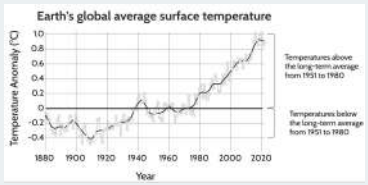
Lesson 6: How can we use interactions between matter and electromagnetic radiation to explain the increase in global temperatures?

Previous Lesson *We argued for, planned, and carried out investigations to determine what happens to the energy transferred by two forms of EM radiation when they reach and interact with the materials in the microwave oven door and walls. We developed a model to explain the results of our investigation, and generated new questions.*

This Lesson

Putting Pieces Together

1 day



Data Source: NASA/GISS

We revisit the Driving Question Board and add new questions about the interactions of electromagnetic radiation with matter inside the microwave oven. We complete an assessment to explain that an increase in greenhouse gases in the atmosphere contributes to the overall increase in global temperatures because the gases absorb electromagnetic radiation.

Next Lesson *We will use simulations to model how various particles (water molecules, plastic molecules, free electrons) interact with changing electric fields of different frequencies. We will connect this particle-scale evidence to macroscopic evidence about the behavior of various materials (water, plastic, aluminum) inside the microwave oven, then model our understanding. We will read articles to consider whether metal in the microwave oven is safe, and consider the validity and reliability of the authors' claims.*

BUILDING TOWARD NGSS	What students will do
HS-PS2-5, HS-PS4-1, HS-PS4-2, HS-PS4-3, HS-PS4-4, HS-PS4-5, HS-ESS2-4	**6.A** Ask questions about how the structure of the matter in a microwave oven affects reflection, absorption, and transmission of energy in the oven. (SEP: 1.2; CCC: 6.2; DCI: PS4.B.2) **Transfer Task PE: HS-ESS2-4** Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. (SEP: 2.4; CCC: 5.2, 2.1; DCI: ESS2.D.1, ESS2.A.3, PS4.B.2)

What students will figure out

- EM radiation is emitted by the Sun.
- A percentage of that EM radiation is absorbed, reflected, or transmitted when it enters Earth's atmosphere.
- After EM radiation reaches Earth, matter on the surface absorbs it and then emits infrared radiation that is more readily absorbed by the greenhouse gases in the atmosphere.
- Because of carbon's prevalence and longevity in the atmosphere, carbon has contributed to the increased temperatures globally and will continue to do so.

Lesson 6 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	4 min		**NAVIGATE** Consider the interaction of microwave radiation with the matter in the microwave oven walls and door and with the water inside the oven.	A	
2	8 min		**ASK QUESTIONS AND CONNECT THEM TO OUR ANCHORING PHENOMENON** Ask new questions and add them to the Driving Question Board. Identify sections of the DQB that have not been answered.	B-C	sticky note questions from Lesson 5, 3" x 3" sticky notes, marker, Driving Question Board
3	33 min		**EXPLAIN RELATED PHENOMENA IN AN ASSESSMENT** Introduce the global temperature assessment and new data sets. Complete the assessment individually.	D-F	*Explaining Temperature Rise Transfer Task*, Physical Wave Properties poster, EM Radiation Interactions Chart poster

End of day 1

Lesson 6 • Materials List

	per student	per group	per class
Lesson materials	• science notebook • sticky note questions from Lesson 5 • 3” x 3” sticky notes • marker • *Explaining Temperature Rise Transfer Task*		• Driving Question Board • Physical Wave Properties poster • EM Radiation Interactions Chart poster

Materials preparation (15 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.

Make sure that the EM Radiation Interactions Chart and Physical Wave Properties posters are displayed where all students can see them for reference while completing the assessment.

Lesson 6 • 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 (DCIs):

- **PS4.B.2: 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)~~
- **ESS2.D.1: Weather and Climate.** The foundation for Earth's global climate systems is the electromagnetic radiation from the sun, as well as its reflection, absorption, storage, ~~and redistribution among the atmosphere, ocean, and land systems,~~ and this energy's re-radiation into space.

In past courses, students gained an understanding of the relationship between greenhouse gases and global climate, but they did not examine the interactions between the atmosphere and EM radiation. Until this point in the Physics course, they could not fully explain the process of climate change or the reason why increased carbon dioxide in the atmosphere has contributed to this change. The interactions between carbon and EM radiation are specific to this unit.

Students explain how the types of EM radiation from the Sun versus those from Earth affect greenhouse gases differently and lead to different absorption rates, which influence the warming of the atmosphere at rates that are out of line with past data trends.

