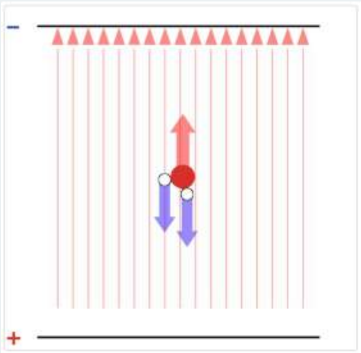
Lesson 7: Why do some substances heat up faster than other materials in a microwave oven?

Previous Lesson *We revisited the Driving Question Board and added new questions about the interactions of electromagnetic radiation with matter inside the microwave oven. We completed 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.*

This Lesson

Investigation, Putting Pieces Together

2 days



We use simulations to model how various particles (water molecules, plastic molecules) interact with changing electric fields of different frequencies. We 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 read articles to consider whether metal in the microwave oven is safe, and consider the validity and reliability of the authors' claims.

Next Lesson *We will develop and revise a model of wave interference in the microwave oven to explain hot and cold spots in the oven. We will consider the function of the turntable. We will revise our consensus model from the anchor phenomenon and our Driving Question Board.*

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

7.A Develop and revise a model to illustrate absorption of microwave radiation as movement of charged particles in response to particle-level forces from changing electric fields. (SEP: 2.3; CCC: 2.2; DCI: PS2.B.2, PS4.B.2)

7.B Evaluate multiple claims from advertisement media to determine the validity and reliability of claims made about the relationship between the structure, shape, and molecular substructure of aluminum foil and its interaction with electromagnetic radiation. (SEP: 8.4; CCC: 6.2; DCI: PS2.B.2)

What students will figure out

- Charged particles in an electric field experience force, the direction of which depends on the direction of the field and the charge of the particles.
- The forces from changing electric fields in the microwave oven cause polar molecules, such as water, to rotate in the direction of those fields.
- The interaction between the microwave radiation and the water molecules transfers energy out of the fields and into thermal or kinetic energy of the water.
- Some materials contain mostly neutral particles, so these materials don’t interact much with microwave radiation.
- Electrons can move inside conductors, such as metal, when pushed by changing electric fields in microwave radiation, which can cause reflection, or dangerous arcing in some cases.

Lesson 7 • Learning Plan Snapshot

Part	Duration		Summary	Slide	Materials
1	5 min		**NAVIGATE** Discuss what we figured out last class and what we need to figure out this lesson.	A-C	
2	10 min		**CONNECT MACROSCOPIC EVIDENCE TO PARTICLES** Identify patterns in charge distribution in water and ethylene molecules. Learn the term *polar molecule*.	D-E	
3	15 min	☑	**MODEL MATTER-ELECTRIC FIELD INTERACTIONS** Use the *Molecule Cutouts* to make predictions about particle-electric field interactions. Use computers and the *Field-Particle Interactions* handout to investigate particle-electric field interactions.	F-G	*Field-Particle Interactions*, an individual molecule cut out from *Molecule Cutouts*, computer with access to https://www.openscied.org/general/fieldparticleinteractions/
4	10 min		**REVIEW MATTER-ELECTRIC FIELD INTERACTIONS** Discuss findings from the simulation to make connections between particle motion, absorption of microwave radiation, and increase in temperature of certain materials.	H-J	*Field-Particle Interactions*
5	5 min	☑	**NAVIGATE** Complete an exit ticket as a pre-assessment of understanding of microwave radiation interactions with particles.	K	*Field-Particle Interactions*
					End of day 1
6	5 min		**NAVIGATE** Review responses to the exit ticket from day 1. Brainstorm key components to include in a consensus model.	L	exit ticket from day 1
7	10 min		**DEVELOP A CONSENSUS MODEL** Build a class consensus model to explain why polar particles heat up in the microwave oven but nonpolar particles don’t.	M-O	chart paper, markers

8	25 min		**EVALUATE THE VALIDITY AND RELIABILITY OF CLAIMS** Learn how to use the *Evaluating Information Checklist*. Evaluate the *Metal in Microwave Ovens* reading in partners.	P-T	*Evaluating Information Checklist*, *Metal in Microwave Ovens*, https://www.openscied.org/general/fieldparticleinteractions/
9	5 min		**NAVIGATE** Record a definition for *polar molecule* in Personal Glossaries, and add an entry in the *Progress Tracker*. Turn and talk about whether our new particle-scale model explains hot and cool spots in food heated in the microwave oven.	U-V	

End of day 2

Lesson 7 • Materials List

	per student	per group	per class
Lesson materials	• *Field-Particle Interactions* • an individual molecule cut out from *Molecule Cutouts* • science notebook • exit ticket from day 1 • *Evaluating Information Checklist* • *Metal in Microwave Ovens*	• computer with access to https://www.openscied.org/general/fieldparticleinteractions/	• chart paper • markers • https://www.openscied.org/general/fieldparticleinteractions/

Materials preparation (10 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.

