page and meets the minimum expectations for the assignment.
8.5	The student is approaching/secure and closer to the secure end of learning.
8	The student is approaching/secure and closer to the approaching end of learning.
7.5	**Approaching**: The student demonstrated some expectations of creativity and vision with assistance. The student demonstrated some care in the materials, technique, attention to detail, and craft of the assignment. The student demonstrated some elements of art, but not consistently and did not demonstrate the minimum required elements of art for the project. The student demonstrated some design principles with assistance and/ or did not demonstrate the minimum design principles for the assignment.
7	The student is beginning/approaching and closer to approaching the standard of learning.
6.5	The student is beginning/approaching and closer to beginning the standard of learning.
6	**Beginning:** Student relied on copying the work and ideas of others to create their own work. The Student started to demonstrate care in materials, techniques, attention to detail, and craft of the assignment. The Student demonstrated minimal elements of art and did not meet the required elements of art for the assignment. The student started to demonstrate design principles with assistance and did not meet the requirements for the assignment.
5	No Evidence

Artwork Reflection Form *Project:*

Name: Period:

What is something you love about your artwork?	**What is something you could improve within your artwork?**
What is a struggle you overcame when creating this art?	**What is something you are still struggling with in your artwork?**
Where did you do better than you expected?	**What part of your artwork would you still like help to improve?**
Elements of Art/Design	**Principles of Art/Design**
Line, Shape, Form, Color, Value, Space, Texture	Pattern, Contrast, Rhythm, Unity/Variety, Balance, Emphasis, Movement
*use the Canvas modules for resources on the the meanings and uses of the elements and principles of art/design	
Describe how your artwork demonstrates 2 elements of art. Be specific with describing evidence from your work.	**Describe how your artwork demonstrates 1 principle of art. Be specific with describing evidence from your work.**

Name: ____ **Date:** ___________________________

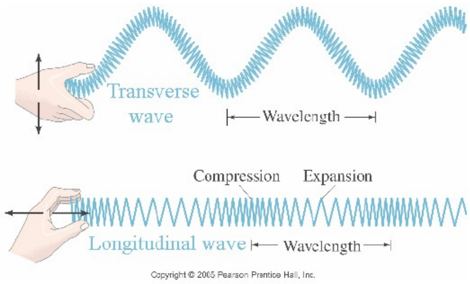
All About Waves—Notes Outline

A ______________ is a disturbance that carries ______________ from one place to another.

___________ is NOT carried with the wave! A wave can move through matter (a ___________). If it must have a medium, it is called ______________ wave. If it can travel without a medium (such as in space), it is called ______________ wave.

Wave Types

1. _______ waves: Waves in which the medium moves at _______ angles to the wave direction.
   Parts of a transverse wave:
   _______: the highest point of the wave
   trough: the _______ point of the wave
2. ___________ (longitudinal) wave: Waves in which the medium moves ____________________ in the same direction as the wave.
   Parts of a compressional wave:
   ________: where the particles are close together
   ________: where the particles are spread apart



Comparing transverse and longitudinal waves.

Wave properties depend on what _________________ makes the wave.

1. _______: The distance between one point on a wave and the ________________________ on the next wave.
2. _______: How many waves go past a point in _______; measured in _______ (Hz). The higher the frequency, the more _______ in the wave.
3. _______: How far the medium (crests and troughs, or compressions and rarefactions) moves from _________________ (the place the medium is when not moving). The _______ energy a wave carries, the _______ its amplitude. Amplitude is related to energy by ____________.
4. _______: Depends on the medium the wave is traveling in. This varies in _______, _______ and _______.
   Equation for calculating wave speed:
   wave speed = _______ (in m) x _______ (in Hz)

Problem: So- if a wave has a wave speed of 1000 m/s and a frequency of 500 Hz, what is its wave length? Answer: wavelength= __________________

Changing Wave Direction

1. __________: When waves __________ off a surface. If the surface is __________, the angle at which the wave hits the surface will be the __________ as the angle that the wave __________ the surface. In other words, the angle _____ equals the angle _____. This is called the ____.
2. __________: Waves can __________; this happens when a wave enters a __________ and its __________; the amount of bending depends on the medium it is entering
3. __________: The bending of waves __________ an object. The amount of bending depends on the ______________ and the ______________.
   __________ obstacle, __________ wavelength = low diffraction
   __________ obstacle, __________ wavelength = large diffraction

A demonstration of refraction.