Though this lesson's assessment is centered around Earth and Space Science ideas, it utilizes a set of physics DCIs to better explain the phenomenon. It asks students to use the DCIs in a new context and allows them to show their three-dimensional understandings from one context to another.

Students will not encounter or co-develop definitions for their Personal Glossaries in this lesson.

Where We Are NOT Going

Though students use a model of absorption of EM radiation to explain the increase in global temperatures, they will not be able to explain the variances in wavelength that lead to increases in absorption rate by greenhouse gases. Other than specifying that the Sun's radiation is different from that emitted from Earth, no attempt is made in this lesson to explain this difference. In later lessons, students will learn about the differences between various wavelengths and how those wavelengths interact differently with matter.

LEARNING PLAN for LESSON 6

1 · NAVIGATE

4 min

MATERIALS: None

Review what we learned about EM radiation and matter interactions. Present **slide A**. Start the lesson with the prompts on the slide:

- *What did we figure out in the last lesson about the ways that microwave radiation can interact with matter?*
- *How does this help us explain what happens to microwave radiation when it reaches the microwave oven's metal walls, the door, and the water inside the oven?*

Listen for the following ideas:

- Microwave radiation is absorbed, reflected, and transmitted.
- When microwave radiation reaches water, it is absorbed.
- Microwave radiation is reflected when it reaches the walls and door of the oven.

Say, *We figured out a lot, but at the end of the last lesson we were still curious about some of the interactions between the microwave radiation, the oven, and the items inside the oven. Let's share questions we might have that can help us move our thinking forward.*

2 · ASK QUESTIONS AND CONNECT THEM TO OUR ANCHORING PHENOMENON

8 min

MATERIALS: science notebook, sticky note questions from Lesson 5, 3" x 3" sticky notes, marker, Driving Question Board

Ask new questions. Present **slide B**. Distribute 2 sticky notes and a marker to each student, and read the text on the slide aloud:

- *What new questions did you have at the end of the last lesson? Get out your questions from last time. Feel free to write any new questions you now have.*

Give students a couple of minutes to write new questions and revise their prior questions, if they wish.

Share and post questions on the DQB. Present **slide C**. Invite students to add new questions to the DQB and categorize them. Read the instructions on the slide aloud to guide this task:

- *Add your new questions to the corresponding category on the DQB. Quickly read them aloud to the class as you post them.*
- *Consider what types or categories of questions we still have left. What do they have in common?*

Guide students quickly through this process: Have students read their questions and post them to the areas on the DQB that they believe are relevant or connected to them. Begin a new section on the DQB if a question does not seem to fit in any existing area. At this time, do not ask students to explain how their questions connect to the corresponding area on the DQB; simply allow them to share their questions for now. Continue this process until everyone has posted at least one question.

Prompt areas for further investigation. Ask students to quickly scan the DQB and identify any topics or clusters of questions that we have not answered yet. Point out that a lot of those unanswered questions are associated with food, heating items in the oven, and/or communication. Suggest that we look into those topics next.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: Students posting and sharing the following:

- Questions that arise from study of the Lesson 5 models about how reflective properties of the inner surfaces of the microwave oven affect electromagnetic radiation absorption, reflection, and/or transmission. (SEP: 1.2; CCC: 6.2; DCI: PS4.B.2)
- Questions that seek additional information about various types of matter and why/how they interact with electromagnetic radiation within the context of the microwave oven system. (SEP: 1.2; CCC: 6.2; DCI: PS4.B.2)

What to do: If students struggle to develop new questions, prompt them to look back at their models from the end of Lesson 5. Ask if they have any questions about the oven or other objects that end up in it that we cannot yet answer. Prompt them to consider how what we have learned might help explain what happened with the Bluetooth speaker or the other items we have explored since Lesson 1, and what questions are still lingering.

It is not critical that all students raise questions in the areas suggested above, but some should. At this point in the course, all students should be gaining proficiency at raising questions from examining a model or a theory, in order to clarify and/or seek additional information and relationships.

Building toward: 6.A Ask questions about how the structure of the matter in a microwave oven affects reflection, absorption, and transmission of energy in the oven. (SEP: 1.2; CCC: 6.2; DCI: PS4.B.2)

3 · EXPLAIN RELATED PHENOMENA IN AN ASSESSMENT

33 min

MATERIALS: *Explaining Temperature Rise Transfer Task*, science notebook, Physical Wave Properties poster, EM Radiation Interactions Chart poster

ADDITIONAL GUIDANCE

If your students have not had prior experience with the OpenSciEd Biology and Chemistry courses, preview the next section and determine the best way to segue into the assessment that leverages their prior personal experiences.

