Level	Electromagnetic spectrum
High School	

Time Required	Lesson Summary
125 min. (2.5- 50 min. class periods)	In this lesson, students will learn about the categories of electromagnetic waves. They will investigate the uses and dangers of one type of these waves and share their findings with peers. Finally, they will debate how one section of the spectrum should be used.

Standards

NGSS:

HS-PS4-4. Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter

Vocabulary	Objectives
Gamma rays X-rays Ultraviolet rays Infrared waves Microwaves Radio waves	• Students will be able to describe the categories of electromagnetic waves • Students will determine the uses and dangers of different types of electromagnetic waves

Materials

- student copies of handouts

Pre-Requisites

Students need to understand wave characteristics and electromagnetic waves.

Safety Considerations

None

Pacing Notes

This lesson has been designed to take two and a half class periods (50 min each). If your class periods differ in length from this, you will need to adjust the following schedule.

Day 1: The first class period should consist of the starter activity, the metric conversion review, and students should begin the research.

Day 2: During the second class period, students should complete the research, meet with similar peers, jigsaw with other peers, and you should guide the whole class discussion. At the end of this period, students should be assigned to read one of the three articles listed in the closure section below.

Day 3: The activity for the third class period will only take half of the time. The students will participate in a whole class or small group debate during this time.

Before the Lesson

Print out the metric review sheet, the electromagnetic research page, and the jigsaw page.

Ether print out or post links to your learning management system for the three debate articles (see conclusion section below).

Assessments	Classroom Instructions
Pre-Activity Assessments	*Introduction*
	Have the electromagnetic spectrum diagram provided with this lesson either projected on the board or printed and available at each desk. Then, while you take attendance and accomplish other administrative tasks, students should look at the figure and make as many observations about it as possible. Hint: If you can offer a small prize, make this a contest to come up with the largest number of quality observations (something other than the line is curvy or hilly).

Activity Embedded Assessments	Activities
	1. Discuss the electromagnetic spectrum diagram a. Allow students to share their observations with the class and create a list on the board. Call on as many students as possible, so everyone has the chance to participate. If you make the provision that their observation must be different than others on the board, it should cut down on time for this activity. b. Tell students the category names, for example, gamma rays were created people who wanted to talk about parts of the spectrum with their peers. *** Misconception alert*** one of those category names, radio, may cause your students to misunderstand these waves. The radio students are familiar with brings music and talk into cars. Therefore, they may think sound waves are electromagnetic waves, which they are not. Sound waves are compression or longitudinal waves. You may need to explain how a radio station and the radio in a car work. In short, radio stations convert voices and music to electronic signals, which are transmitted by the antennae. Then a car antenna receives the signal, and the radio converts the electromagnetic wave back to a sound wave. You can find some references for this process in the educator resources section at the bottom of the document. 2. Introduce the units used on the spectrum
Make sure you stop reading (or have the student stop) and ask questions about the information in that paragraph. Look for the students who seem least engaged and assess their understanding. Repeat the paragraph if necessary. While doing the first two as examples, allow students to ask clarifying questions. Walk around while students are working.	a. Students will probably not be familiar with some of the units on the diagram. For example, while they should be familiar with a meter, a nanometer (nm) may be new. Therefore, spend some time reviewing the metric scale. Then, hand out the unit review sheet. Read the top paragraphs to the students or have one of them read aloud for the class. b. Complete numbers one and two as examples.

