

### **5E Integrated STEM Lesson Plan – Template**

This template serves as a guide for developing a lesson that integrates across subject areas and includes the components of a quality STEM lesson. Please use it to support your work and engage in discussions with your instructors and peers when you have questions.

**Lesson Title:** Spectrum Hunt

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**Topic:** Visible Light Spectrum and Patterns. **NOTE: NEVER LOOK AT THE SUN WITH THE NAKED EYE!**

<https://link.springer.com/article/10.1007/s11191-020-00150-6>

**Targeted Grade Level:** 6<sup>th</sup> grade-7<sup>th</sup> grade

**Time Needed:** ~3 60-minute sessions

Day 1 – Engage and Construct

Day 2 – Explore and Explain

Day 3 – Explore, Explain and Evaluate

Materials: Making a Spectroscope

Diffraction grating 1 inch square

8 ½ x 11 piece of card stock

Scissors, Masking tape, colored pencils, Student data sheet

Electromagnetic spectrum handout

Light sources: incandescent bulb, flashlight, iPhone flashlight, candle (with parent's permission)

Sheets of material: 8-1/2x11 sheet of white paper, wax paper, colored cellophane/filters

Vocabulary Sheet, print out of different spectrum

**Subject Integration:** Science, Technology and Literacy

**Justification:** Scientific literacy is a key component for understanding science concepts and will involve students in making decisions based on information using the scientific method. Using scientific and engineering practices, crosscutting concepts to integrate space science, the applications of science, engineering, and technology. This topic will ask questions, use models, carry out an investigation, interpret and analyze data, engage thinking, construct a simple spectroscope, and asked if the design can be improved.

**Standards:** NJSLs: State of New Jersey Department of Education 2020 NJ Student Learning Standards

<https://www.nj.gov/education/cccs/2020/>

<https://www.nextgenscience.org/new-jersey>

**STEM Involvement:** The S.T.E.M. Education Innovation campaign, mentioned above, is the state's most current initiative regarding S.T.E.M. involvement. Through this campaign New Jersey hopes to work with local communities and organizations to coordinate S.T.E.M. related efforts and establish funding for strong professional development. The goal of this campaign is the creation of a S.T.E.M. Council and a S.T.E.M. Education Network which will continue to advance S.T.E.M. education, professional development, and resources throughout the state. The National Research Council, National Governor's Association, and the U.S. Chamber of Commerce have worked to map out this campaign, and the work of the future Council and Network will take it into action.

• **MS-PS4-2** Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials. [Clarification Statement: Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.] [Assessment Boundary: Assessment is limited to qualitative applications pertaining to light and mechanical waves.]

Science and Engineering Practices	Disciplinary Core Ideas	Crosscutting Concepts:
<p>Developing and Using Models 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.</p> <p>♣ <b>Develop and use a model to describe phenomena. (MS-PS4-2) Using Mathematics and Computational Thinking Mathematical and computational thinking at the 6–8 builds on K–5 and progresses to identifying patterns in large data sets and using mathematical concepts to support explanations and arguments.</b></p> <p>♣ Use mathematical representations to describe and/or support scientific (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.</p>	<p>PS4.A: Wave Properties</p> <p>♣ A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-1)</p> <p>♣ <b>When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object’s material and the frequency (color) of the light. (MS-PS4-2)</b></p> <p>♣ <b>The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. (MS-PS4-2)</b></p> <p>♣ A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media. (MS-PS4-2)</p> <p>♣ However, because light can travel</p>	<p>Patterns</p> <p>♣ <b>Graphs and charts can be used to identify patterns in data. (MS-PS4-1)</b></p> <p><b>Structure and Function</b></p> <p>♣ <b>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)</b></p> <p>♣ <b>Structures can be designed to serve particular functions. (MS-PS4-3)</b></p> <p><b>Connections to Engineering, Technology, and Applications of Science Influence of Science, Engineering, and Technology on Society and the Natural World</b></p> <p>♣ <b>Technologies extend the measurement, exploration, modeling, and computational capacity of scientific investigations. (MS-PS4-3)</b></p>

<p>♣ 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)</p>	<p>through space, it cannot be a matter wave, like sound or water waves. (MS-PS4-2) PS4.C: Information Technologies and Instrumentation</p>	
<p style="text-align: center;"><b>Common Core State Standards:</b></p> <p>Math: Connections to NJSLs – Mathematics • MP.2 Reason abstractly and quantitatively. (MS-PS4-1) • MP.4 Model with mathematics. (MS-PS4-1)</p> <p>ELA/Literacy</p> <ul style="list-style-type: none"> <li>• SL.8.5 - Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (MS-PS4-2)</li> </ul> <p>ELA: Connections to NJSLs - English Language Arts • 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)</p>		
<p style="text-align: center;"><b>ITEEA Standards Design: Iterative, Brainstorming, Modeling, Testing, Evaluating, and modifying</b></p>		

**Measurable Student Learning Objectives:**

Students will be able to understand what light is and what it is made of. What is visible light?

Students will be able to understand the terms, refraction, reflection, absorption, frequency, wavelength, and energy.

Students will be able to construct a simple spectroscope to study light.

Students will be able to understand that each light source has its own fingerprint.

Students will be able to understand how color and temperature are related and introduced to the HR Diagram.

Students will be able to experiment and see how light travels through objects, reflection, absorption, etc.

Students will be able to see images taken in different wave lengths from the Hubble and learn that the data is different.

