Lesson 9: What other types of EM radiation are there, and how do we use them?

Previous Lesson *We developed and revised a model, using wave properties of interference that we observed while using simulations of waves, to explain hot and cold spots in the microwave oven. We used our model to make sense of the turntable's function. We revised our initial consensus model from the anchor phenomenon and our Driving Question Board.*

This Lesson

Investigation, Problematizing

2 days

European Southern Observatory (ESO)/C. Malin

We examine the remaining categories of questions on the Driving Question Board. We explore various types of EM radiation and construct the EM spectrum based on their wavelength and frequency. We write an argument about the relationship between the frequency and wavelength of EM radiation and its interactions with matter, and how this relationship helps explain some of the uses of EM radiation. We add new questions to the DQB and decide to examine why some types of EM radiation can harm living organisms and others do not.

Next Lesson *We will sort cards and identify the wave properties that better characterize harmful EM radiation. We will use various data sources to identify the pattern of increased frequency and increased cancer risk. We will analyze a wave model and a photon model of EM radiation and determine that the photon model better explains our evidence.*

BUILDING TOWARD NGSS

HS-PS2-5, HS-PS4-1, HS-PS4-2, HS-PS4-3, HS-PS4-4, HS-PS4-5, HS-ESS2-4

What students will do

9.A Develop an argument about why EM radiation can be used in multiple technologies to do specific tasks based on its frequency, wavelength, and interactions with matter. (SEP: 7.4; CCC: 4.1; DCI: PS4.B.2, PS4.C.1)

9.B Ask questions that arise from examining a model of the electromagnetic spectrum related to the uses and material interactions of different types of electromagnetic radiation. (SEP: 1.2; CCC: 4.1; DCI: PS4.B.2, PS4.C.1)

What students will figure out

- EM radiation with high frequencies has short wavelengths; EM radiation with low frequencies has long wavelengths.
- The EM radiation spectrum is arranged from high- to low-frequency EM waves.
- Different types of EM radiation have different interactions with matter, including heating it, ionizing it, or breaking apart its molecules.
- These interactions can be harnessed for various applications, such as medical imaging, telecommunications, and energy production.
- Ionizing radiation can harm living organisms.

Lesson 9 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	5 min		**NAVIGATE** Gather in a Scientists Circle to determine which group of questions on the Driving Question Board to answer next.	A	Driving Question Board
2	8 min		**ORIENT TO THE EM RADIATION TYPES** Make sense of the quantitative information presented in the *Electromagnetic Radiation Cards*.	B-D	*Electromagnetic Radiation Cards*
3	11 min		**IDENTIFY TRENDS IN FREQUENCY AND WAVELENGTH** Complete the card sort(s) and record trends in the handout. Co-construct the spectrum of EM radiation based on wavelength and frequency.	E-F	*EM Radiation Applications*, *Electromagnetic Radiation Cards*
4	10 min		**MAKE SENSE OF THE SPEED OF LIGHT** Use the values of frequency and wavelength to calculate the speed of some of the EM radiation types. Use the mathematical model of wave speed developed in Lesson 3 to make sense of the speed of light.	G-H	*EM Radiation Applications*, calculator, *Electromagnetic Radiation Cards*
5	11 min		**IDENTIFY CONNECTIONS BETWEEN THE USES OF EM RADIATION AND THEIR PROPERTIES** Identify the properties of EM radiation that could help explain their uses, and write a short argument to support these ideas.	I	*EM Radiation Applications*, *Electromagnetic Radiation Cards*
					End of day 1
6	2 min		**NAVIGATE** Review the arguments recorded last time about the uses of EM radiation.	J	*EM Radiation Applications*

