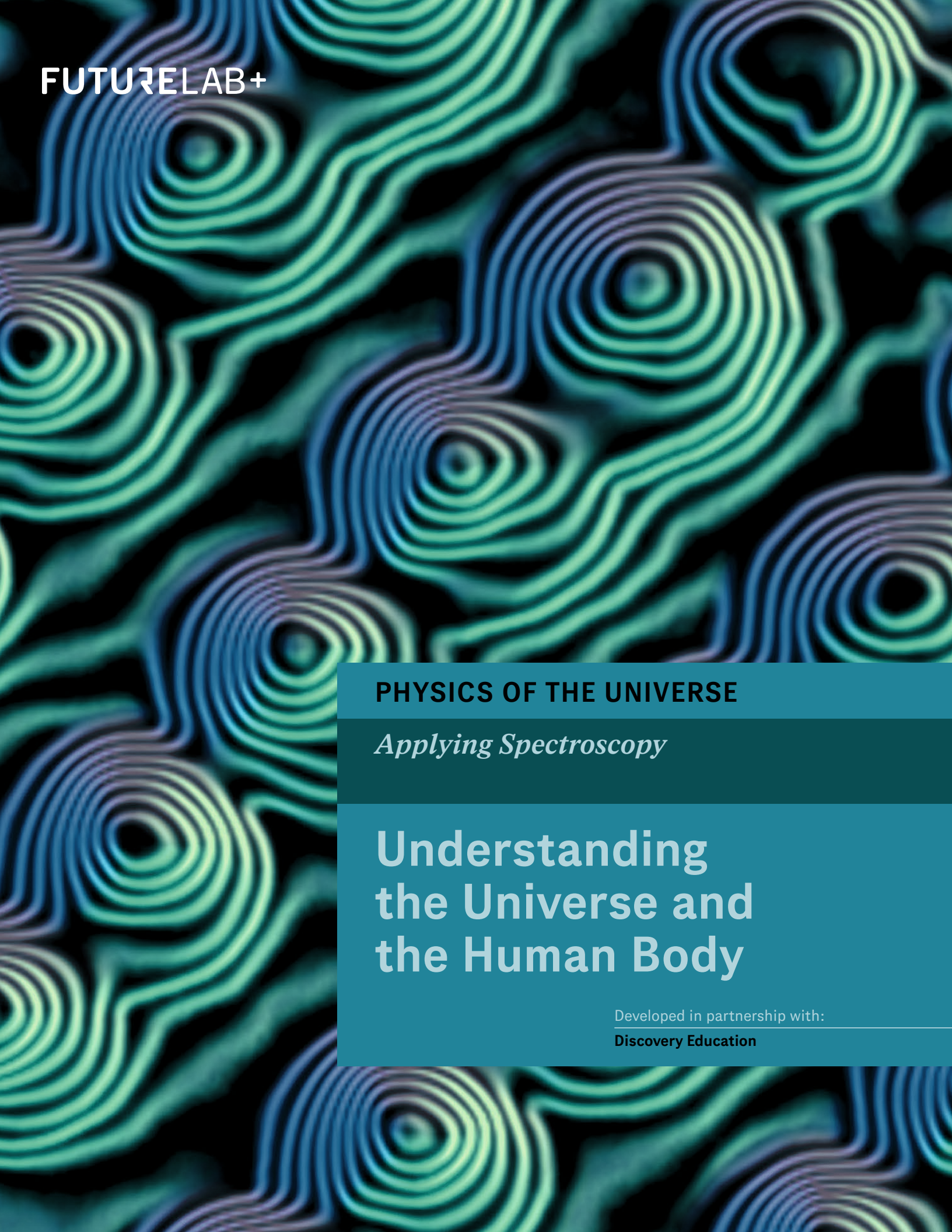


FUTURELAB+

PHYSICS OF THE UNIVERSE

Applying Spectroscopy

Understanding the Universe and the Human Body

Developed in partnership with:

Discovery Education

In this Lesson Plan:

Print the **Teacher Section** →

Print the **Student Section** →

This document is separated into two sections, For Teachers [T] *and* Student Resources [S]*, which can be printed independently.*

Select the appropriate printer icon above to print either section in its entirety.

Follow the tips below in the Range field of your Print panel to print single pages or page ranges:

Single Pages (use a comma): T3, T6

Page Range (use a hyphen): T3–T6

Cover Image
Image of magnetic flux lines around nickel nanodots.

PHYSICS OF THE UNIVERSE / APPLYING SPECTROSCOPY

Understanding the Universe and the Human Body

DRIVING QUESTION

How can we identify the chemical composition of newly discovered stars?

OVERVIEW

Spectroscopy is a science that studies the interaction between matter and electromagnetic (EM) radiation. By seeing how matter absorbs, reflects, or emits EM radiation, we can figure out what the matter is made of. Because of this, spectroscopy is critical to helping us identify objects in the universe. In this activity, students watch a short video about how a spectrum is formed and learn why spectroscopy is an important tool for astronomers. Next, students rank types of EM radiation by wavelength, frequency, and energy. Then, students engage in a hands-on lab activity where they conduct flame tests. As they participate in the lab, they will learn how spectra are determined, and how to identify different elements or unknown substances based on their spectral "fingerprints." Finally, students will assume the role of astronomers by using spectral analysis to identify the chemical composition of distant stars. As an extension, students uncover the biomedical applications of spectroscopy. They learn about how it gives scientists a non-invasive, optical way to detect disease or damage, as well as how spectroscopy can be used in treatment.