**Nature of STEM:** This activity provides an interdisciplinary approach to learning about light. Students are asked “What is light?” Is it a wave or a particle? They are encouraged to discuss It using the scientific principles and investigation. Using data about the Electromagnetic spectrum from NASA will be integrated. \

Nature of Science:

- Science knowledge is based upon logical and conceptual connections between evidence and explanations.
- Science disciplines share common rules of obtaining and evaluating empirical evidence.

**Engaging Context/Phenomena:**

This will use engaging phenomena from <https://www.nasa.gov/content/explore-light>

This page shows an image taken by the Hubble Telescope of the Carina Nebula. The left hand of the image shows the image taken using visible light while the right-hand side is taken in Infrared. Students can use the slider back and forth to see the different detail on the nebula. There are several examples on the page that give the WOW factor.

**Data Integration:** Data is from the NASA Tour of the Electromagnetic Spectrum.

Why would we want to see things in different parts of the Electromagnetic Spectrum? What can we learn from the Hubble Space Telescope Images? What does the data tell us? Everyday there are energy waves all around us that transport light. Using data is crucial to understanding interactions, observations and what it tells us about the components of the light. Using the data will bridge scientific theory and investigation with cross cutting concepts.

[https://science.nasa.gov/ems/01\\_intro](https://science.nasa.gov/ems/01_intro)

<https://asd.gsfc.nasa.gov/Koji.Mukai/spectra/index.html>

<https://imagine.gsfc.nasa.gov/science/toolbox/spectra1.html>

Students will see a visual difference of the difference between continuous light, emission lines and absorption lines.

**Differentiation of Instruction:**

Students may work together in small groups to discuss and analyze. Students may work with instructor to help guide them. Assessment will not be based heavily on interpretation of accurate light colors for those that are color blind. Color blind students could share their interpretations of the light they see to help others understand what they see. Making this accessible to all students is important. Kids living in urban cities may not see any stars in the night sky so access to NASA Hubble Images is important. Translating the lesson into Spanish would be a good start for non-English speaking students.

**Real-life Connection:**

Light is around us everywhere whether by the sun, lights in the house or a candle burning. Are all these light sources the same? Why is the color different? Why do the stars shine with a different color in the night sky? Nasa data source connects to the Nature of Science. Kids can develop a model of the electromagnetic spectrum to represent light in its components and describe its nature as a wave or a particle. The electromagnetic spectrum is a wave that transports energy around us. “How does a remote control use Infrared light to transport energy to turn on a TV? “ is a great way to integrate technology usage and how it transfers information.

**Possible Misconceptions:** All light is the same.

**Lesson Procedure:**

5E Model	5E Objectives
<b><u>Engage</u></b>	<p><b>Procedure: Engaging phenomena from <a href="https://www.nasa.gov/content/explore-light">https://www.nasa.gov/content/explore-light</a></b></p> <p>Light is all around us. Why does sunlight look different than a flashlight or a candle? Have you ever noticed that the light bulb from your lamp is a different color than the light bulb in your kitchen? Have you noticed that the headlights on cars have all sorts of colors? Talk about the Electromagnetic Spectrum. Is light a wave or a particle? Watch video on “Introduction to the Electromagnetic Spectrum” (EM Waves)</p> <p><b>What is Electromagnetic energy?</b></p> <p>Electromagnetic energy travels in waves and spans a broad spectrum from very long radio waves to very short gamma rays. The human eye can only detect only a small portion of this spectrum called visible light. A radio detects a different portion of the spectrum, and an x-ray machine uses yet another portion. NASA's scientific instruments use the full range of the electromagnetic spectrum to study the Earth, the solar system, and the universe beyond.</p> <p>When you tune your radio, watch TV, send a text message, or pop popcorn in a microwave oven, you are using electromagnetic energy. You depend on this energy every hour of every day. Without it, the world you know could not exist.</p> <p><b><a href="https://science.nasa.gov/ems/01_intro">https://science.nasa.gov/ems/01_intro</a></b></p> <p><b>Justification:</b> Students will learn to look at light. It comes from many natural and artificial sources. They will learn terminology related to light and communicate their representation of it. Emphasis is on both light and mechanical waves. Examples of models could include drawings, simulations, and written descriptions.</p> <p>Objectives: Students will</p> <ul style="list-style-type: none"><li>➤ Students develop a model to make sense of a given phenomenon. In the model, students identify the relevant components, including: Light, including brightness (amplitude) and color (frequency).</li><li>➤ learn about the electromagnetic spectrum</li></ul>

	<ul style="list-style-type: none"><li>➤ learn what light is</li><li>➤ learn terminology related to light</li><li>➤ learn why scientists need a spectroscope</li></ul> <p><b>Modification:</b></p> <ul style="list-style-type: none"><li>➤ Students requiring help with construction and analyzing light may work in small group with a mentor</li><li>➤ Students may have a vocabulary with definitions provided or work together to discuss</li><li>➤ Students may draw their interpretation of what light is</li></ul> <p><b>Standards Addressed: MS PS4-2 Science &amp; Engineering Practices</b></p> <p><b>Developing and Using Models</b></p> <p>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.</p> <ul style="list-style-type: none"><li>• Develop and use a model to describe phenomena.</li></ul> <p>A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. (MS-PS4-1)</p> <p><b>Formative/Summative Assessments</b></p> <p>Ask kids to work in small groups to come up with answers to the questions and determine questions they have.</p> <p><b>Resources:</b> <a href="https://science.nasa.gov/ems/01_intro">https://science.nasa.gov/ems/01_intro</a></p>
<u><b>Explore</b></u>	<p><b>Procedure: MS PS4-2</b></p> <p>In order to see the components of light, we must construct a simple spectroscope. Students will build and use a simple spectroscope to ‘see the light’ Have students work together to collect, analyze, and communicate about the data. Have them go on a ‘Spectrum Hunt’. Can students make predictions if the light source will be</p>