Prepare chart paper for the poster you will make in this lesson:

- Matter Changes in the Microwave Oven

Print the *Molecule Cutouts* and cut out some samples of each molecule. Each page contains six copies of each molecule type. Many students will likely use these manipulatives as they work through the simulation investigation.

Open https://www.openscied.org/general/fieldparticleinteractions/ on a computer and ensure that you understand how to navigate all available functions.

If you anticipate that students may have trouble remembering that EM radiation means a changing electric field, open https://www.openscied.org/general/fieldsthroughspace/ from Lesson 4 on a handheld device or laptop, and display a single arrow flipping up and down. You may want to show this to students as needed.

Lesson 7 • 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:

- **PS2.B: Types of Interactions.** Forces at a distance are explained by fields (gravitational, electric, and magnetic) permeating space that can transfer energy through space. ~~Magnets or electric currents cause magnetic fields; electric charges or changing magnetic fields cause electric fields.~~ (HS-PS2-4, HS-PS2-5)
- **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)

This is the first lesson in this unit in which students engage in *Obtaining, Evaluating, and Communicating Information*. To scaffold engagement with this science and engineering practice (SEP), they are introduced to the *Evaluating Information Checklist*, along with examples of how to use it. This tool will help them quickly assess the validity and reliability of claims from sources they evaluate. Throughout the rest of the unit, these supports will be adjusted and gradually removed so students become increasingly responsible for evaluating the validity and reliability of the information they explore. In *OpenSciEd Unit P.6: Earth's History and the Big Bang (Cosmology Unit)*, they will continue using various elements of this SEP.

In this lesson, we also develop a relationship of matter's interactions with changing electric fields (microwave radiation). Students build an understanding that the changing electric field applies forces to polar molecules (water), causing them to move. In high school chemistry, students developed the conceptual understanding of what a polar molecule is while examining the properties of water.

Students encounter or co-develop definitions for the following words in this lesson: *polar molecule*. **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 intentionally does not introduce the idea of the dual nature of light (waves and photons) to explain differences in polar and nonpolar molecule interactions with microwave radiation. Students will be introduced to this concept in later lessons when they investigate ionizing radiation.

LEARNING PLAN for LESSON 7

1 · NAVIGATE

5 min

MATERIALS: None

Review that water absorbs electromagnetic radiation. Present **slide A**. Say, *In our experiments, we used water to measure energy transfer in the microwave oven. Turn and talk with a partner about the questions on the slide.* After a minute or two, elicit student ideas as shown in the table below.

Suggested prompt	Sample student response
How does electromagnetic radiation interact with water in a microwave oven?	It is absorbed into the water.
What evidence do we have for this interaction?	The water heats up when we run the microwave oven. It heats up because of the energy transferred from the absorbed radiation.

Present **slide B**. Ask, *Does every substance that we put in the microwave oven absorb electromagnetic radiation just like water does? What evidence do we have for this?* If students have trouble finding examples, point them to our investigation of heating food in Lesson 1, or our investigations in Lesson 5. They should notice from these investigations or their own experience that not all containers and foods heat up as quickly as water does. Chips and plastic, for example, are often room temperature after being in a microwave oven.

Present **slide C**. Pose the first prompt:

- *What makes the matter in water different from the matter in substances that do* **not** *heat up in the microwave oven?*

Listen for initial ideas about molecules or properties of water. Accept all ideas. Pose the second prompt:

- *On what scale should we investigate the matter to get a better idea about how these substances might be different from each other?*

Listen for students to suggest "zooming in" on the molecular, atomic, particle, or electron scale. If students do not suggest zooming in, then they may not have an intuitive understanding of scale. Offer an analogous example, such as, *A satellite-scale picture is useful for analyzing the weather, but it wouldn't help us investigate a single water drop. What size scale do we need to analyze to see why water behaves differently from plastic in the microwave oven?*

2 · CONNECT MACROSCOPIC EVIDENCE TO PARTICLES

10 min

MATERIALS: None

Look for patterns in charge distribution in water and ethylene. Present **slide D**. Say, *Here are visualizations of a water molecule, which we figured out absorbs electromagnetic radiation really well, and an ethylene molecule, which is what most microwave-safe plastic containers are made of.*

Elicit student ideas in response to the prompts, as shown in the table below.

Suggested prompt	Sample student response
What do you notice about these models?	There's a colored scale for electron density. In water, the O side has more electron density, and each H has a red tip, which means there aren't as many electrons there. The plastic is more balanced. There are minuses on both sides and a plus in the middle.
How is the matter similar? How is it different?	The plastic has more parts (atoms)--it looks like about twice as many. The charge is different because the electron density is different.