ACTIVITY DURATION

Three Days (45-minute sessions)

ESSENTIAL QUESTIONS

What are the different types of electromagnetic radiation and how are they different from one another?

How can we determine unknown substances using electromagnetic radiation?

How do scientists determine the chemical composition of distant stars?

OBJECTIVES

Students will be able to:

Describe how the types of electromagnetic radiation differ from one another in terms of wavelength, frequency, and energy.

Identify unknown chemicals using element emission lines seen during the flame test lab.

Identify the chemical composition of stars using emission lines of distant stars.

STUDENT TASKS

Day 1	*Day 2*	*Day 3*
Prism light spectrum demo observation and questions Electromagnetic radiation review Types of Electromagnetic radiation sorting activity	Flame test lab	Identify the chemical composition of distant stars

MAKE CONNECTIONS!

How does this connect to careers?

Astronomers study the stars and identify the chemical composition of celestial objects by using spectroscopy.

Sensor scientists develop and improve biotech sensors that are used to collect data. These professionals analyze, test, and evaluate complex sensor system designs. They are experts in sensor manufacturing processes and techniques, and they often invent new technologies that are used in the biotech industry.

Biotech research and development engineers develop and implement new biotech products. To do this, they use established biotech design control processes and engineering practices. They are expert problem-solvers whose specialized knowledge of product design helps them ideate, prototype, test, and bring new technology to market.

X-ray and MRI technicians specialize in using radiation to take diagnostic images. They use a variety of machines to do their job, including X-ray and magnetic resonance imagery (MRI) machines. X-ray and MRI images are used for lots of things in medicine, but are especially important for detecting disease and monitoring treatment effectiveness.

Radiation oncologists specialize in giving radiation therapy to cancer patients. They develop treatment plans, oversee radiation procedures, and monitor patients' responses to treatment. Radiation is a powerful tool in treating cancer, and it can be administered in a variety of ways. Sometimes, patients are exposed to external beams of radiation that target their cancer. In other cases, radiation is put directly in the body, either through an implant, IV, or by having the patient ingest the treatment.

How does this connect to our world?

Spectroscopy provides us with a powerful way to find out what things are made of—from the biggest planets to the smallest cells. In this lesson, students examine how we perceive light and color in our environment by learning about the electromagnetic spectrum and the science of spectroscopy. Students uncover the biomedical connection to spectroscopy by researching its diagnostic and therapeutic applications, such as non-invasive optical detection of diseased or damaged tissues and cells.

Pedagogical Framing

Instructional materials are designed to meet national education and industry standards to focus on in-demand skills needed across the full product development life cycle—from molecule to medicine—which will also expose students and educators to the breadth of education and career pathways across biotechnology.

Through this collection, educators are equipped with strategies to engage students from diverse racial, ethnic, and cultural groups, providing them with quality, equitable, and liberating educational experiences that validate and affirm student identity.

Units are designed to be problem-based and focus on workforce skill development to empower students with the knowledge and tools to be the change in reducing health disparities in communities.

SOCIAL-EMOTIONAL LEARNING

The strategies that encourage social-emotional learning center on the key attitudes and skills necessary for understanding and managing emotions, listening, feeling and showing empathy for others, and making thoughtful, responsible decisions. During the small group work and the labs included in this lesson, students will have opportunities to make use of these soft skills as they learn about the electromagnetic spectrum.

CULTURALLY AND LINGUISTICALLY RESPONSIVE INSTRUCTION

Instruction in this lesson provides for many small group interactions. This allows for culturally and linguistically diverse students to receive peer support and scaffolding during the lesson. The lesson uses such strategies as a Whip Around to ask students to identify questions from a list that they will need to answer in order to solve the lesson challenge. The lesson provides information about what NASA space scientists do, which allows students to more easily consider this as a career path.

COMPUTATIONAL THINKING PRACTICES

In this lesson, students learn how scientists use the electromagnetic spectrum to discover more about the universe. As they do this, students employ the computational thinking strategies of decomposition, developing algorithms, building models, and analyzing data. Computational thinking is crucial to the work of astronomers, physicists, and other scientists who study space. They use practices such as finding patterns in data, decomposing problems into smaller subproblems, and abstracting out essential findings in a sea of information.

ADVANCING INCLUSIVE RESEARCH

Magnetic resonance imaging (MRI) technology uses the electromagnetic spectrum to create noninvasive pictures of the inside of the body. MRI machines are crucial in the detection of many cancers and health events, such as strokes. They are essential for many clinical trials, but MRI machines are expensive and only well-resourced hospitals have access to them. MRI scans are also cost prohibitive for patients who are not sufficiently insured or enrolled in a clinical trial. Making MRI technology more accessible will greatly broaden access to one of the most important diagnostic tools known to medicine, and allow clinical trials to take place in more locations.

CONNECTION TO THE PRODUCT LIFE CYCLE

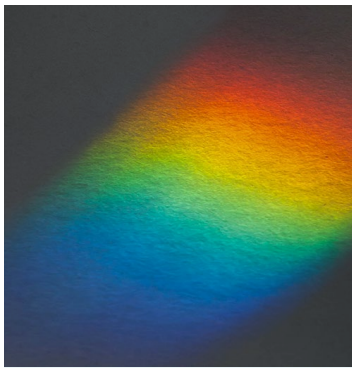
In this lesson, students develop their own versions of the electromagnetic spectrum and rearrange them in order to identify different chemicals. This exercise is an interpretation of spectroscopy, which is established science used for many different purposes. Spectroscopy technology is in the **commercialization** phase of the product life cycle.