reflectance, absorption or continuous

**Remind Students: NEVER LOOK DIRECTLLY AT THE SUN**

- Take an 8-1/2 x 11-inch piece of card stock or used a paper towel tube
- Use a cardboard paper towel tube or roll into a tube length wise like a paper towel tube
- Cut 1 inch square of diffraction grating. Handle by edges to avoid fingerprints.
- Cut 2 pieces of aluminum foil 4x4 inches
- Cut a slim slit in one piece of foil and tape it to the end of the tube.
- Cut a 1/2 x 1/2 inch square in unused piece of foil. (Size of a dime)
- Tape a 1-inch square piece of diffraction on the foil
- Tape foil with diffraction grating to other side of the tube.
- Look at, compare light sources to spectrum guide.
- Look at the light from your tv screen, phone flashlight. How are they different? Similar?
- Students may work together to help hold a light source and discuss the similarities and differences.
- Have light spectrum resources available as guides
- If in person, have stations set up with various light sources. Have students rotate stations and observe the light using the spectroscope.
- Allow students to draw what they see to record their data using color, line size and spacing

Justification: Science behind light and its components. Students will see how tools can help scientists learn about elements, light, and stars.

Objectives:

- Light travels in straight lines, but the path of light is bent at the interface between materials when it travels from one material to another.
- learn to construct a simple spectroscope
- analyze data of at least 3 light sources and its spectrum
- analyze how shining the light through various material affect the light and its spectrum

Standards Addressed

PS4.B: Electromagnetic Radiation

- When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending

	<p>on the object's material and the frequency (color) of the light.</p> <ul style="list-style-type: none"><li>• The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends.</li><li>• A wave model of light is useful for explaining brightness, color, and the frequency-dependent bending of light at a surface between media.</li><li>• However, because light can travel through space, it cannot be a matter wave, like sound or water waves.</li></ul> <p>Observe colors. List colors from left to right in order. Are any colors brighter or thicker than others? Do the colors blend into each other or do they fade? Does each light source produce the same group of colors? How are they alike? How are they different? What happens when you use a material in front of the light source? Does it change its spectrum?</p>
<p><u>Explain</u></p>	<p><b>Procedure:</b> Compare EM spectrum of different light sources. What can we learn from this? What is happening when we look at light sources using the diffraction grating? Ask students to communicate results. Can they explain any of the differences in the light patterns?</p> <p><a href="https://imagine.gsfc.nasa.gov/science/toolbox/spectra1.html">https://imagine.gsfc.nasa.gov/science/toolbox/spectra1.html</a></p> <ol style="list-style-type: none"><li>1. Discuss what the diffraction grating does</li><li>2. What does a diffraction grating remind you of?</li><li>3. Why do the light sources have different spectrum?</li><li>4. What is the relationship between color and temperature?</li><li>5. Did they notice any patterns?</li><li>6. How can scientists relate the spectrum to the stars?</li><li>7. What happens if we transmit the light source through various materials?</li></ol> <p><b>Standards Addressed PS4.B: Electromagnetic Radiation</b></p> <ul style="list-style-type: none"><li>➤ An object can be seen when light reflected from its surface enters the eyes.</li><li>➤ Cause and effect relationships</li></ul> <p>3 Planning the investigation</p>

	<p>a In the collaboratively developed investigation plan, students individually describe* (with support):</p> <ol style="list-style-type: none"><li>i. The materials to be placed in the beam of light, including:<ol style="list-style-type: none"><li>1. A material that allows all light through (e.g., clear plastic, clear glass).</li><li>2. A material that allows only some light through (e.g., clouded plastic, wax paper).</li><li>3. A material that blocks all of the light (e.g., cardboard, wood).</li><li>4. A material that changes the direction of the light (e.g., mirror, aluminum foil).</li></ol></li><li>ii. How the effect of placing different materials in the beam of light will be observed and recorded.</li><li>iii. The light source used to produce the beam of light</li></ol> <p>Common Core State Standards Connections:</p> <p>ELA/Literacy -</p> <p>SL.8.5 Integrate multimedia and visual displays into presentations to clarify information, strengthen claims and evidence, and add interest. (MS-PS4-2)</p> <p><b>Resources</b> <a href="https://asd.gsfc.nasa.gov/Koji.Mukai/spectra/index.html">https://asd.gsfc.nasa.gov/Koji.Mukai/spectra/index.html</a></p> <p><a href="https://science.nasa.gov/ems/03_behaviors">https://science.nasa.gov/ems/03_behaviors</a></p>
<p><b><u>Elaborate</u></b></p>	<p><b>Procedure:</b> Diffraction is the bending and spreading of waves around an obstacle. It is most pronounced when a light wave strikes an object with a size comparable to its own wavelength. An instrument called a spectrometer uses diffraction to separate light into a range of wavelengths—a spectrum. In the case of visible light, the separation of wavelengths through diffraction results in a rainbow. A spectrometer uses diffraction (and the subsequent interference) of light from slits or gratings to separate wavelengths. Faint peaks of energy at specific wavelengths can then be detected and recorded. A graph of these data is called a spectral signature. Patterns in a spectral signature help scientist identify the physical condition and composition of stellar and interstellar matter. When light waves encounter an object, they are either transmitted through, reflected, or absorbed depending on the composition of the object and the wavelength of the light. When incident light (incoming light) hits an object and bounces off, this is an example of reflected energy. Very smooth surfaces such as mirrors reflect almost all incident light. The color of an object is the color of the light reflected while</p>

all other colors are absorbed. Color, in this case, refers to the different wavelengths of light in the visible light spectrum. Absorption occurs when photons from incident light hit atoms and molecules and cause them to vibrate. The more an object's molecules move and vibrate, the hotter it becomes. This heat is then emitted from the object as thermal energy.