7	5 min		**PRESENT ARGUMENTS ABOUT EM RADIATION APPLICATIONS** Share arguments and provide feedback in pairs.	K	*EM Radiation Applications*, *Electromagnetic Radiation Cards*
8	5 min		**REVISE ARGUMENTS BASED ON FEEDBACK** Revise arguments based on partner discussion and turn in *EM Radiation Applications*.	L	*EM Radiation Applications*
9	8 min		**DEBRIEF ARGUMENTS ABOUT EM RADIATION APPLICATIONS** Discuss the reasons why some EM radiation types but not others are used in certain applications.	M	
10	6 min		**DEFINE ELECTROMAGNETIC SPECTRUM** Discuss the inferences we can make about EM radiation types from their place in the electromagnetic spectrum. Record a definition for *electromagnetic spectrum* in Personal Glossaries.	N-O	spectrum of *Electromagnetic Radiation Cards*
11	10 min		**UPDATE THE DRIVING QUESTION BOARD** Add questions to the Driving Question Board.	P-Q	3” x 3” sticky notes, markers, Driving Question Board
12	9 min		**NAVIGATE: EXIT TICKET** Update the *Progress Tracker* and complete an exit ticket.	R-S	8.5” x 11” paper

End of day 2

Lesson 9 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • *EM Radiation Applications* • calculator • 3" x 3" sticky notes • markers • 8.5" x 11" paper	• *Electromagnetic Radiation Cards*	• Driving Question Board • spectrum of *Electromagnetic Radiation Cards*

Materials preparation (20 minutes)

Review teacher guide, slides, and teacher references or keys (if applicable).

Make copies of handouts and ensure sufficient copies of student references, readings, and procedures are available.

Three-hole-punch all handouts so they can be added to students' notebooks.

Print a copy of the *Electromagnetic Radiation Cards* for each pair of students, plus an additional set of cards to construct the EM radiation spectrum with your class.

Display the Driving Question Board where it is visible to students.

Lesson 9 • Where We Are Going and NOT Going

Where We Are Going

This lesson is designed to coherently build ideas related to the following disciplinary core ideas:

- **PS4B: Electromagnetic Radiation.** When light or longer wavelength electromagnetic radiation is absorbed in matter, it is generally converted into thermal energy (heat). Shorter wavelength electromagnetic radiation (ultraviolet, X-rays, gamma rays) can ionize atoms and cause damage to living cells. (HS-PS4-4)
- **PS4.C: Information Technologies and Instrumentation.** Multiple technologies based on the understanding of waves and their interactions with matter are part of everyday experiences in the modern world (e.g., medical imaging, communications, scanners) and in scientific research.~~ They are essential tools for producing, transmitting, and capturing signals and for storing and interpreting the information contained in them.~~ (HS-PS4-5)

Students build the EM radiation spectrum in order of increasing or decreasing frequency or wavelength. They then delve deeper into the connections between these quantitative variables and the interaction of EM radiation with matter, as well as the ways in which it is employed.

Students encounter or co-develop a definition for *electromagnetic spectrum.* **Do not** post any words or ask students to add them to their Personal Glossaries until after the class has developed a shared understanding of their meaning.

Where We Are NOT Going

This lesson does not discuss how increasing energy can lead to ionization. Lesson 10 will explore how increasing energy transfer from EM radiation to an object can fundamentally change the object by causing electrons to fly off of it (ionization).

LEARNING PLAN for LESSON 9

1 · NAVIGATE

5 min

MATERIALS: science notebook, Driving Question Board

Decide which group of DQB questions to answer next. Present **slide A**. Give the class a moment to consider the questions on the slide before gathering in a Scientists Circle around the DQB:

- *What category(ies) of DQB questions do we still have left to answer?*
- *How could we answer some of the questions for each of these categories?*

Ask for a few volunteers to share their ideas for the first prompt. Listen for them to identify questions about other forms of EM radiation. Summarize students' ideas and transition to the next slide by saying one of the following:

- *It sounds like many of you think we have not answered questions about the existence and properties of other types of EM radiation, other than microwaves and light.*

Or

- *It sounds like many of you think we have not answered questions about other uses of EM radiation, besides warming food (and sight).*

Ask for volunteers to share their ideas for the second prompt. Accept all responses. Use these ideas to motivate looking at additional data about all the other forms of EM radiation and their uses.