Name: ____ **Date:** ________________________

Anatomy of a Wave Worksheet

Objective: Identify the parts of a wave and draw your own diagrams of waves.

Background: Many types of waves exist, including electromagnetic waves and mechanical waves. Waves move in different ways and have different properties.

Part 1

In the diagram below, identify the parts of a wave by using the provided definitions.

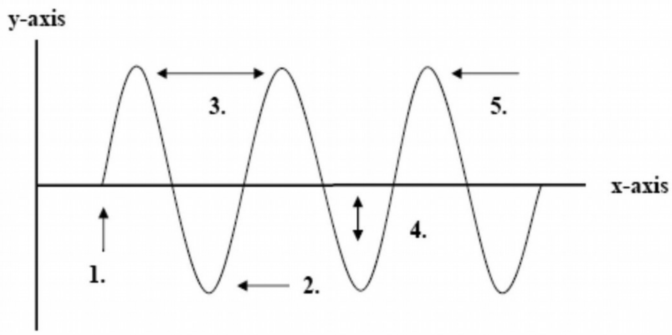
#____ = **crest** The highest point of the wave above the line of origin.

#____ = **trough** The lowest point of the wave below the line of origin.

#____ = **line of origin** Signifies the original position of the medium.

#____ = **wavelength** The distance between two consecutive crests.

#____ = **amplitude** The distance from the line of origin to a crest or trough of a wave.



Part 2

On separate sheets of graph paper, draw four different waves with the following measurements. Label the parts and include the measurements.

wave #	crest	trough	wavelength
1	1 cm	1 cm	2 cm
2	3.5 cm	3.5 cm	2.5 cm
3	.5 cm	.5 cm	3 cm
4	2 cm	2cm	.5 cm

Concluding question: State which wave you think has the *highest frequency* and which might have the *lowest frequency*. Explain the reasons for your selections.

Waves and Wave Properties

Why are we able to see?

Answer: Because there is light.

And…what is light?

Answer: Light is a wave.

So…what is a wave?

Answer: A wave is a disturbance that carries energy from place to place.

A wave does NOT carry matter with it! It just moves the matter as it goes through it.

Some waves do not need matter (called a “medium”) to be able to move (for example, through space).

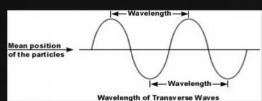
These are called electromagnetic waves (or EM waves).

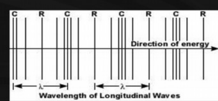
Some waves MUST have a medium in order to move. These are called mechanical waves.

Wave Properties

Wave properties depend on what
(type of energy) is making the waves.

1. Wavelength: The distance between one point on a wave and the exact same place on the next wave.





2. Frequency: How many waves go past a point in one second; unit of measurement is hertz (Hz).

The higher the frequency, the more energy in the wave.

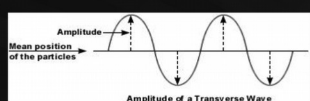
10 waves going past in 1 second = 10 Hz

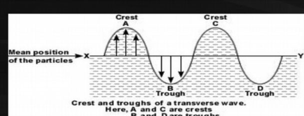
1,000 waves go past in 1 second = 1,000 Hz

1 million waves going past = 1 million Hz

3. Amplitude: How far the medium moves from rest position (where it is when not moving).

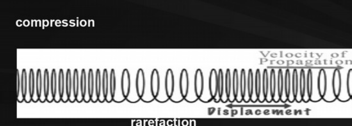
Remember that for transverse waves, the highest point is the crest, and the lowest point is the trough.





Remember that for compressional waves, the points where the medium is close together are called compressions and the areas where the medium is spread apart are called rarefactions.

The closer together and further apart the particles are, the larger the amplitude.



The energy of a wave is proportional to the square of its amplitude. Mathematically speaking . . .

$$E = CA^2$$

Where:

E = energy (the capacity to do work)
C = a constant (depends on the medium)
A = amplitude

For example:

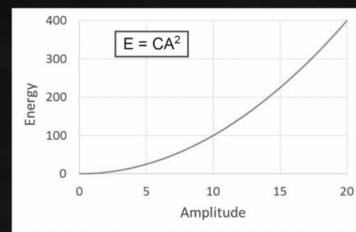
If the amplitude is equal to 3 units
(and we assume C = 1 for this case) . . .

$$E = (1)\,(3)^2 = (1)\,(9) = 9 \text{ units}$$

Note that when the amplitude of a wave is one unit, the energy is one unit.