How do we capture images using scientific instruments? Digital cameras use a sensor to capture red, green and blue light. It records the brightness of these values as a number and then the data is combined on a computer using the red, green, and blue channels to create a color image. Satellites and scientific instruments capture and record visible light data to create true color images. The data from the visible light bands are composited on the computer or a screen. The image simulates a color image that we would see with our eyes. Sensors may also record images in other wavelengths such as the Hubble Space Telescope. It combines infrared wavelengths with red, green, and blue to create a false color image. These reveal patterns and variations that would otherwise be invisible.

Introduce the HR Diagram which correlates light and temperature of stars and why would Astronomers want to study this

**Standards Addressed:**

**Cross cutting ideas**

**Patterns**

- Graphs and charts can be used to 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)

**Discuss the influence of Engineering, Technology and Science on Society and the Natural World:**

Engineering advances have led to important discoveries in virtually every field of science and scientific discoveries have led to the development of entire industries and engineered systems. • Science and technology drive each other forward.

	<p>Emphasis is on a basic understanding that waves can be used for communication purposes. Examples could include using fiber optic cable to transmit light pulses, radio wave pulses in wifi devices, and conversion of stored binary patterns to make sound or text on a computer screen.</p> <p>Define a simple design problem that can be solved through the development of an object, tool, process, or system and includes several criteria for success and constraints on materials, time, or cost.</p> <p>reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.</p> <p><b>Resources</b> <a href="https://imagine.gsfc.nasa.gov/features/yba/M31_velocity/spectrum/spectra_more.html">https://imagine.gsfc.nasa.gov/features/yba/M31_velocity/spectrum/spectra_more.html</a></p>
<p><u>Evaluate</u></p>	<p><b>Procedure:</b> A simple rubric may be used</p> <p>Did students collect and record 3 different light source data?</p> <p>Did they recognize any patterns?</p> <p>Did they construct a simple spectroscope?</p> <p>Did students make predictions and draw any conclusions how filters affect light?</p>

**Teacher Background: NEVER LOOK DIRECTLY AT THE SUN**

The electromagnetic (EM) spectrum is made up of all the different wavelengths of light, including visible and ranging from radio waves to gamma rays. Just as our ears can only hear certain frequencies of sound, our eyes can only see visible light, which makes up a tiny portion of the entire spectrum. Remember, scientists use the word “light” for any wavelength of energy and will use the words ‘light’ and ‘energy’ interchangeably at time.

**Engaging Phenomenon:** <https://www.nasa.gov/content/explore-light>

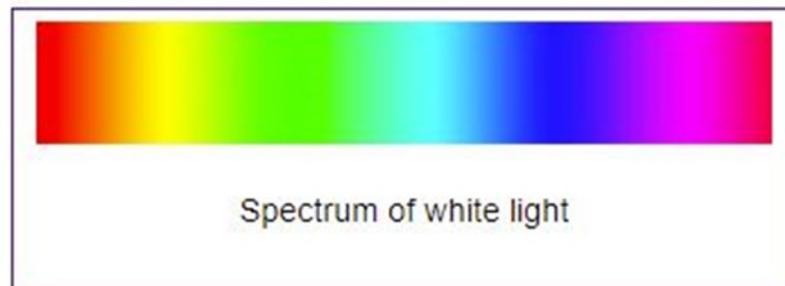
### What does a star's color mean?

When you look at the night sky, you may notice that some stars shine more brightly than others. The brightness of a star is related to how much energy it puts out, as well as how close it is to Earth.

Stars also vary in color – because they vary in temperature. Hotter stars appear blue or white, while cooler stars look orange or red. Astronomers use these characteristics to classify main sequence stars into categories by color and temperature: O (blue), B (blue-white), A (white), F (yellow-white), G (yellow), K (orange), and M (red), from hottest and biggest to coolest and smallest. Stars at the ends of their lives are out of the main sequence. These include supergiant, red giants, and white dwarfs.

<https://exoplanets.nasa.gov/what-is-an-exoplanet/stars/#:~:text=Astronomers%20use%20these%20characteristics%20to,out%20of%20the%20main%20sequence.>

<https://imagine.gsfc.nasa.gov/science/toolbox/spectra1.html>



### Vocabulary:

**Absorption:** Absorption occurs when photons from incident light hit atoms and molecules and cause them to vibrate. The more an object's molecules move and vibrate, the hotter it becomes. This heat is then emitted from the object as thermal energy.

**Color:** The visual perception of light that enables human eyes to differentiate between wavelengths of the visible spectrum, with the longest wavelengths appearing red and the shortest appearing blue or violet.

**Data:** Collected acts, statistics, or information about something being observed, investigated or studied.

**Diffraction:** Diffraction is the bending and spreading of waves around an obstacle. It is most pronounced when a light wave strikes an object with a size comparable to its own wavelength. An instrument called a spectrometer uses diffraction to separate light into a range of wavelengths—a spectrum. In the case of visible light, the separation of wavelengths through diffraction results in a rainbow.