ADDITIONAL GUIDANCE	If students struggle to identify where to go next based on the questions on the DQB, do not attempt to funnel them into suggesting that the next set of questions to answer should be around other types of EM radiation and how they are used. A more powerful approach is to draw attention to a particular question that the class has not explored yet. For example, ask: • *Other than the light, microwave radiation, and radio waves we've studied, do you think there are other types of EM radiation? If so, what other types do you think there are?* • *Can we explain how EM radiation can be used for heating food and sending information (connection to the anchoring phenomenon)?* • *Can we explain whether all EM radiation is safe for us?*

2 · ORIENT TO THE EM RADIATION TYPES

8 min

MATERIALS: *Electromagnetic Radiation Cards*

Orient to the *Electromagnetic Radiation Cards*. Remaining in the Scientists Circle, organize students into groups of 3. Distribute the *Electromagnetic Radiation Cards* to each group. Cue students to make sure each person in their group has at least one card. Have your own set of cards on hand to use for the next activity.

Present **slide B**. Have students consider the questions on the slide before exploring them as a class:
Examine the Electromagnetic Radiation Cards.

- *What type of information is on these cards?*
    - Accept all answers.
- *What variables do we recognize that we have worked with before?*
    - wavelength
    - frequency
    - speed
- *What do you notice about the numbers and units used for each of those variables?*
    - They have exponentials.
    - What is a GHz?
    - What is a nm?
    - The speed is really fast!
    - Some of the numbers are really big or really small.
    - We don't recognize the units.

Transition to the next slide by saying, *Let's take a minute to think about some of the scales of these units.*

ALTERNATE ACTIVITY	If you want to give students more practice with calculating speed, remove speed from the *Electromagnetic Radiation Cards*. To reuse the cards between classes, have students record the speeds on sticky notes.

Have students return to their seats. Present **slide C**. Give them a couple of minutes to think on their own about the information on the slide::

- *The size of cells in our body is often measured in um.*
    - *1 um = 0.01 mm = 0.000001 m*
- *Consider the units being used for describing these waves:*

✱ SUPPORTING STUDENTS IN ENGAGING IN USING MATHEMATICS AND COMPUTATIONAL THINKING

If this is difficult for students, slow down and help them understand that the higher the positive exponent, the more place values (or zeroes) to add to the right. Some students might understand this by moving the decimal point.

- *GHz = 1,000,000,000 cycles/sec*
- *1 nm = 0.00001 mm = 0.000000001 m*

Students should have seen scientific notation in prior units; this is a Common Core Math Standard for middle school (Expressions and Equations 8.EE.A.4). But if they struggle with scientific notation, the next slide briefly reviews it.

Pose the question on **slide C**:

- *What does seeing units like GHz for frequency and nm for wavelength tell us about the scales involved with these types of waves?*

Listen for the following ideas:

- Some wavelengths are very small, and some are very large.
- The frequency of some EM radiation types is really fast compared to others.
- There is a large variation.

Suggest that we make sure we grasp the meaning of these units, as the *Electromagnetic Radiation Cards* seem to include very large and very small numbers.

Practice using scientific notation. ✱ Present **slide D**. Say, *Some of you mentioned scientific notation is challenging. Let's talk it through so you have it as a possible strategy to identify patterns across these cards. Here's one of the quantitative variables we are analyzing: the frequency of EM radiation.*

Talk through the example on the slide. Highlight that the numbers work out to be equivalent and that this is a representational difference.

3 · IDENTIFY TRENDS IN FREQUENCY AND WAVELENGTH

11 min

MATERIALS: *EM Radiation Applications*, *Electromagnetic Radiation Cards*

Identify trends in quantitative variables. Display **slide E**. Distribute *EM Radiation Applications* to each student. Review the directions on the slide:

- *Sort the cards by one of the quantitative variables to identify trends in the others.*
- *Describe these trends in Part 1 of your handout.*

ADDITIONAL GUIDANCE	Students are asked to identify EM radiation properties that could help explain the uses of some EM radiation types, and to develop an argument as a group to support their ideas. In the next class, each student will present and defend their argument to a partner, so encourage all students to work on their own handout to be ready for that discussion.

Give groups about 6 minutes to complete the card sort(s) and record the trends they see.

Co-construct the extremes of the EM radiation spectrum. Present **slide F**. You will tape copies of the *Electromagnetic Radiation Cards* to the board as you co-construct the spectrum. **Note:** do not call this a spectrum yet, as we will introduce and define that term later.