As soon as students notice the electron density and make a connection to charge, proceed to **slide E**. Revoice their noticings in response to the prompt (or ask students to revoice them) in terms of forces in order to highlight that the water is not balanced in terms of charge, whereas the plastic is balanced; see the table below.

Suggested prompt	Sample student response	Follow-up question

How do you predict the charge will be distributed in each of these molecules?	The water is going to be more positive on the right and more negative on the left. The plastic is going to be positive in the middle and negative around the outside.	*I hear you saying that the water has a positive side and negative side, but the plastic is going to be more balanced in terms of charge--is that right?* *Remember that opposites attract, and like charges repel. Can someone revoice that in terms of what a negatively charged electron would feel if it was near one of these molecules?*

Introduce the term *polar molecule*. Quickly tell students that scientists call molecules like water *polar*, because they have a negative pole and a positive pole. The plastic molecule, on the other hand, is nonpolar, because it doesn't have a positive side and a negative side.

ADDITIONAL GUIDANCE	In *OpenSciEd Unit C.3: How could we find and use the resources we need to live beyond Earth? (Space Survival Unit)*, students were introduced to properties of water. Students who have experienced that unit will know more about water as a *polar molecule*. When students use that term, take a moment to remind the class what it means. Ask, *What do you mean by polar molecule? What is it about a water molecule that classifies it as a polar molecule?* Listen for them to explain that polar molecules have unequal positive and negative charges due to the interactions between the different atoms and electrons in the outer energy level. For students who have not encountered the term, suggest that they add it to their Personal Glossaries.

3 · MODEL MATTER-ELECTRIC FIELD INTERACTIONS

15 min

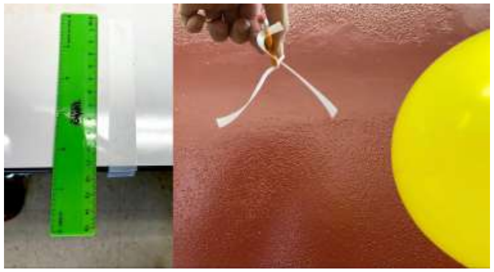
MATERIALS: *Field-Particle Interactions*, an individual molecule cut out from *Molecule Cutouts*, computer with access to https://www.openscied.org/general/fieldparticleinteractions/

Use manipulatives to make predictions about particle motion. Present **slide F**. Say, *We have two examples of how charge distribution can be different in different molecules. And we know that EM radiation in a microwave oven is made up of changing electric fields. Let's think about how these different particles would behave in a changing electric field.*

As students turn and talk about the question on the slide, distribute one molecule cutout to each student. Encourage them to use the cutouts to consider how charges would respond to a field. Say, *Try using these to help visualize what different parts of each molecule would feel in an electric field.* ✱

ALTERNATE ACTIVITY

If students struggle during the Turn and Talk to conceptualize how fields affect charged particles, ask them if they have ever seen something push and pull at a distance that they think might be related to electric charges. Listen for examples of electrostatic interactions, and suggest that we try to replicate an example in the classroom. A "charged" balloon, for example, will attract a lot of neutral objects, such as hair or small bits of paper. To demonstrate this attraction, you can charge a balloon by rubbing it against your hair (or a student's hair, with their permission), or rub a plastic ruler with felt.



If you want students to see both attraction and repulsion, you can achieve this by sticking two pieces of cellophane tape on top of each other on a table, each with a small piece folded over to allow you to hold it. Pull the top tape off the bottom tape, and stick it to one side of a pencil. Then pull the bottom tape off the table and stick it to the other side of the pencil, far enough away that the two tapes do not attract. With a charged balloon in one hand and the pencil in the other, you can walk from table to table as students are working. Ask, *If the balloon is creating an electric field, why are the two tape pieces pushed in opposite directions?*

Use a simulation to observe particle-level changes. After the Turn and Talk, you do not need to discuss answers as a class. Instead, present **slide G**. Say, *Let's use a simulation to test our predictions about how a changing electric field can affect these two particles of matter differently.*

Organize students in groups of 3-4. Read the slide's instructions aloud to guide their work:

✱ ATTENDING TO EQUITY

Universal Design for Learning: Encourage students to physically move these paper models to make sense of the relationship between changing electric fields, electric charge, and particle motion. Physical action provides multiple means of *Action and Expression*. As you listen, encourage students to present their ideas about forces acting on the molecule due to its charge distribution. This will help them explain the particle's motion beyond using only written descriptions. Providing multiple modalities to show their thinking creates a clear, accessible, equitable pathway for all students to express themselves and communicate.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING CAUSE AND EFFECT

Note that students' focus is on developing a particle-scale cause-effect mechanism for a macroscopic observation we made in the previous lesson. Help students to make this connection--although we can't see this mechanism on a particle scale directly, the connection between the mechanism and the

Make observations in a computer model of a changing electric field to explain changes in matter when EM radiation:

- *absorbs into matter*
- *transmits through matter*
- *reflects off of matter*

Make sure each group has a computer capable of running the simulation https://www.openscied.org/general/fieldparticleinteractions/. Distribute a copy of *Field-Particle Interactions* to each student. Give them about 13 minutes to complete this handout.