**Electromagnetic Spectrum:** The entire range of wavelengths of electromagnetic radiation, including radio waves, microwaves, infrared light, visible light, ultraviolet light, X-rays, and gamma rays

**Image:** The appearance of an object, as is produced by reflection from a mirror or refraction by a lens.

**Observation:** In science, an observation is a fact or occurrence that is noted and recorded.

**Reflection:** Reflection occurs when light changes direction as a result of “bouncing off” a surface like a mirror.

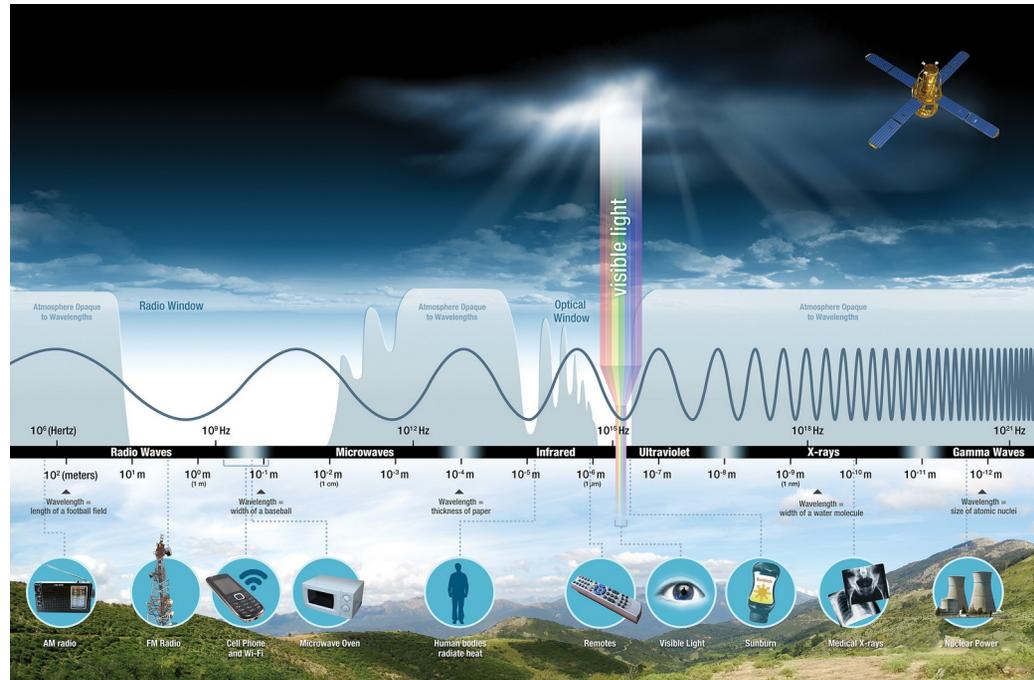
**Refraction:** Refraction is the bending of light as it passes from one substance to another. Here, the light ray passes from air to glass and back to air. The bending is caused by the differences in density between the two substances.

**Star:** A huge ball of gas held together by gravity. The central core of a star is extremely hot and produces energy. Some of this energy is released as visible light, which makes the star glow. Stars come in different sizes, colors, and temperatures. Our Sun, the center of our solar system, is a yellow star of average temperature and size.

**Visible Light:** The part of the electromagnetic spectrum that human eyes can detect; also known as the visible spectrum. The colors of the rainbow make up visible light. Blue light has more energy than red light.

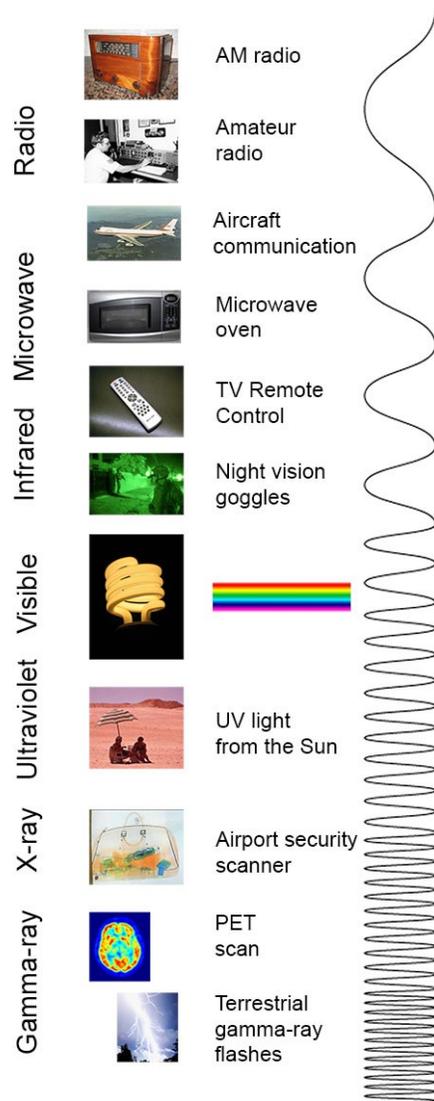
**Wavelength:** The distance between adjacent peaks in a series of periodic waves. Also see [electromagnetic spectrum](#).

**Yellow Star:** These stars are middle-aged and not extremely cool nor hot for a star. Earth's Sun is an example of a yellow star.