Check that they are getting the correct answers. If students have the wrong answer, stop and reteach that pair. If several teams have the wrong answer for the same question, stop and reteach the entire class.	c. Have students complete numbers 3 and 4 with a partner.
Walk around and assess students as they work. Look for confused students and check to see if they are getting the correct answers. If not, reteach. *Collect the sheets and grade them.*	d. Have students finish the page by themselves.
While students are researching, walk around the class. **Ask**: Which item are you researching? What have you found out? **Ask**: Do you think this type of EM wave is more helpful or harmful? Request students to give a reason for their answer. **Ask**: What is the most	4. Spectrum research During this activity, students will research a portion of the electromagnetic spectrum. a. Divide your class into six sections. Each section will research a different portion of the spectrum. Although this is individual research, there will be time to collaborate with others later in the lesson. b. Pass out the pages and assign students a portion of the spectrum to research. Give students 30 minutes to complete this activity. <u>Portions of the spectrum</u> Gamma rays X-rays Ultraviolet rays Visible light Infrared waves Microwaves Radio waves

interesting thing you found about this type of wave? If a student responds "nothing," then ask what they have found out, choose something you think is interesting, and talk to them about that fact.	c. No computer alternative: If your school does not have computers for students, you can still complete this activity. Locate several sources of information about each portion of the spectrum and print them off. To save paper, you could create packets for each topic and instruct students that these are a class set and will be reused.
Walk around while groups are sharing. Make sure several students are contributing to the conversation. If you encounter a group where only one student is sharing, **Say**: That is excellent information, student x, but I would like to hear what student y has to say about the matter.	d. Same topic peer share The students who researched the same portion of the spectrum should be given 12 minutes to discuss their topic. First, one student should share their answer, and then others in the group should add additional information. To ensure equal participation, a different student should initially answer each question (if possible, given group sizes). In the end, students should decide what information from each answer is most important to share with other groups. Inform them that they will only have 3 minutes to share what they learned.
Walk around while groups are sharing. Ensure students are writing down important information shared by their peers. *Collect the papers and grade them.*	e. Jigsaw Create groups that contain one student from each of the six topic groups. In some cases, there may be two students from a topic group in one jigsaw group depending on class size. Distribute jigsaw recording pages to the group. Instruct students that they need to be concise when providing information to peers. They need to provide their answers in 2 minutes and will have 1 minute for questions from their peers.
Monitor the students for engagement. If several seem disinterested in the conversation, change your approach. Ask alternative	5. Whole class discussion After the jigsaw activity has ended take some time to discuss the uses of the electromagnetic spectrum as a whole group. There is no need to go over the questions for the pages here, as students have just spent a considerable time

questions instead, such as: **Ask**: If you were a superhero and wanted to protect the planet from asteroids, what category of EM wave would you need to emit?	discussing that information. Instead, probe student understanding by asking questions such as: **Ask**: Which category of electromagnetic waves are the most dangerous? Support your statement with evidence. **Ask**: Which category of electromagnetic waves are the most useful to humans? Support your statement with evidence. Notice the above questions don't have an answer. There are several possibilities as long as students have evidence to support their statements.
Post Activity Assessments	Closure
Given the nature of a debate, this is not a learning activity that should be graded. If you would like to give a grade for this part of the lesson consider assigning a writing assignment based on	At the end of the second class meeting, you should have assigned students to read one of the following articles as homework. You can allow students to choose an article or assign each student to read a specific article. If you allow students to choose, try to keep the three groups as similar in size as possible. Tell students that they will be taking the side of the group portrayed in the article. Cell phone companies https://www.lifewire.com/5g-spectrum-frequencies-4579825 - (last accessed 6/24/23) Military https://www.defense.gov/Explore/News/Article/Article/2404027/new-spectrum-strategy-reveals-dods-plan-to-master-airwaves/ (last accessed 6/24/23) Researchers https://www.aip.org/fyi/2019/scientists-wary-interference-impending-telecommunications-initiatives (last accessed 6/24/23) Today the students are going to participate in a debate. It is the teacher's choice if this debate is held as a whole class or in small groups. Regardless of the size of the debating groups, you must specify the rules of the debate before starting the activity. Students should only be allowed to speak one at a time. They should always provide a reason for their position backed up by evidence from the readings. It is okay for them to disagree, but they need to do so in a respectful manner. Consider providing a list of sentence starters to help students find the correct words to interact with their peers. **The main question of the debate is:** Should companies be allowed to use the same frequencies as researchers and the

the debate. During the debate, pay attention to students' responses. If a student provides incorrect information, don't intervene. Instead, allow the other students to correct the misinformation. If the information persists despite several students chiming in on the matter, step in and correct the misconception.	military? Remind students that they should be supporting the position in the article they were given to read. If the discussion wanes interject additional, related questions for the students to discuss.