Day 1

Slides 1–10

COMPUTATIONAL THINKING IN ACTION

Prisms are an example of the computational thinking strategy of decomposition at work. Prisms take a ray of light and decompose it into different wavelengths, which are viewable as different colors. By decomposing things like rays of light, we can better understand how they are made.



Slides 1–6

As a class, generate a list of student questions connected to the visible light spectrum. (10 minutes)

1	Set up a prism light demonstration using the following materials: • A half-full glass of water • A small mirror placed in the glass of water • A flashlight
2	Turn off the classroom lights and shine the light into the water so that it hits the mirror under the water.
3	Have students record their observations in the *Light Demo Observation and Questions* capture sheet.
4	Have students share their observations with a *Turn and Talk*.
5	Have students write down their questions. As students share their questions, add them to a large poster paper. Leave the poster paper untitled for now.

Slides 7–10

Students are introduced to the Electromagnetic Spectrum and the lesson's driving question. (10 minutes)

1.	Show the NASA Video: *Introduction to the Electromagnetic Spectrum*. As students watch the video, have them consider this key question: *How do scientists determine the composition of a planet or galaxy in space using the electromagnetic spectrum?*
2	After facilitating a class discussion around this question using a *Stand and Share* protocol, introduce the Driving Question: *How can we identify the chemical composition of newly discovered stars?*
3	Ask students to write down any new questions they have about the challenge of the lesson they will help solve. Have students share their questions aloud again and add them to the Need to Know Questions poster. Now, title the poster "Electromagnetic Spectrum Need to Know Questions."

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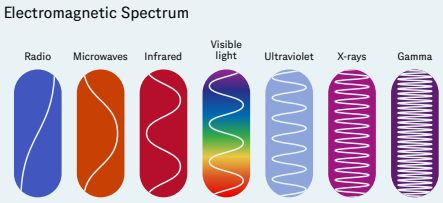
Day 1

Continued

Slides 11–16



Slides 11–16

Students complete a sorting activity to understand the types of electromagnetic radiation. (25 minutes)

1. Review key vocabulary using the NASA Video: *Introduction to the Electromagnetic Spectrum*, review these key vocabulary terms:
   - Electromagnetic Spectrum
   - Wavelength
   - Frequency
   - Energy
2. Place students in groups of three.
3. Give each group the *Electromagnetic Spectrum Cutouts*. The Electromagnetic Spectrum Cutouts include:
   - Radio Waves
   - Microwaves
   - Infrared Waves
   - Reflected Near-Infrared
   - Visible Light
   - Ultraviolet Waves
   - X-rays
   - Gamma Rays
4. In their groups, have students place the spectra in the correct order using the following prompts, one at a time:
   - **a.** Place the cut outs in order of highest frequency to lowest frequency.
   - **b.** Place the cut outs in order of longest wavelength to shortest wavelength.
   - **c.** Place the cut outs in order of highest energy to lowest energy.

Continues next page >

Day 1

Continued

Slides 11–16

5 Use the following table to check student work:

Prompt A Order	Prompt B Order	Prompt C Order
Gamma Rays	Radio Waves	Gamma Rays
X-rays	Microwaves	X-rays
Ultraviolet Waves	Infrared Waves	Ultraviolet Waves
Visible Light	Reflected Near-Infrared	Visible Light
Reflected Near-Infrared	Visible Light	Near-Infrared Reflected
Infrared Waves	Ultraviolet Waves	Infrared Waves
Microwaves	X-Rays	Microwaves
Radio Waves	Gamma Rays	Radio Waves

6 As individuals, have students complete the *Electromagnetic Spectrum Exit Ticket* to answer the question: *"How does the wavelength and frequency of the electromagnetic spectrum change when energy increases and decreases?"* Have them share their answers in their small groups and discuss.

Day 2

Slides 17–21

Slides 17–19

Students review the Electromagnetic Spectrum Need to Know Questions. (5 minutes)

1. In their groups, have students review the questions from the list and identify questions they can answer based on the content and work from the previous day.
2. Ask students to identify what new questions they have and add them to the list.
3. Remind students of the Driving Question for the lesson. Now, use a quick *Whip Around* to ask students to identify the questions from the list they need to answer next in order to get close to solving this challenge. Use this discussion to transition to introduce the guiding question for today: "How can we use the electromagnetic spectrum to determine different types of chemicals?"

Slides 20–21

Students conduct the Flame Test Lab to determine unknown substances using emission spectroscopy. (25 minutes)

Teacher Note > *Perform the lab yourself prior to class in order to establish how to perform it safely.*

1. Pass out diffraction grating film to students.
2. Have students view the various elements placed in the Spectroscope tube and draw the emission lines they see for the various elements in Part 1 of the *Discovering Unknown Chemicals* capture sheet.
3. Move into Part 2 of the Flame Test Lab by doing one of the options below. The unknown chemicals for the experiment include:
   - **a.** Sodium
   - **b.** Iron
   - **c.** Sulfur
   - **d.** Magnesium
   - **e.** Calcium

Continues next page >

Day 2

Continued

Slide 22

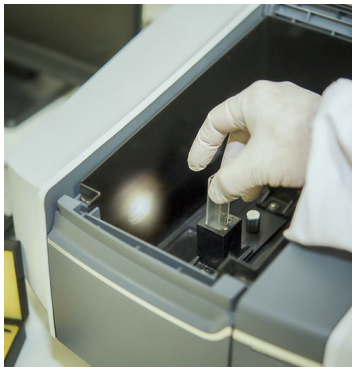
Slides 22	
Students identify unknown substances. (15 minutes)	
1	Perform the flame test yourself with students observing the color of the flames as you pass the unknown chemicals in the flame.
2	Students use the diffraction grating films to observe the emission lines for each unknown chemical.
3	Students complete Part 2 of the *Discovering Unknown Chemicals* capture sheet.
4	When done, have students complete The Big Question at the end of Part 2. Have students share their responses with their previous group of three and discuss how astronomers are able to identify the chemical composition of distant stars. Have each group do a quick *Round Robin* to share important points from their discussion.