The Electromagnetic Spectrum [https://science.nasa.gov/ems/01\\_intro](https://science.nasa.gov/ems/01_intro)

**ATMOSPHERIC WINDOWS** Electromagnetic radiation is reflected or absorbed mainly by several gases in the Earth's atmosphere, among the most important being water vapor, carbon dioxide, and ozone. Some radiation, such as visible light, largely passes (is transmitted) through the atmosphere. These regions of the spectrum with wavelengths that can pass through the atmosphere are referred to as "atmospheric windows." Some microwaves can even pass through clouds, which make them the best wavelength for transmitting satellite communication signals. While our atmosphere is essential to protecting life on Earth and keeping the planet habitable, it is not very helpful when it comes to studying sources of high-energy radiation in space. Sensitive instruments are positioned above the Earth's energy-absorbing atmosphere to "see" light from energetic ultraviolet, x-ray and gamma ray sources. The atmosphere is also a hindrance to studying very low energy radio waves coming from space, as these waves are reflected by plasma in the Earth's upper atmosphere.



<https://imagine.gsfc.nasa.gov/science/toolbox/empectrum1.html>

*Afterschool Universe* Session 5 — Diagram of Paper Towel Tube Spectroscope

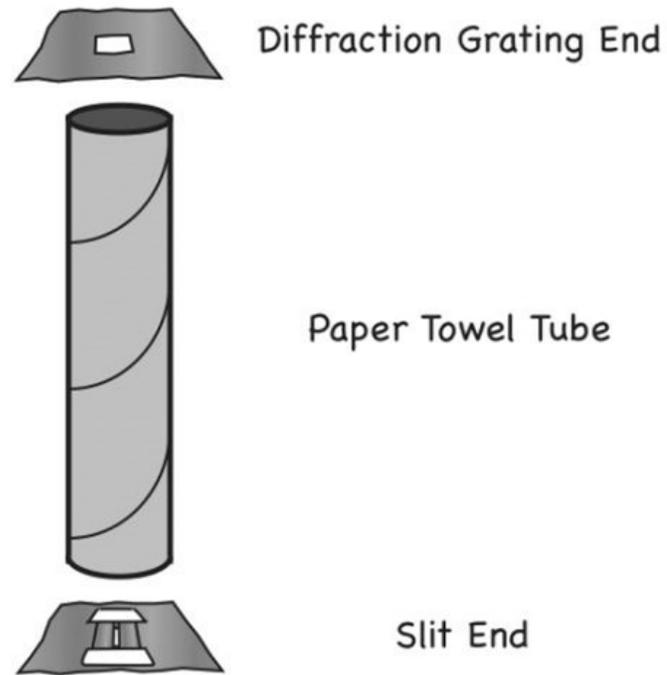
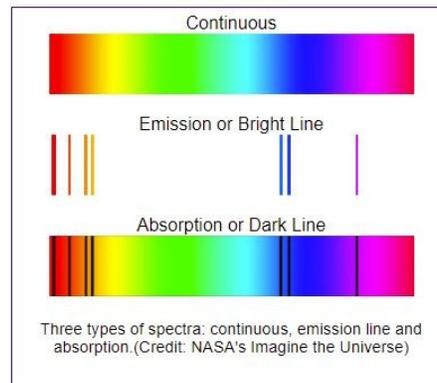


Diagram of cardboard (Paper towel or rolled up cardstock) spectroscope: *Afterschool Universe*

## What Can Scientists Learn From a Spectrum?



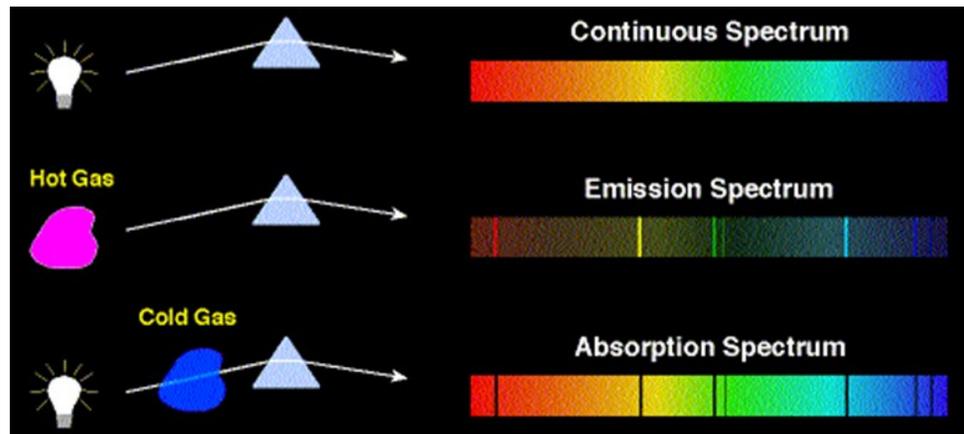
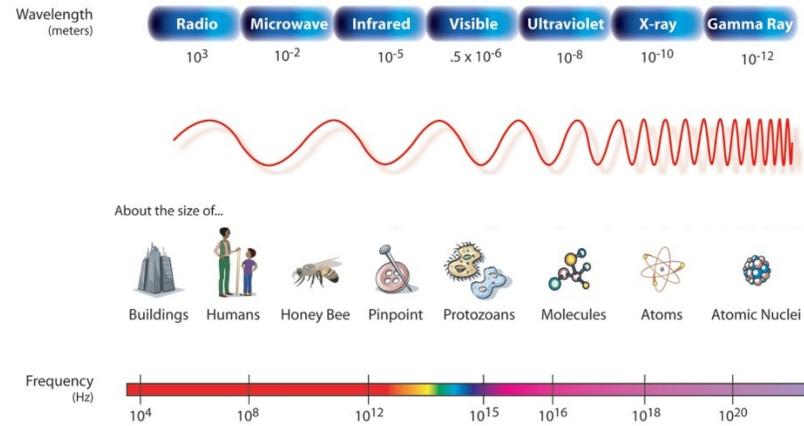
Each **element** in the periodic table can appear in gaseous form and will produce a series of bright lines unique to that element. **Hydrogen** will not look like **helium** which will not look like carbon which will not look like iron... and so on. Thus, **astronomers** can identify what kinds of stuff are in **stars** from the lines they find in the star's spectrum. This type of study is called **spectroscopy**.