Use the first two prompts on the slide to cue students to identify the two ends:

- *Which type of EM radiation has the shortest wavelength?*
- *Which type of EM radiation has the longest wavelength?*

Listen for students to say that gamma rays have the shortest wavelength and radio waves have the longest. Tape the Gamma Rays and Radio Waves cards to the board. Continue with the third prompt:

- *Which type of EM radiation has the lowest frequency?*

Listen for students to say radio waves. Say, *That's interesting--the lowest frequency has the longest wavelength! This confirms our ideas about the relationship between frequency and wavelength, so let's continue to build this out.*

ADDITIONAL GUIDANCE	If students struggle to recall the relationship between wavelength and frequency, prompt them to review that in their Personal Glossaries.

✱ SUPPORTING STUDENTS IN ENGAGING IN USING MATHEMATICS AND COMPUTATIONAL THINKING

In this lesson, students use scientific notation to compare the magnitude of the difference in wavelength and frequency between different types of EM radiation. This is a grade 8 CCMS (CCSS.MATH.CONTENT.8.EE.A.3). If you want to provide additional practice, remove the values in scientific notation from the *Electromagnetic Radiation Cards* and ask students to express the cards' values in scientific notation.

To confirm and reinforce the point about the inverse relationship between frequency and wavelength, ask, *Which type of EM radiation has the highest frequency?* Listen for students to say gamma rays.

To help students get a sense of the difference in magnitude of the values of frequency and wavelength for these types of EM radiation (gamma and radio waves), go on to the fourth prompt:

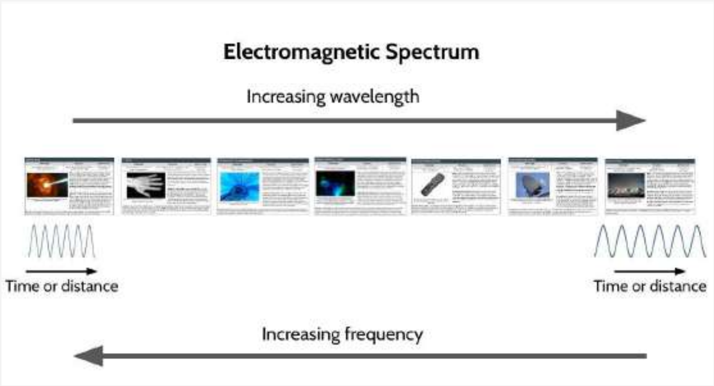
- *How great are the differences in wavelength and frequency between them?* ✱

Listen for students to say that the frequency of gamma rays is 10,000,000,000 (10 billion) times greater than the frequency of radio waves, and that the wavelength of radio waves is 10 billion times longer than the wavelength of gamma rays.

Co-construct the rest of the spectrum. Use the final prompt to organize the remaining cards:

- *Where are the other Electromagnetic Radiation Cards located in relation to these extremes?*

Foreground that the *x-axis* on such a wave could be time or distance. Add arrows showing increasing wavelength and decreasing frequency, as shown in the image below.



4 · MAKE SENSE OF THE SPEED OF LIGHT

10 min

MATERIALS: *EM Radiation Applications*, calculator, *Electromagnetic Radiation Cards*

Make sense of the speed of light. Present **slide G**. Elicit responses to the first prompt:

- *How does the speed of each EM radiation type compare?*

Listen for students to say that the speed is the same for all EM radiation types. To motivate investigating the mathematical relationship between frequency, wavelength, and speed, pose the second prompt:

- *Is this in line with the relationship between frequency and wavelength that we just found?*

Accept all answers. Then say, *How could speed be the same for each EM radiation type when their frequencies and wavelengths are different? Let's revisit the relationships we discovered between these three variables earlier and see if we can make sense of this.*

Make sense of EM radiation speed values. Display **slide H**. Direct students to look at the slide to be reminded of the equation (wave speed = frequency * wavelength). Distribute calculators for students to complete Part 2 of the handout with their group. Encourage them to use the cards to explore this mathematical relationship further to see if we can explain it.