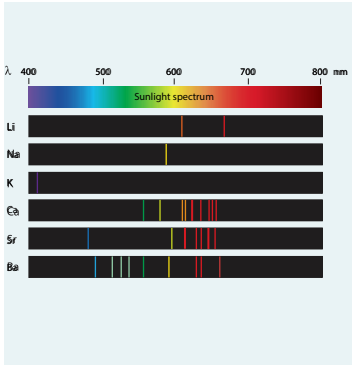
Day 3

Slides 23–30

INDUSTRY AND CAREER CONNECTIONS

Astronomers use spectroscopy to identify the different elements that can be found in stars. They also use electromagnetic waves to discover where other stars, planets, and galaxies reside in the universe.





COMPUTATIONAL THINKING IN ACTION

As students think about how to solve the problem of identifying mystery elements in stars, they must use the computational thinking strategy of analyzing data. Scientists identify the chemical composition of stars by using spectroscopy, which is a method of analyzing data that uses the electromagnetic spectrum.

Slides 23–25

Review the Electromagnetic Spectrum Need to Know Questions with students. (5 minutes)

1	In their groups, have students review the questions from the list and identify questions they can answer based on the content and work from the previous day.
2	Ask students to identify what new questions they have and add them to the list.
3	Remind students of the Driving Question for the lesson. Now, ask students to identify the questions from the list they need to answer next in order to get close to solving this challenge. Use this discussion to transition to the next section of the class.

Slides 26–30

Students identify the chemical composition of stars. (40 Minutes)

1	Tell students that stars are composed of multiple types of elements. Pose the question for students: *"If stars are composed of multiple elements, how do you think the emission lines of stars would appear in a spectroscope?"* In order to consider this question, ask students to reflect on their experience viewing the emission lines from the previous day.
2	Use the *Give One, Get One* strategy for students to share their answers with one another for this question and the one that follows.
3	Ask students to reflect on the following question: *"How can we use the element spectrum they used to identify the mystery elements on the previous day to identify multiple elements that appear on the same electromagnetic spectrum?"*
4	Use these conversations to introduce the *Element Spectra Cutouts* and the *Newly Discovered Star Identification* capture sheet.
5	Have students use the *Element Spectra Cutouts* and the *Newly Discovered Star Identification* capture sheet to identify the chemical composition of the stars.

Continues next page >

Day 3

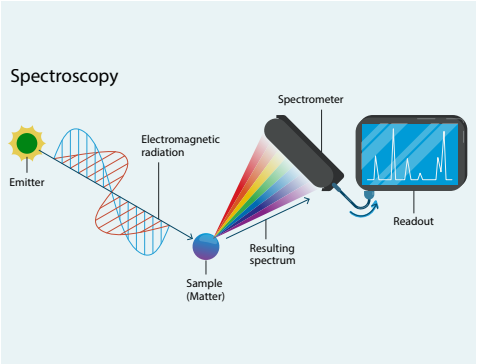
Continued

Slides 26–35

6 As an exit ticket, have students use the same *Give One, Get One* strategy to discuss the following question: *"We can use spectroscopy to determine the chemical composition of newly discovered stars in our galaxy. What other applications do you think we can use spectroscopy for?"*

INDUSTRY AND CAREER CONNECTIONS

Radiation oncologists, MRI technicians, and X-ray technicians all use spectroscopy to administer medical care to patients. Radiation is a powerful tool for detecting damaged and diseased cells. Often, X-ray and MRI scans are vital for diagnosing patients. Radiation is also a common treatment for disease and it can be administered in lots of ways. The science of spectroscopy helps medical practitioners harness the power of light.



Slides 31–35

Students explore the ways that spectroscopy applies to other fields of science. (45 minutes)

1 Explain to students that they will research the applications of spectroscopy in diagnostic or therapeutic applications. After, they will present their findings to the class.

2 Divide students into groups of 3–4 and ask them to choose one of the topics below to research. In their presentation, ask students to include how this technology revolutionized healthcare.

- **a.** Optical Detection of Diseased/Damaged Cell Tissues
- **b.** X-Ray, Radiation, MRI for Diagnosis of Disease
- **c.** Plasma Therapy
- **d.** Radiotherapy
- **e.** Low Intensity Millimeter Wavelength Electromagnetic waves to treat disease:
  - Cardiovascular disorders/disease
  - Diabetes—wound healing and pain relief
- **f.** Choose Your Own Topic

3 Have each group present their topic to the class.

4 Have students complete the *Applications of Spectroscopy in Biotechnology* capture sheet as they listen to the presentations conducted by their peers.