Although the ideas students bring from OpenSciEd High School Chemistry and Biology provide additional mechanisms that they can use to make sense of the information provided in this activity, they will not depend on these ideas to be able to complete this assessment successfully. If they have not yet experienced OpenSciEd High School Biology or Chemistry, you do not need to spend time teaching any of these ideas; but if they have taken those courses, use this opportunity to help them make connections.

Motivate the assessment. Remind students that this is not the only context in which we have investigated energy transfer through systems, but it is the first time we have included EM radiation as a part of our models. Display **slide D**. Read the prompt aloud:

- *What other systems have we investigated where electromagnetic radiation might be an important part of explaining phenomena?*

Accept all ideas, but listen for ideas about sunlight; for example, in the context of ecosystems, weather, or climate change. If sunlight is not mentioned, say, *What about radiation from the Sun? What systems have we investigated where modeling sunlight as EM radiation might help us explain phenomena?*

Introduce a new context. Say, *Before we go back to the microwave oven system, and other technologies that use EM radiation, let's consider how our understanding of EM radiation can inform our models for Earth's systems. In particular, maybe these models can help us explain why Earth's surface is warming.* ✱

Present **slide E**. Pose the prompt:

- *How could modeling sunlight as electromagnetic radiation help us understand why Earth's surface is warming?*

Have students turn and talk to a partner about their ideas for a couple of minutes. ✱

ADDITIONAL GUIDANCE

If students have experienced the prior OpenSciEd Biology and Chemistry courses but do not immediately remember what they learned, use the brief reminders below to help them make connections between those courses and their experiences thus far in this unit.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING ENERGY AND MATTER

This assessment asks students to make connections between the flow of energy into and within Earth's systems to explain why an increase in carbon has increased global temperatures over time. They are asked to reason through why this increase is occurring, even though the amount of energy entering the system has not changed. They use the idea of energy being absorbed at a greater rate than before (due to the changes in matter in the atmosphere--an increased presence of carbon) to explain the overall increase in global temperatures.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING CAUSE AND EFFECT

Students use empirical evidence to make claims about causation (versus correlation) to explain how radiation absorbed over time by atmospheric carbon dioxide contributes to an increase in temperatures. This builds upon evidence used in prior OpenSciEd courses (Biology and Chemistry) about cause-and-effect relationships for the overall increase in global temperatures. This assessment provides the mechanism related to the absorption of radiation that students

have not been able to explain in prior courses or units.

Say, *In Biology, we learned that wildfires that burn carbon sinks, such as forests or peat, create a positive feedback loop. Fires increase carbon dioxide in the atmosphere, leading to higher temperatures. Higher temperatures then lead to drought and more fires that release even more carbon dioxide into the atmosphere.*

In Chemistry, we learned that changes in carbon dioxide due to plant growth and human activity can affect climate and can help explain current temperature increases. When energy enters a system, it is less likely to exit if there is more carbon dioxide.

Remind students that in prior courses we learned that there is now more carbon in Earth's atmosphere than at any other period in human history. Carbon dioxide and other greenhouse gases are doing something to create the warming effect on our planet. However, up to this point, we have not had the chance to explain the energy-matter interactions (the mechanism) because we have not figured out the nature of electromagnetic radiation until now.

Distribute the assessment. Present **slide F**. Distribute *Explaining Temperature Rise Transfer Task* to each student. Read the text on the slide aloud:

- *Use the assessment to explain interactions of electromagnetic radiation with matter in Earth's systems, and how this could cause increasing global temperatures.*

Give students the remaining time to work individually on the assessment, referencing their own science notebook, the data sources, and class posters as needed. Collect this assessment before the end of the class period.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: See *Lesson 6 Assessment Scoring Guidance* for what to look for across three dimensions.

What to do: See *Lesson 6 Assessment Scoring Guidance* for how to provide feedback and adjust instruction.

This assessment does not build toward a lesson level performance expectation. It is designed to assess a performance expectation from the NGSS, below:

Transfer Task HS-ESS2-4. Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate. (SEP: 2.4; CCC: 5.2, 2.1; DCI: ESS2.D.1, ESS2.A.3, PS4.B.2)

Additional Lesson 6 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA

This is the Common Core State Standard-related idea that is used to support sensemaking in this lesson:

- CCSS.ELA-LITERACY.RI.11-12.7 Integrate and evaluate multiple sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a question or solve a problem.

Students compare and integrate a variety of sources in different formats as well as in words to explain how radiation interacting with greenhouse gases contributes to the increased global temperatures on Earth.