- When the amplitude is doubled, the energy is quadrupled.
- When the energy is 10 times greater, the energy is 100 times greater!

Amplitude	Energy
1	1
2	4
3	9
4	16
5	25
6	36
7	49
8	64
9	81
10	100



4. Wave speed: Depends on the medium in which the wave is traveling. It varies in solids, liquids and gases.

A mathematical way to calculate speed:

wave speed = wavelength x frequency
(in meters) (in Hz)

OR

$$v = f \times \lambda$$

Problem: If a wave has a wavelength of 2 m and a frequency of 500 Hz, what is its speed?

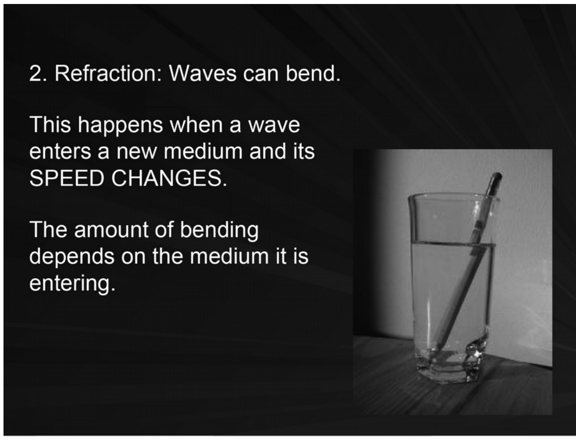
Answer: speed = 2 m x 500 Hz = 1000 m/s

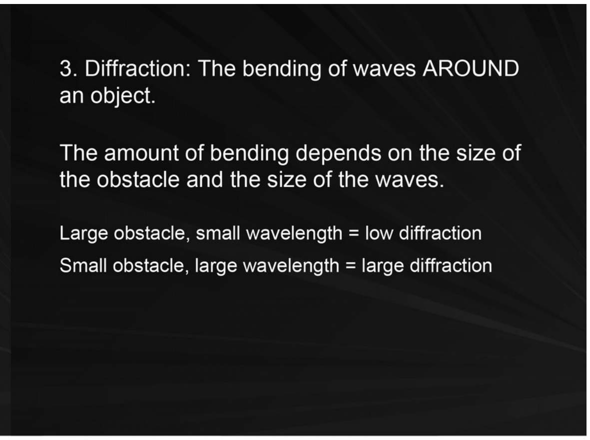
Changing Wave Direction

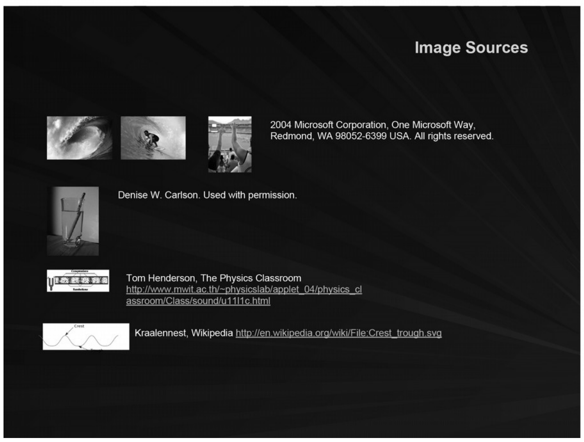
1. Reflection: When waves bounce off a surface.

If the surface is flat, the angle at which the wave hits the surface will be the same as the angle at which it leaves the surface
(angle in = angle out).

This is the law of reflection.


2. Refraction: Waves can bend.
This happens when a wave enters a new medium and its SPEED CHANGES.
The amount of bending depends on the medium it is entering.


3. Diffraction: The bending of waves AROUND an object.
The amount of bending depends on the size of the obstacle and the size of the waves.
Large obstacle, small wavelength = low diffraction
Small obstacle, large wavelength = large diffraction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Denise W. Carlson. Used with permission.
Tom Henderson, The Physics Classroom http://www.mwit.ac.th/~physicslab/applet_04/physics_classroom/Class/sound/u11l1c.html
Kraalennest, Wikipedia http://en.wikipedia.org/wiki/File:Crest_trough.svg

Name: ____ **Date:** ____________________

All About Light—Notes Outline

The speed of light is ______________ in space. In glass, light slows down to ______________.