5 As an Exit Ticket, have students answer the following question with the *Tweet, Tweet* strategy: *How will spectroscopy further change the way we diagnose, treat or manage diseases in the future?*

National Standards

Next Generation Science Standards

Science Engineering Practices (SEP)

Practice 2
Developing and Using Models

Develop a model based on evidence to illustrate the relationships between systems or between components of a system.

Practice 3
Planning and Carrying Out Investigations

Students should have opportunities to plan and carry out several different kinds of investigations during their K–12 years. At all levels, they should engage in investigations that range from those structured by the teacher—in order to expose an issue or question that they would be unlikely to explore on their own (e.g., measuring specific properties of materials)—to those that emerge from students' own questions.

Disciplinary Core Ideas (DCI)

ESS1.A
The Universe and Its Stars

The study of stars' light spectra and brightness is used to identify compositional elements of stars, their movements, and their distances from Earth. (HS-ESS1-3)

Crosscutting Concepts (CC)

Systems and System Models

Models (e.g., physical, mathematical, computer models) can be used to simulate systems and interactions—including energy, matter, and information flows—within and between systems at different scales.

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Light Demo Observation and Questions Capture Sheet

Directions
Write down your observations from the demonstration. Based on the observations you made, what questions do you have?

	My Observations	My Questions
1		
2		
3		
4		
5		

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Electromagnetic Spectrum Cutouts

Directions
Cut out the slips and place the spectra in the correct order as prompted by your teacher.

Radio Waves	Microwaves
Infrared Waves	Reflected Near-Infrared
Visible Light	Ultraviolet Waves
X-Rays	Gamma Rays

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Electromagnetic Spectrum Exit Ticket

Directions
Respond to the prompt.

When the frequency of electromagnetic radiation increases, what happens to the wavelength and energy?

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Discovering Unknown Chemicals Capture Sheet, Part 1

Element Emission Lines

Directions

Draw the emission line spectra that you view through the diffraction grating film for each element below. Use the color pencils to match the colors you see through the film.

1	Sodium (NA)
2	Hydrogen (H)

Continues next page >

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Discovering Unknown Chemicals Capture Sheet, Part 1

Element Emission Lines

Continued

3	Helium (He)
4	Iron (Fe)
5	Sulfur (S)

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Discovering Unknown Chemicals Capture Sheet, Part 1

Element Emission Lines

Continued

6	Nitrogen (N)
7	Magnesium (Mg)
8	Calcium (Ca)

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Discovering Unknown Chemicals Capture Sheet, Part 2

What Chemical Element Is It?

Directions

When the teacher places the different mystery chemicals under the flame, use the diffraction grating sheet to draw the Emission Lines for the mystery chemical. Use your work in Part 1 of this capture sheet to identify each mystery chemical.

1	Mystery Chemical A
Based on the Emission Lines of the mystery chemical, which element is this?	

2	Mystery Chemical B
Based on the Emission Lines of the mystery chemical, which element is this?	

Continues next page >

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Discovering Unknown Chemicals Capture Sheet, Part 2

What Chemical Element Is It?

Continued

3	Mystery Chemical C
Based on the Emission Lines of the mystery chemical, which element is this?	

4	Mystery Chemical D
Based on the Emission Lines of the mystery chemical, which element is this?	

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Discovering Unknown Chemicals Capture Sheet, Part 3

Spectroscopy, Emission Lines, and Astronomy

Directions

Respond to the prompt.

Now that you have learned how to identify an unknown substance using emission lines, how do you think astronomers are able to determine the chemical composition of stars far away from our solar system?

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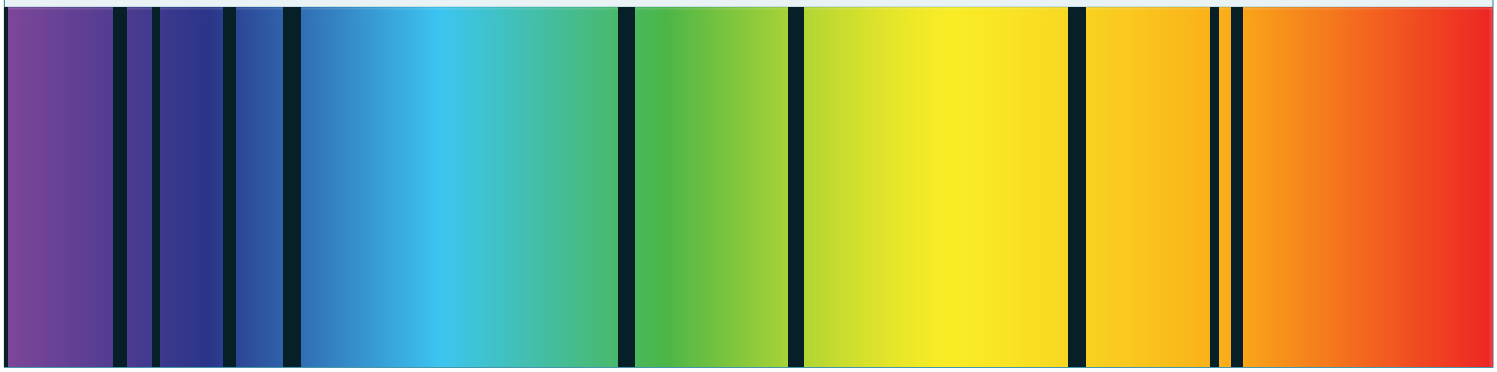
Element Spectra Cutouts