The science of spectroscopy is quite sophisticated. From **spectral lines** astronomers can determine not only the element, but the temperature and **density** of that element in the star. The spectral line also can tell us about any **magnetic field** of the star. The width of the line can tell us how fast the material is moving. We can learn about **winds in stars** from this. If the lines shift back and forth we can learn that the star may be orbiting another star. We can estimate the **mass** and size of the star from this. If the lines grow and fade in strength we can learn about the physical changes in the star. Spectral information can also tell us about material around stars. This material may be falling onto the star from a doughnut-shaped disk around the star called an **accretion disk**. These disks often form around a **neutron star** or **black hole**. The light from the stuff between the stars allows astronomers to study the **interstellar medium (ISM)**. This tells us what type of stuff fills the space between the stars. Space is not empty! There is lots of gas and **dust** between the stars. Spectroscopy is one of the fundamental tools which scientists use to study the Universe.

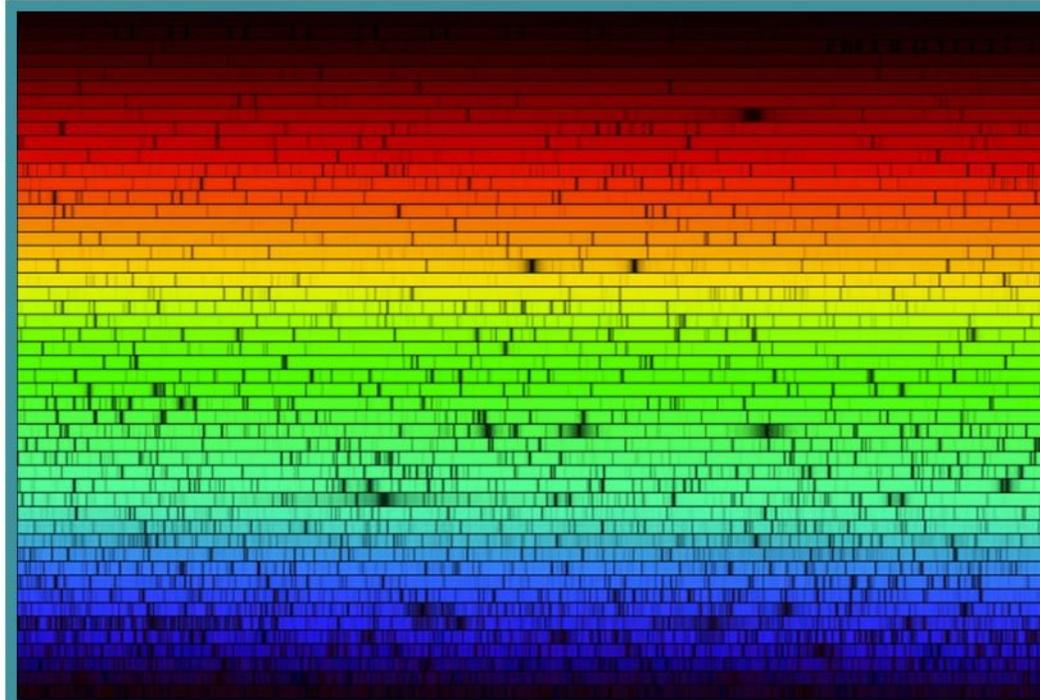


*The spectrum of the star Vega*

## THE ELECTROMAGNETIC SPECTRUM



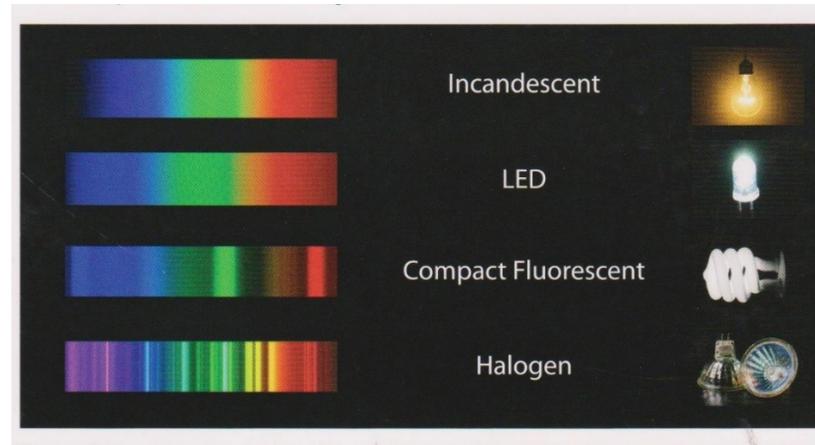
## Sun's Spectrum



Credit: N.A. Sharp, NOAO/NSO/Kitt Peak FTS/AURA/NSF

This patch of rainbow colors shows the visible light spectrum of the Sun. If you used a prism to separate sunlight into its constituent colors, you would see something like this. Astronomers used a large, prism-like instrument to create this extremely detailed view of the Sun's spectrum. The spectrum starts with red light, with a wavelength of 700 nanometers (7,000 angstroms), at the top. It spans the range of visible light colors, including orange and yellow and green, and ends at the bottom with blue and violet colors with a wavelength of 400 nm (4,000 angstroms). The spectrum is so long and detailed that it had to be cut into strips; each of the 50 strips spans a wavelength range of 6 nanometers (60 angstroms). The dark lines throughout the spectrum are caused by absorption of light by various elements in the Sun's atmosphere. This dark-line absorption spectrum is sort of like a fingerprint of the Sun; it provides scientists with lots of information about the chemical composition of the Sun and even about the temperature of different regions of the solar atmosphere. This spectrum was created using the McMath–Pierce solar telescope at the National Solar Observatory on Kitt Peak, near Tucson, Arizona.