Light wave wavelengths go from about ______________ to about ______________ in length.

A nm, ______________, is ______________ meter, which is one ______________ of a meter.

When light strikes an object, it will do one of several things:

1. It can be ______________; it is ______________ to the object (mainly as ______________).
2. It can be ____________________, meaning it ______________ the object.
3. It can be ____________________, or _________________ the object.

______________ objects ______________ allow light to pass through; they ______________ or ______________ it all. ______________ objects can be seen ______________, but not ______________; they ______________, ______________ and ______________ the light.

______________ objects allow ________ of the light to __________, so they can be seen through ______________.

White light is made up of ___________________________. A ______________ splits the light into its ______________________ colors.

We see the color of light that is being ______________ by an object.

A blue object is ______________ blue light and ______________ all the other colors. A black object absorbs ______________, and reflects ______________. A white object ______________ all light and ______________ none.

The three ___________________ colors of light are: ______________, ______________ and ______________.

Light and Reflection

______ types of reflection of light:

- __________ diffusion occurs when light strikes a __________ surface causing you to see an __________ on the surface because most or all of the reflected light __________ your eyes. Example: a __________ displays regular reflection, and with a __________ (flat) mirror,

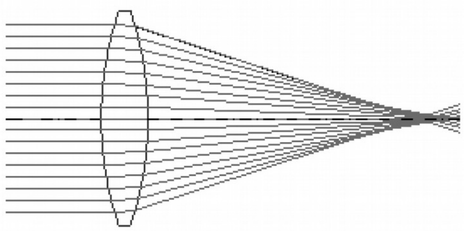
Name: ____ **Date:** __________________________

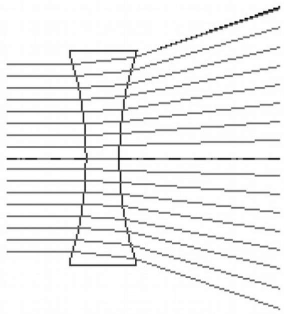
you see an __________, __________ -size image. Curved mirrors change the __________ of the image.

- With __________ reflection, a __________ surface __________ the light in many different __________ so that not all of it reaches your ______, and you ______ see a reflection.

Light and Refraction

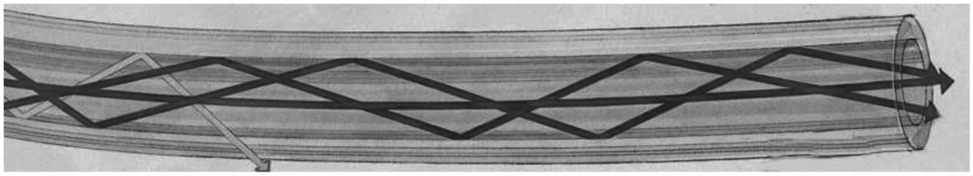
Light __________ as it goes from space into air, water, or solids. Why? Because the __________ get in the way. A __________ is a clear, curved __________ object used to bend light. ➘__________ lenses __________ light and can form an __________.





_______________ lenses _______________ light rays. ⇖

When light strikes a boundary between two __________ materials at the correct __________, all the light gets __________. This is called total __________ reflection and it is how __________ work. It allows the __________ of light to travel great __________ over __________ paths. 🡻



Lasers

The word "lasers" stands for "light ____________ by stimulated ____________ of ____________." Lasers use ______ wavelength of light so that all the ____________ and ____________ line up. Because they are all lined up, they do not ____________ with each other and ____________ the light out like white light.

2/12/20

Properties of Light

All About Light

What is light?

It is a small part of the EM spectrum, but it is the one we are most familiar with.

How fast does light travel?

The speed of light! This is 300,000km/s in space, or 197,000km/s in glass.

How big are light waves?

From 400nm to 700 nm in length.

More about Light

How big is a nm (nanometer)?

It is one ***billionth*** of a meter! (**1×10^{-9}**)

What happens when light strikes an object?