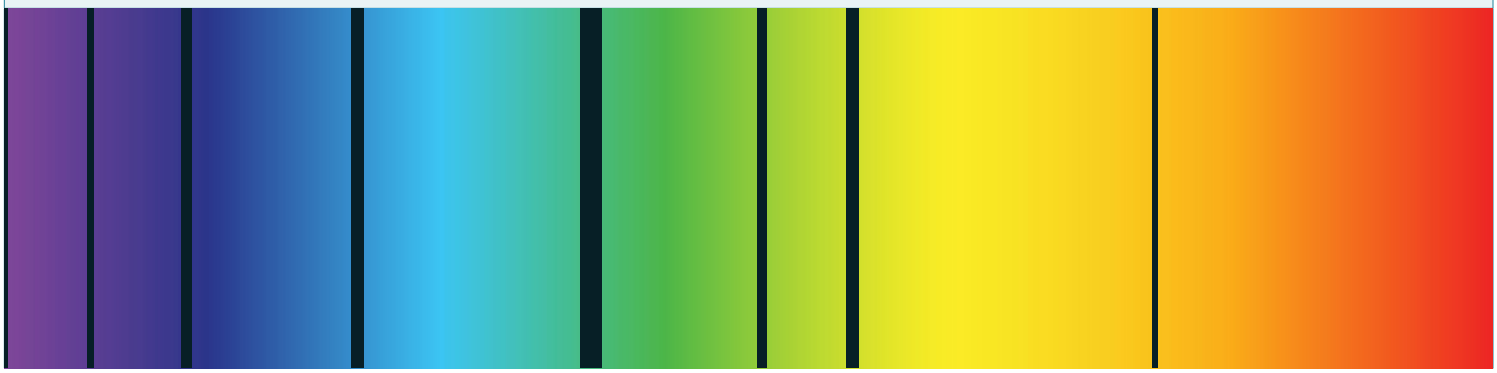
Directions
Cut out the element spectra below in order to identify the chemical compositions of the newly discovered stars.

Iron

Calcium



Magnesium



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Element Spectra Cutouts

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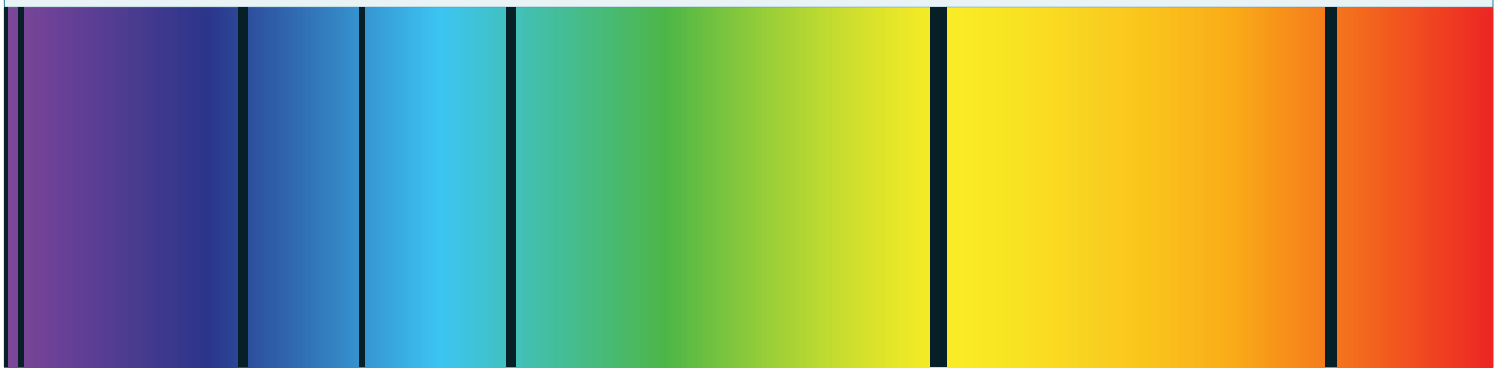
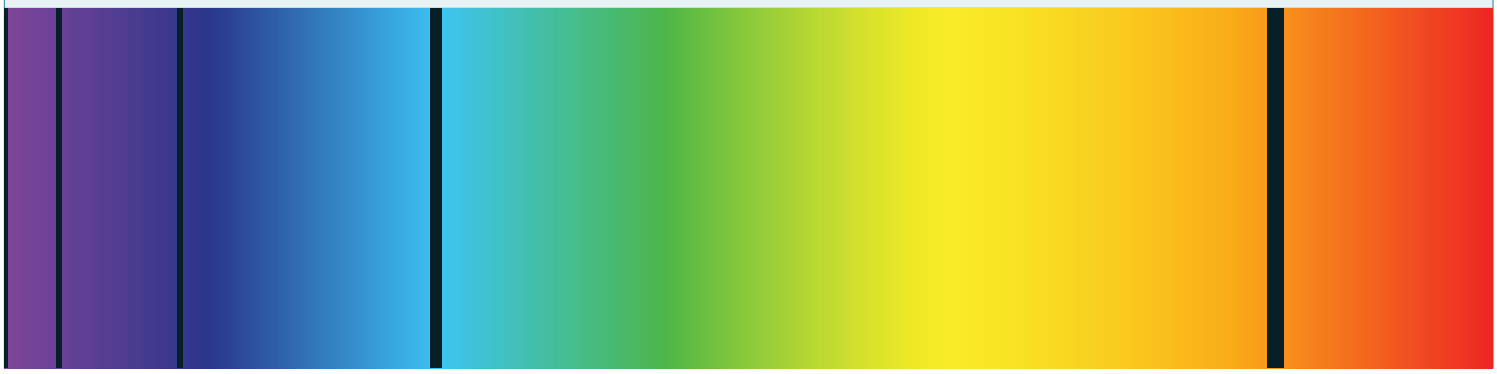
Sodium

Helium



Hydrogen



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Newly Discovered Star Identification Capture Sheet

Directions

Use the element spectra cutouts to identify the chemical composition of the newly discovered stars below.