Culturally Inclusive/Responsive Components

Be aware of your students' cultures. For example, in some cultures, it is taboo to challenge the answers of others in public. As a result, individuals from those cultures may struggle with the debate activity. If possible, speak to these students before the activity. Explain to them the learning objectives and ask how you can make this activity more comfortable for them.

The following people have done some interesting things relating to the EM spectrum. A brief description is included below. Underrepresented minority students must understand people from their ethnicity have participated in important scientific research. You could have students research these individuals, create a PowerPoint and present it to your class, or create posters about these individuals and post them on your classroom walls.

George Robert Carruthers – An African American who designed his first telescope at age ten. He created a camera that allowed astronauts to take pictures of UV waves. https://www.biography.com/inventor/george-carruthers (last accessed 6/24/23)

Walter Samuel McAfee – African American who participated in the Project Diana Team during WWII. This team conducted experiments to see if radio frequencies could travel through the Earth's atmosphere. This research was important for our current satellite communications. http://www.math.buffalo.edu/mad/physics/mcafee_walters.html (last accessed 6/24/23)

France Cordova – a Hispanic woman who became the first woman to lead Purdue University. Before becoming university president, Ms. Cordova studied astrophysics and served as chief scientist at NASA. During her time at NASA, she focused on elements of science policy. https://www.purdue.edu/fac/about/ (last accessed 6/24/23)

Ellen Ochoa – A Hispanic woman who served as the director of the Johnson Space Center. Before that, she was the first Hispanic woman to go to space. She spent nine days in space on board the space shuttle Discovery. https://www.nasa.gov/centers/johnson/about/people/orgs/bios/ochoa.html (last accessed 6/24/23)

Accommodations

Alter the assignments to meet the needs of students with IEPs.

Allow English language learners to partner with a native speaker for the research component. This will help them develop their language skills while completing the assignment.

Be aware of students who are anxious about speaking in front of others. Accommodate this by allowing them to choose a partner to work with and allowing that person to speak for the two of them.

Educator Resources

How radio stations work
https://www1.udel.edu/nero/Radio/readings/classes.html (last accessed 6/24/23)

https://flexbooks.ck12.org/cbook/ck-12-middle-school-physical-science-flexbook-2.0/section/18.5/primary/lesson/radio-waves-ms-ps (last accessed 6/24/23)

Electromagnetic spectrum categories
https://courses.lumenlearning.com/boundless-physics/chapter/the-electromagnetic-spectrum/ (last accessed 6/24/23)

Optional Extension Activities

Cosmic coloring Compositor
https://public.nrao.edu/color/ (last accessed 6/24/23)

The images on this page were created by combining the images from several telescopes to give a complete picture of space phenomena. This web page allows you to select a color to represent each category of Electromagnetic radiation. By choosing a different color for each type of radiation, a student can see how each type of wave contributes to the finished image. Alternatively, students can select one type of wave at a time and compare the images produced by each telescope.

Acknowledgments

This is the third lesson in a nine-lesson series intended to increase student understanding of radio frequencies. You are welcome to just use this lesson but if you are interested in this topic consider checking out the others in the series.

Lesson One: Mechanical Waves
Lesson Two: Electromagnetic Waves
Lesson Three: Electromagnetic Spectrum
Lesson Four: Argumentation and Radio Waves
Lesson Five: Investigating Spectrum Users
Lesson Six: Aircraft and Newton's Second Law of Motion
Lesson Seven: Weather Forecasting and Radio Waves
Lesson Eight: Satellites and Society
Lesson Nine: Spectrum Management

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