- **absorbed*:*** transferred to the object (mainly as heat)
- **reflected**: it bounces off (such as with a mirror)
- **transmitted*:*** goes through (such as with glass)

Light & Objects

Objects are classified by what they do to light:

- **opaque**: Does not allow light to pass through. All light is either absorbed or reflected.
- **translucent**: Can be seen through, but not clearly. Allows some light to go through, but some is also absorbed or reflected. (such as waxed paper)
- **transparent**: Allows almost all light to go through, so can be seen through clearly. (such as window glass)

White Light

White light is made up of all the colors of the rainbow. ***How do we know?***

Because a prism splits the light into its component colors.

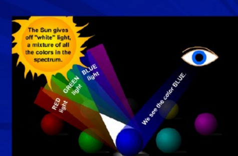
So… how or why do we see colors?

We see the color of light being REFLECTED from an object.

For example, a blue object reflects blue light and absorbs all others.

A black object absorbs all colors of light and doesn't reflect any.

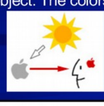
A white object reflects all light and absorbs none.



Subtractive Color System

So, what makes a red car appear red and a blue car appear blue?

Objects create color by subtracting or absorbing certain wavelengths of color while reflecting other wavelengths back to the viewer. This subtractive color system uses colorants and reflected light. You start with an object that reflects light and use colorants (dyes or pigments) to subtract portions of the white light that is shining on the object. The colors are **cyan, magenta and yellow**.



So—the red car really has no color; it reflects the wavelengths of white light that cause us to see red and absorbs most of the other wavelengths.

Additive Color System

How do monitors and TVs display color?

They produce color based on the additive color system, which involves light emitted directly from a source before an object reflects light.

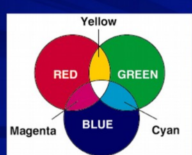
A TV screen or computer monitor creates color using the primary colors of light: **red, blue and green**. From these three colors a wide range of colors can be produced.

Thousands of red, green and blue phosphor dots emit light to make the images seen on monitors.

The three primary colors of light are:

red, green and **blue**

(Remember this is LIGHT!)



All colors we see are made from these three colors being reflected in different combinations and amounts.

Three secondary colors of light are made by combining two primary colors in equal amounts:

red + blue = **magenta**
blue + green = **cyan**
red + green = **yellow**

Since white light is all colors of light, mixing red + green + blue light = WHITE light

(Mixing the primary pigment colors: yellow, cyan and magenta = black)

Light and Reflection

Two types of reflection are:

- ***regular:*** When an object surface is smooth, and you see an image. Example: a plane (flat) mirror
- ***diffuse:*** When a rough surface scatters light in many directions, and no image appears. Example: paper is rough enough to scatter light so there is no image

Light and Refraction

Light slows down as it goes from space to air. It slows down even more in water and glass. ***Why?***

The atoms get in the way.

We use lenses to curve light on purpose.

(A lens is a clear, curved transparent object used to bend light.)

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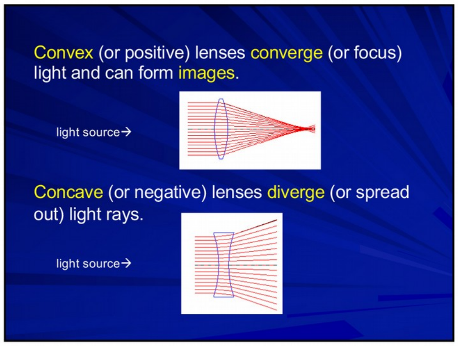
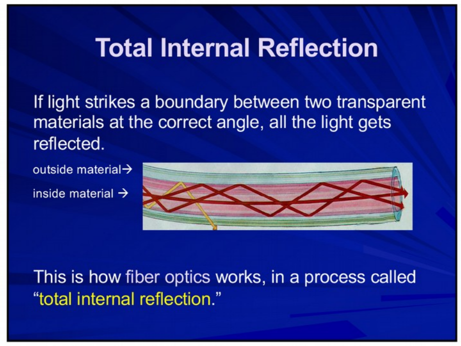
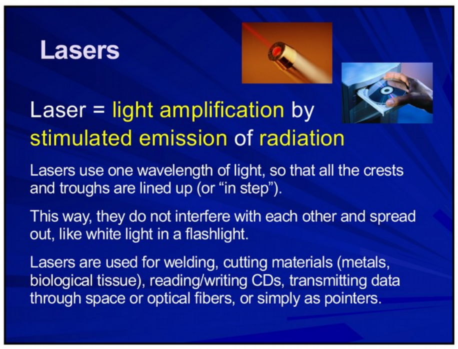
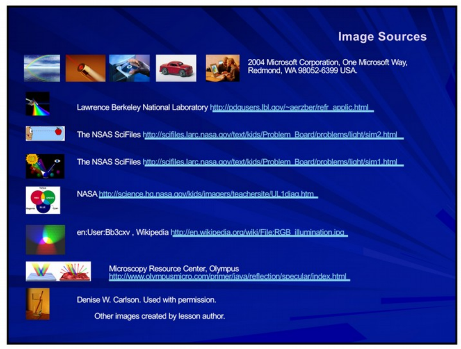