1 Star A

Based on the cut outs, what is the chemical composition of this star?	

2 Star B

Based on the cut outs, what is the chemical composition of this star?	

Continues next page >

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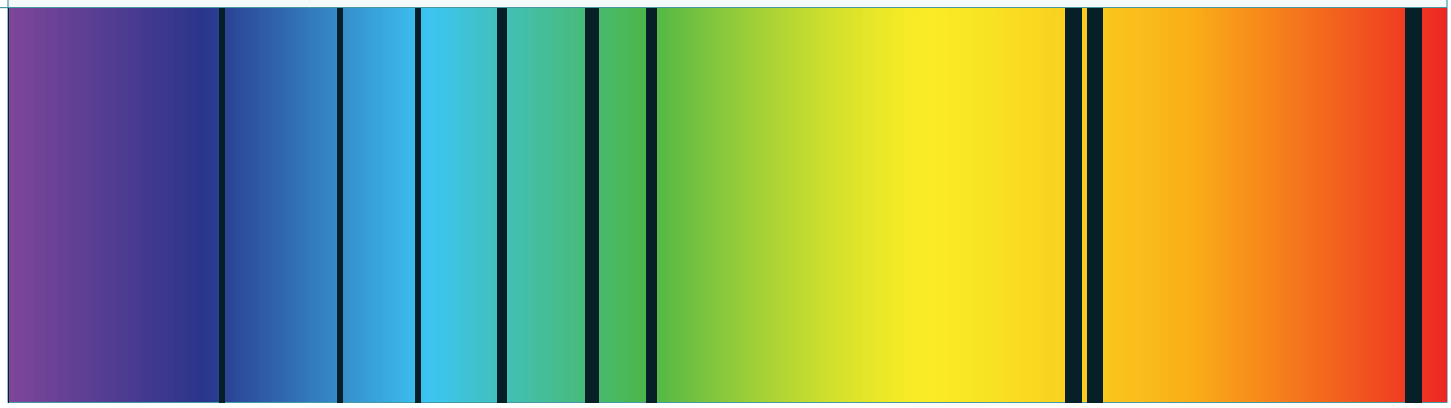
Newly Discovered Star Identification Capture Sheet

Continued

3 Star C

Based on the cut outs, what is the chemical composition of this star?

4 Star D



Based on the cut outs, what is the chemical composition of this star?

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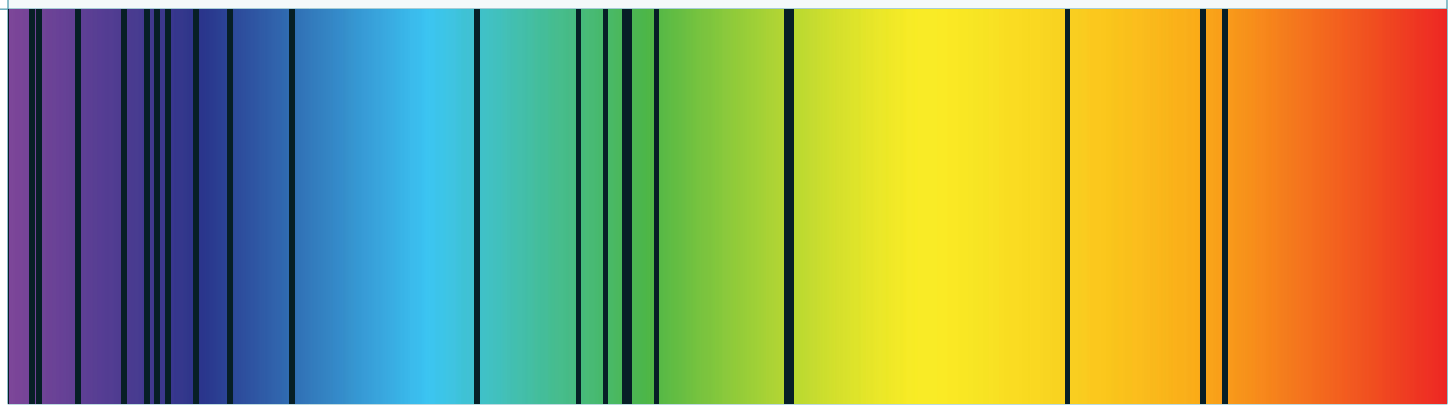
Newly Discovered Star Identification Capture Sheet