After 6 minutes, ask students to share out. Listen for these ideas:

- If speed doesn't change, then frequency should go up as wavelength goes down, and vice versa.
- If speed is the same, that means the product of frequency * wavelength should be the same.
- If you plug in numbers for speed and frequency, you get the wavelength.
- If you use a frequency and wavelength for any EM radiation, you always get the same speed (approximately).

ADDITIONAL GUIDANCE	Emphasize that the constant wave speed referred to as the speed of light is indeed the speed at which EM radiation travels in a vacuum. This term was coined because visible light was the first type of EM radiation that scientists were able to measure. However, over time, they discovered that this constant speed holds true for all types of EM radiation. Despite this, scientists continue to use the term "speed of light" for the constant speed at which all forms of EM radiation travel.

5 · IDENTIFY CONNECTIONS BETWEEN THE USES OF EM RADIATION AND THEIR PROPERTIES

11 min

MATERIALS: *EM Radiation Applications, Electromagnetic Radiation Cards*

Identify EM radiation properties that could explain their uses. Present **slide I**. Describe the task by reading the instructions aloud:

- *Identify some of the ways that EM radiation types are used.*
- *Use the information on the cards and the guiding questions in Part 3 of the handout to identify connections between the uses of EM radiation types and their properties.*

- *Be ready to present an oral argument about why we can use some EM radiation types for some applications but not others.*

Give groups the rest of the class period to complete this part. Encourage them to use some of the guiding prompts included in *EM Radiation Applications*:

- How do different frequencies and wavelengths of EM radiation affect their ability to interact with matter?
- How do interactions of EM radiation with matter help explain its use in some applications?
- Why are some EM radiation types used for some applications but not others?

Collect *EM Radiation Applications* as students leave the classroom.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Look for students to draw connections between the use of EM radiation with its frequency, wavelength, and interactions with matter. These are some examples of arguments they can make:

- EM radiation types used for communication (radio waves, IR, microwaves, visible light) are part of the EM spectrum with lower frequency and longer wavelength. All these EM radiation types can cause electrons to move, and when electrons move, they produce electric current. Other types of EM radiation can knock electrons out of atoms, so this does not seem to be useful in communication. (SEP: 7.4; CCC: 4.1; DCI: PS4.B.2, PS4.C.1)
- EM radiation types used for killing microorganisms or cancer cells are part of the EM spectrum with higher frequency and shorter wavelength. All these EM radiation types can ionize matter by knocking electrons out of atoms or breaking molecules. This interaction is harmful to living cells, so this is probably why these types of EM radiation are used for this purpose. (SEP: 7.4; CCC: 4.1; DCI: PS4.B.2, PS4.C.1)
- EM radiation types used for detecting defects in metal (gamma rays, X-rays) are the types with the highest frequency and shortest wavelength. Unlike other types of EM radiation, gamma rays and X-rays can pass through dense materials, such as metal, so this is probably why they can be used for this purpose. (SEP: 7.4; CCC: 4.1; DCI: PS4.B.2, PS4.C.1)

What to do: Move around the room and ask probing questions, such as:

- *How do different frequencies and wavelengths of EM radiation types affect their ability to interact with matter?*
- *How do the interactions of EM radiation with matter help explain why it is used in this particular way?*
- *What can't we use this type of EM radiation for ____?*

- *Is this true for all the EM radiation types used for this purpose?*

Building toward: 9.A.1 Develop an argument about why EM radiation can be used in multiple technologies to do specific tasks based on its frequency, wavelength, and interactions with matter. (SEP: 7.4; CCC: 4.1; DCI: PS4.B.2, PS4.C.1)

End of day 1

6 · NAVIGATE

2 min

MATERIALS: *EM Radiation Applications*

Reorient students to their written arguments. Present **slide J**. Say, *I went through the arguments you wrote last time, and I found different ways that you explained why some types of EM radiation are used for particular applications.*

Return *EM Radiation Applications* to students. Prepare them by reading the slide's instructions aloud:

- *Review the argument you developed with your group last time.*
- *Be ready to present your argument to a partner.*

7 · PRESENT ARGUMENTS ABOUT EM RADIATION APPLICATIONS

5 min

MATERIALS: *EM Radiation Applications*, *Electromagnetic Radiation Cards*

Share EM radiation application arguments in pairs. Begin by reorganizing students from groups to pairs. Try pairing students who explored different applications of EM radiation (e.g., one who explored medical imaging with one who explored communication). Make sure all pairs have a set of the *Electromagnetic Radiation Cards*.