**NEVER LOOK AT THE SUN WITH THE NAKED EYE**



Can you match these light patterns?

Discussion questions:

1. What is light? Is it a wave or a particle?
2. Discuss what the diffraction grating does
3. What does a diffraction grating remind you of?
4. Why do the light sources have different spectrum?
5. Did you notice any patterns?
6. What is the relationship between color and temperature?
7. How can scientists relate the data about spectrum to a star?
8. What happens if we transmit the light source through various materials?
9. How can we construct a better spectroscope?

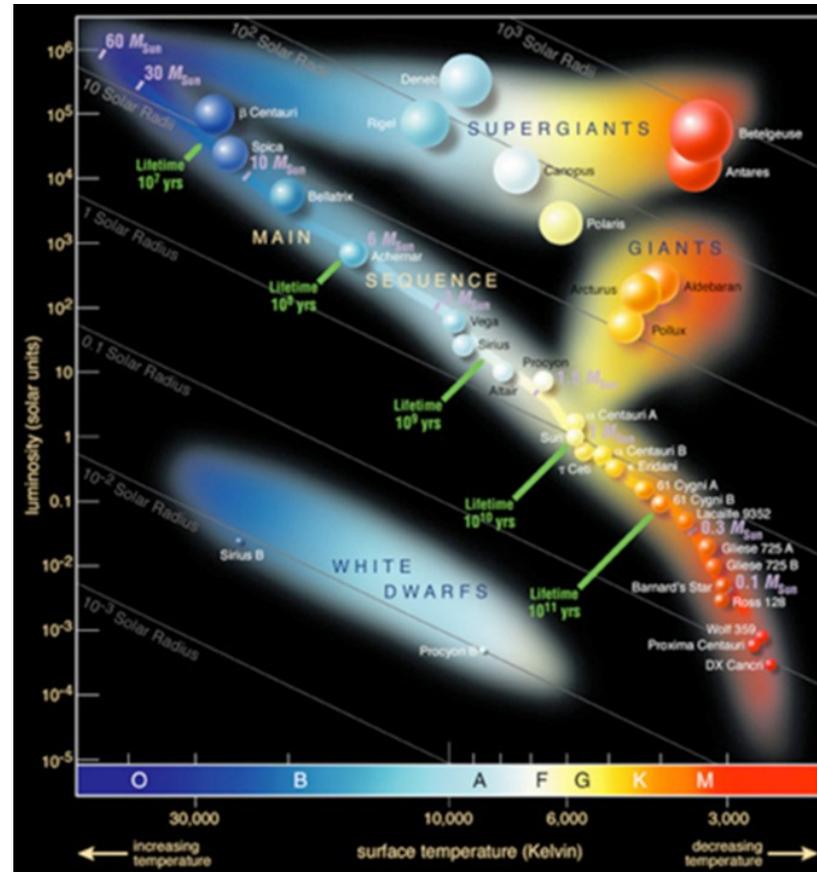
Red                      Orange                      Yellow                      Green                      Blue                      Indigo                      Violet

<b>R</b>	<b>O</b>	<b>Y</b>	<b>G</b>	<b>B</b>	<b>I</b>	<b>V</b>
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Students should color these with crayons or colored pencils

<b>Student Data</b>	<b>Light Source 1</b>	<b>Light Source 2</b>	<b>Light Source 3</b>
<b>Type of Light</b>			
<b>Color of Light</b>			
<b>Colors left to right</b>			
<b>Materials:</b>			
<b>White paper</b>			
<b>Wax paper</b>			
<b>Choice of 3<sup>rd</sup>...Sunglasses</b>			

HR Diagram: The Periodic Table of stars



What is the relationship between a star's brightness and its temperature?

### Hertzsprung-Russell diagram

[https://chandra.harvard.edu/edu/formal/stellar\\_ev/story/index3.html](https://chandra.harvard.edu/edu/formal/stellar_ev/story/index3.html)

<https://science.nasa.gov/ems/>

**Formative Assessment:**

Groups of students will build a spectroscope: cardstock, diffraction grating, tape, penny, pencil, flashlight, incandescent light bulb, candle or headlight on car. Students will analyze light sources and compare data looking for patterns.

Summative Assessment: Scoring Rubric Students present drawings, data, and conclusions.

<b>Rating</b>	<b>3</b>	<b>2</b>	<b>1</b>
<b>Collaboration</b>	Students worked together Open to other's ideas Analyzed 3 light sources Used 3 filters	Students worked together Not collaborating on ideas Analyzed 2 light sources Used 2 filters	Students were unable to collaborate Not open to each other's ideas Analyzed 1 light source Used 1 filter
<b>Build</b>	Student focused on Building spectroscope	Student somewhat focused on building spectroscope	Student was not focused on building spectroscope
<b>Analyze Data</b>	Student able to Represent data with colors	Student able to Represent data with colors	Student able to Represent data with colors
<b>Evaluate</b>	All 3 light sources	2 light sources	1 light source

Total Points Scored: \_\_\_\_\_

Comments: \_\_\_\_\_

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