Convex (or positive) lenses converge (or focus) light and can form images.
light source→
Concave (or negative) lenses diverge (or spread out) light rays.
light source→


Total Internal Reflection
If light strikes a boundary between two transparent materials at the correct angle, all the light gets reflected.
outside material→
inside material →
This is how fiber optics works, in a process called "total internal reflection."


Lasers
Laser = light amplification by stimulated emission of radiation
Lasers use one wavelength of light, so that all the crests and troughs are lined up (or "in step").
This way, they do not interfere with each other and spread out, like white light in a flashlight.
Lasers are used for welding, cutting materials (metals, biological tissue), reading/writing CDs, transmitting data through space or optical fibers, or simply as pointers.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Microscopy Resource Center, Olympus
http://www.olympusmicro.com/primer/java/reflection/specular/index.html
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Color Magic Demos Worksheet

Demo 1: Color Indicator

	Initial Observations	Prediction	Final Observations	Explanation
Beaker 1				
Beaker 2				
Beaker 3				

Demo 2: Goldenrod Paper

Initial Observations

Prediction

Final Observations

Explanation

Demo 3: Luminol

Initial Observations

Final Observations

Explanation

Lab Report Guidelines and Rubric

Lab Report Format: Write in 12 pt, Times New Roman Font, use rulers on data tables and graphs, headings should be bold-faced and each section should be separated space. Use complete and full sentences. Use proper spelling and punctuation.

Report Sections:

I. Question(s)/Problem(s): Scientific question(s) written that you are studying and researching through research and labs. What was the purpose

II. Background Research: research about the topic. Helps you to begin to understand the problem and questions you are trying to answer. Use class notes and presentations to complete this section.

III. Hypothesis/Predictions: What predictions did you have? Explain them and your reasoning behind them?

IV. Observations/Data: Organize your observations during the labs and investigations into coherent paragraphs by topic. Use diagrams, data tables, graphs, drawings, photographs, etc. to support your writing. This is a neutral description of the information you have gathered.

V. Conclusion:
   a. Restate your hypothesis/predictions and tell whether or not your data supports it.
   b. Answer the questions to your problem using your data. Include specific data with your answer.
   c. Share any problems you encountered while conducting the experiment.
   d. Identify changes you could make if you were to do this again.
   e. Your reflections about the experiment.

Lab Report Rubric

Name:				Date:	
	Beginning/ Incomplete 1	Approaching 2	Secure 3	Exemplary 4	Score
Question(s/ Problem(s)/	Not clearly stated or does not pertain to the lab(s) to be used for the report.	Shared some information, but still missing some major points.	Question(s) and problems are nearly completed with some minor areas missing.	Question(s) and problems are clearly stated.	
Background Information	Very little background information is provided or the information is incorrect.	Some introductory information, but missing some major points.	Background research is nearly complete, missing some minor points	Background information is complete and well-written; provides all necessary information.	
Hypothesis	Hypothesis is not clearly stated or the information does not pertain to the lab.	Began stating a hypothesis but did not share what you thought would happen.	Hypothesis is nearly complete and only missing minor details.	Hypothesis is clearly stated and easy to understand.	
Observations: Graphs/ Tables/ Visuals to Communicate Data	Poorly constructed, not labeled properly, unclear, missing units of measurement, captions and titles.	Most graphs, tables, visuals are okay but missing required features to clearly identify the data.	All graphs, tables, and visuals, are correctly established with minor problems or a few areas that can be improved.	All graphs, tables, and visuals are correctly established and clearly defined and communicated with titles, captions, units of measurement, etc.	
Conclusion	Incomplete or incorrect interpretations	Some results have been correctly	Almost all of the results have been	All important data comparisons	