Present **slide K**. Describe the task by reading the instructions aloud:

1. *Each student will have 1 minute to present their argument.*
2. *The other student will have 1 minute to ask questions and give feedback about the ideas presented.*

Encourage students to use the ideas they wrote in *EM Radiation Applications*, together with the *Electromagnetic Radiation Cards*, to support their ideas in this discussion with their partner. ✱

✱ ATTENDING TO EQUITY

Building classroom culture: Productive conversations in the science classroom require students to listen to each other's ideas and ask questions that might expose ideas that are not aligned with their own. This can be a good opportunity to review the Community Agreements that your class has been building to ensure respectful and equitable interactions among students.

8 · REVISE ARGUMENTS BASED ON FEEDBACK

5 min

MATERIALS: *EM Radiation Applications*

Revise arguments. Have everyone return to their seats. Present **slide L**. Read the prompt to instruct students to revise their argument:

- *Based on the discussion you had with your partner, revise your argument in Part 4 of your handout.*

Give them a few minutes to complete this task, then collect *EM Radiation Applications*.

ASSESSMENT OPPORTUNITY	**What to look for/listen for in the moment:** See the previous Assessment for the types of arguments students could make. See the *EM Radiation Applications Key* for additional guidance. **What to do:** If some students feel they don't need to make any revisions, ask them to describe their partner's argument and the feedback they gave. **Building toward: 9.A.2** Develop an argument about why EM radiation can be used in multiple technologies to do specific tasks based on its frequency, wavelength, and interactions with matter. (SEP: 7.4; CCC: 4.1; DCI: PS4.B.2, PS4.C.1)

ADDITIONAL GUIDANCE	If any students say they did not get clear feedback or only received praise/agreement for their argument, suggest they describe the argument made by their partner and the feedback they wrote in response.

9 · DEBRIEF ARGUMENTS ABOUT EM RADIATION APPLICATIONS

8 min

MATERIALS: None

Discuss EM radiation's uses and interactions with matter. Present **slide M**. Pose the prompts to debrief students' developed arguments, as shown in the table below.

Suggested prompt	Sample student response
Are there any relationships between the frequencies and wavelengths of EM radiation types and their interactions with matter?	High-frequency/long-wavelength EM radiation ionizes matter. High-frequency/long-wavelength EM radiation can pass through dense materials.

	Low-frequency/long-wavelength EM radiation causes charges to move back and forth.
How do interactions of EM radiation with matter help explain its use in some applications?	High-frequency/long-wavelength EM radiation can be used to kill cancer cells and microorganisms because it ionizes matter. Because high-frequency/long-wavelength EM radiation can pass through dense materials, it can be used to detect defects in metals. Microwave radiation can transfer energy to polar molecules, which is why it is used for killing cancer cells that have high water content.
Why are some EM radiation types used for some applications but not others?	Low-frequency/short-wavelength EM radiation cannot pass through dense materials, so it would not work for detecting defects in metal. High-frequency/long-wavelength EM radiation could be dangerous if we use it for communication, because it could ionize our skin or maybe our devices.

10 · DEFINE ELECTROMAGNETIC SPECTRUM

6 min

MATERIALS: science notebook, spectrum of *Electromagnetic Radiation Cards*

Introduce the term *electromagnetic spectrum*. Present **slide N**. Point to the *Electromagnetic Radiation Cards* if they are on the board. Say, *We organized the EM radiation types by frequency and wavelength last time, and we're finding that the behavior of EM radiation changes depending on its frequency and wavelength. This organization is something that scientists call the electromagnetic spectrum.*

Have students turn and talk about the slide's first prompt:

- *What does the word spectrum mean to you?*

After a minute, ask for volunteers to share what they discussed. Listen for them to say that a spectrum is a range or continuum. Then elicit 1-2 ideas about the second prompt:

- *What conclusions can we make about a particular type of EM radiation by looking at where it falls in the electromagnetic spectrum?*

Listen for students to suggest that we can conclude whether it can cause damage to living organisms, or what its applications in different fields might be.