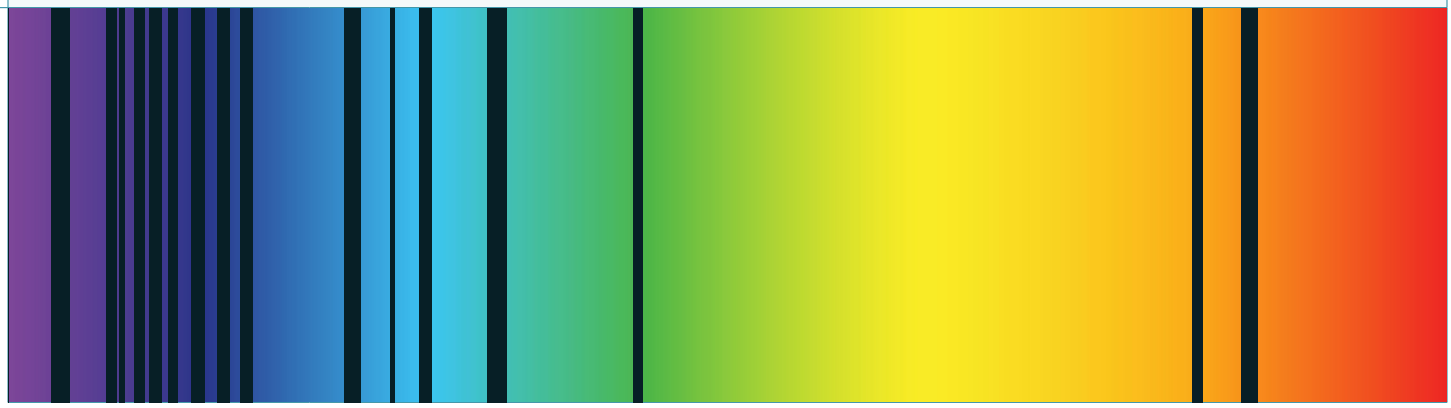
Continued

5 Star E



Based on the cut outs, what is the chemical composition of this star?

6 Star F



Based on the cut outs, what is the chemical composition of this star?

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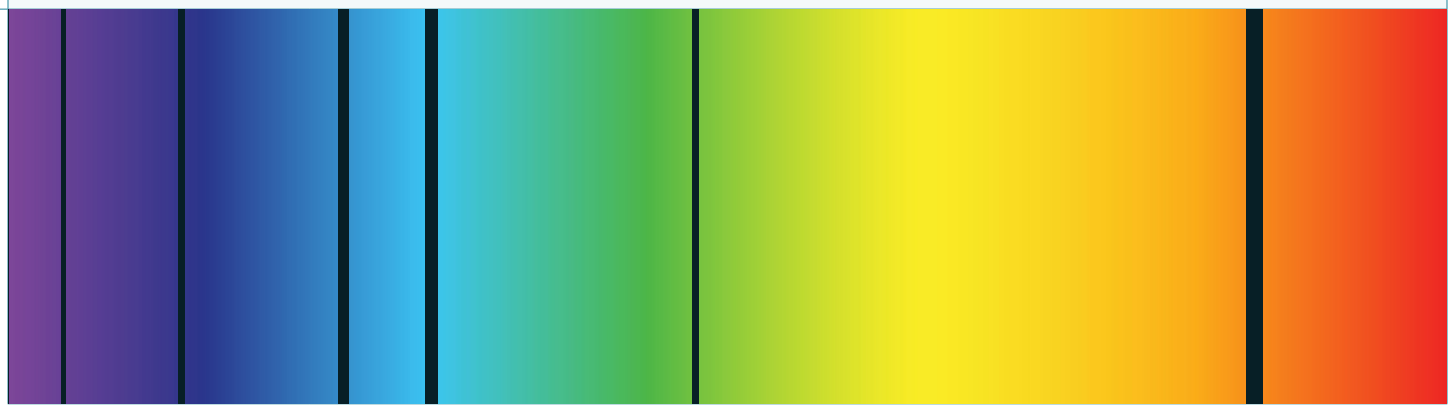
Newly Discovered Star Identification Capture Sheet

Continued

7 Star G



Based on the cut outs, what is the chemical composition of this star?

8 Star H

Based on the cut outs, what is the chemical composition of this star?

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Newly Discovered Star Identification Capture Sheet

Continued

9	Star I

Based on the cut outs, what is the chemical composition of this star?

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Applications of Spectroscopy in Biotechnology Capture Sheet

Directions

Work with your group to discover how a technology that is built on the electromagnetic spectrum changed the world. Put your findings in the table below and then compile them into a presentation for your class.

Hint: review the rubric to identify criteria for your presentation.

Topic Bank

Optical detection of diseases/damaged cell tissues

X-ray/radiation/MRI for disease diagnosis

Plasma therapy

Radiotherapy

Low-intensity electromagnetic millimeter waves as a disease treatment (for cardiovascular disease, diabetes, etc.)

A topic of your choosing

Continues next page >

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Applications of Spectroscopy in Biotechnology Capture Sheet

Continued

Topic	1	What is it?
	2	Who uses it?
	3	When was it developed?
Function	4	How does it work?
	5	How does it use spectroscopy?
Impact	6	How has this technology changed the world?

Continues next page >

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Applications of Spectroscopy in Biotechnology Capture Sheet

Continued

Issues	7	What issues or concerns are related to this technology?
	8	Are the issues and concerns valid? Why or why not? Cite evidence.
Notes	9	What else should people know about this technology?

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Applications of Spectroscopy in Biotechnology Rubric

Directions

Evaluate the presentation by responding with reflective comments based on the expectations below. Use the space in the center column to share evidence with the group. Use the Feedback column for areas of growth and the Exceeded column for areas that excel.

Feedback How can this presentation be improved?	Baseline How does this presentation meet expectations?	Exceeded How does the presentation exceed expectations?
	Content: presentation is thorough and has lots of good information.	
	Style: presentation is clear and easy to understand.	
	Accuracy: presentation includes facts and cites sources.	
	Format: presentation shows prior preparation and uses a visual tool, such as a video, slide deck, etc.	