	of data trends. Lacks understanding of results.	interpreted and discussed, partial but incomplete understanding of results is evident.	correctly interpreted and discussed, only minor improvements are needed, accept/reject hypothesis/ predictions.	interpreted correctly/ Discussed, understanding of the results is conveyed, accept/reject hypothesis.	
Formatting	Frequent grammar and spelling errors. Improper formatting. Incoherent.	Occasional grammar/ spelling errors, writing generally is readable with some confusing areas.	Less than 3 grammar and/or spelling mistakes. Readable in writing style.	Well-written with no grammar or spelling errors.	
				Total Points	
Comments:					

Name: ________________________________

Exploring the Electromagnetic Spectrum Math Worksheet

1) Write the names of the electromagnetic waves by their wavelengths (smallest to largest). They are shown below, but they are not in any order.

X-ray *Infrared (heat)* *Visible Light* *Microwave*

Gamma Ray *Ultraviolet* *Radio wave*

Smallest ---> Largest

2) True or false: A longer wave has a higher frequency? See the wave equation below.

$$v = \lambda / f$$

Where: v = speed of electromagnetic wave through a material (distance/time)
λ = wavelength of electromagnetic wave (distance)
f = frequency of electromagnetic wave (how many per second; 1/time)

3) Write the names of the materials below in order of the speed of an electromagnetic wave through it. Remember:

$$v = c/n$$

Where: v = speed of electromagnetic wave through a material (distance/time)
c = speed of electromagnetic wave in a vacuum (distance/time)
n = refractive index (unit less). These values are shown below.

material	*n*	material	*n*
Vacuum	1	Asphalt	1.635
Diamond	2.42	Air	1.0003
Salt	1.54	Water	1.33

Slowest ---> Fastest

Name: Period:

Electromagnetic Quiz

1. Is this phrase true or false? The longer its wavelength, the more energy light carries.

   Circle One: True False

2. Which characteristic is the same for all photons?
   a. Speed of the photons.
   b. Energy stored in photons.
   c. Wavelength of the photons.
   d. All of the above.

3. Which is not part of the electromagnetic spectrum?
   a. Visible light
   b. Gamma rays
   c. Magnetic Field
   d. X-rays

4. Telescopes have enabled scientists to study which of the following?
   a. The surface of the sun.
   b. Wider range of wavelengths beyond visible light.
   c. Additional layers of the sun.
   d. All of the above.

Questions 1-4 from
https://www.khanacademy.org/partner-content/nova/sunandsolar/e/the-electromagnetic-spectrum-quiz

5. Which of the following is correct in order of lowest to highest energy?
   a. X-rays, Visible Light, Microwave
   b. Ultraviolet, Visible Light, Gamma-rays
   c. Microwave, Visible Light, Gamma-rays

6. The photons that make up radio waves travel at the same speed as the photons that make up visible light.
   a. True
   b. False
   c. We don't know

7. The electromagnetic spectrum can be expressed in terms of energy, wavelength, or frequency.
   a. True
   b. False

8. Low energy photons are waves. High energy photons are particles.
   a. True
   b. False

Questions 5-8 from https://imagine.gsfc.nasa.gov/science/activities/quiz_l2/emspectrum_quiz.html

Name:

What about black and white? Aren't they colors too?

Directions: Visit and read through the information on the following websites before answering the questions below.

https://colormatters.com/color-and-design/are-black-and-white-colors

https://colormatters.com/color-and-design/are-black-and-white-colors/more-about-black-white

https://education.seattlepi.com/not-list-black-white-colors-physics-3426.html

1. What do scientists say about black and white as colors? Why do they believe this?

2. What do artists say about black and white as colors? Why do they believe this?

3. What are your own thoughts about black and white? Should they be considered colors? Why or why not? Give evidence to support your claim from the websites.

4. Typically in the United States, wedding dresses are white or off-white? What countries wear a color besides white? Why is this color valued in that country? https://colormatters.com/color-symbolism/color-and-culture-matters and http://www.tkbridalatlanta.com/7-different-wedding-dress-color-from-around-the-world/