Add this term to Personal Glossaries. Present **slide O**. Give students a couple of minutes to record a definition for *electromagnetic spectrum* in their Personal Glossaries, using words and/or pictures.

11 · UPDATE THE DRIVING QUESTION BOARD

10 min

MATERIALS: 3" x 3" sticky notes, markers, Driving Question Board

Generate new questions about EM radiation. Present **slide P**. Distribute sticky notes and markers. Give students a minute to record any new questions about the different types of EM radiation.

Add questions to the DQB. Present **slide Q**. Gather the class into a Scientists Circle at the DQB. Give them a minute to think on their own about the prompts:

- *To which category(ies) of DQB questions should we assign our new questions?*
- *What new categories do we need?*

Invite students to come up and add their stickies to DQB questions. As in Lessons 3 and 8, encourage volunteers to take over facilitation of this DQB build. If volunteers would benefit from additional support, remind them of the protocols to add questions to the DQB:

- Choose a volunteer to go first. This student reads their question and then posts it on the DQB.
- Raise your hand if you have a question that is related or the same. The first volunteer selects the next student whose hand is raised. The student who is called on reads the related question, says why or how it relates, and then posts it on the DQB with the original question.
- That student who added the sticky selects the next student, who will read another related sticky and post it, and then call on the next student.
- Continue until everyone has at least one question on the DQB.

Look for students to add questions around how EM radiation is used with specific technologies, how EM radiation interacts with different objects, and the safety of using EM radiation in our daily lives.

Say, *I see some of us are wondering about the safety of these EM radiation types. Let's explore that next*.

ASSESSMENT OPPORTUNITY	**What to look for/listen for in the moment:** • Questions that seek additional information about the uses of different types of EM radiation (e.g., "Why does wireless communication seem to rely on microwave radiation?" or "Could we use X-rays for wireless communication?"). (SEP: 1.2; CCC: 4.1; PS4.C.1) • Questions that seek to clarify the relationship between the frequency and wavelength of EM radiation with its safety (e.g., "Why do EM radiation types that can cause harm have higher frequencies?"). (SEP: 1.2; CCC: 4.1; DCI: PS4.B.2) **What to do:** If students feel they don't have any new questions, point to the use of EM radiation for communication and ask, *Do you think you can explain how microwave radiation can be used to heat food in the microwave oven* ***and*** *send/receive information?* **Building toward: 9.B** Ask questions that arise from examining a model of the electromagnetic spectrum related to the uses and material interactions of different types of electromagnetic radiation. (SEP: 1.2; CCC: 4.1; DCI: PS4.B.2, PS4.C.1)

12 · NAVIGATE: EXIT TICKET

9 min

MATERIALS: science notebook, 8.5” x 11” paper

Add new understandings to the *Progress Tracker*. Present **slide R**. Have students use the image to guide their work. Give them 3 minutes to record their ideas in their *Progress Tracker*.

Foreshadow next steps. Present **slide S**. Distribute a sheet of notebook paper to each student. As an exit ticket, ask them to write about the prompt:

- *Why do we think some forms of high-frequency EM radiation (ultraviolet, X-rays, and gamma rays) cause more damage than others?*

Collect the exit tickets before students leave class. You will use them to navigate into Lesson 10.

Additional Lesson 9 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN MATH	This is the CCMS-related idea that is used to support sensemaking in this lesson: **The Number System** • **CCSS.MATH.CONTENT.8.EE.A.3** Expressions and Equations: Use numbers expressed in the form of a single digit times an integer power of 10 to estimate very large or very small quantities, and to express how many times as much one is than the other. In this lesson, students use scientific notation to compare the magnitude of the difference in wavelength and frequency between the various types of EM radiation. This is a grade 8 CCMS. If you want to provide additional practice, remove the values written in scientific notation from the *Electromagnetic Radiation Cards* and ask students to express the values in scientific notation.