Move from table to table and glance at the groups' work on Question 4. If you notice that a group is not making sense of the connection between force and motion for individual particles, consider whether a brief intervention will help them, then consider using the techniques described in the *Field-Particle Interactions Key*. ✱

Most prompts in the handout give students the chance to express their thinking in words or pictures. This is intentional, as emergent multilingual learners may find it easier to model their thinking with minimal use of language. ✱

It's OK if groups don't get as far as tackling Question 7. However, you should be ready to explore the role of frequency when the class goes over this question later on. Move through the classroom with an eye on Question 7 to see which groups will be ready to offer useful ideas about frequency during the class discussion.

ASSESSMENT OPPORTUNITY	**What to look for/listen for in the moment:** See the *Field-Particle Interactions Key* for examples of student responses. (SEP: 2.3; CCC: 2.2; DCI: PS2.B.2, PS4.B.2) **What to do:** Refer to the *Field-Particle Interactions Key* for suggestions on how to respond in the moment, as well as while looking through students' submitted exit tickets. **Building toward 7.A.1** Develop and revise a model to illustrate absorption of microwave radiation as movement of charged particles in response to particle-level forces from changing electric fields. (SEP: 2.3; CCC: 2.2; DCI: PS2.B.2, PS4.B.2)

ADDITIONAL GUIDANCE	If students struggle to visualize the changing field in a light wave, show them https://www.openscied.org/general/fieldsthroughspace/ from Lesson 4 again. If you have a handheld device, you can open the simulation on this device and display a single arrow flipping up and down.

macroscopic evidence helps convince us that it's useful.

✱ ATTENDING TO EQUITY

Supporting emergent multilingual students: If students struggle to put their thinking into words, consider providing sentence frames. For example, a sentence frame for Question 5 could be: *"I think the particle motion of (water / plastic / electrons) could show that energy has (absorbed / transmitted / reflected) because…"*

4 · REVIEW MATTER-ELECTRIC FIELD INTERACTIONS

10 min

MATERIALS: *Field-Particle Interactions*

Lead a Building Understandings Discussion about the behavior of particles. Present **slide H**. Encourage students to use their answers from the *Field-Particle Interactions* handout during this discussion. Use the slide prompts to elicit student ideas, starting with water molecules, as shown in the table below. ✱

Suggested prompt	Sample student response
What changes in the water molecule were caused by changing the electric field?	The molecule rotated in one direction, then gradually stopped in the opposite position of where it started. The two ends have opposite charges, so they get pushed in different directions.
Does this indicate that waves absorb into, transmit through, or reflect off of the water? How do we know?	It seems like it would mean the wave absorbs, because energy transfers to the moving water particle. Motion usually means energy transfer.
How does this help explain some of the macroscopic changes we observed in our microwave oven experiments?	We saw water heat up in the microwave oven. It makes sense that the water particle is moving, because particles moving means heating up.

Consider the behavior of the ethylene molecule. Present **slide I**. Use the prompts to elicit student ideas about the ethylene plastic.

Suggested prompt	Sample student response
How did the ethylene respond to the changing field? Why?	The plastic molecule didn't move at all.

✱ STRATEGIES FOR THIS BUILDING UNDERSTANDINGS DISCUSSION

Use talk strategies to draw out a variety of ideas from a larger pool of students, and get them to respond to each other's ideas. Asking them to restate what another student has said helps them listen carefully so they can work with others' ideas. If students seem to run out of ideas, count to 10 in your head to give them more time to consider. Helpful prompts during this kind of discussion include:

- *What can we conclude from what ____ observed?*
- *How did you arrive at that conclusion?*
- *What's your evidence?*
- *Does any group have evidence to support the claim ____ made?*
- *What data do we have that challenges that claim?*
- *Where else have we seen examples of _______?*

✱ SUPPORTING STUDENTS IN ENGAGING IN DEVELOPING AND USING MODELS

	The forces on the plastic switched direction, but they always balanced out. There was just as much force pointing upward as downward.
Do EM radiation waves absorb into, transmit through, or reflect off of the ethylene plastic? How do we know?	For the plastic, it could mean that the wave transmits through, because it basically doesn't do anything. There's no energy transfer.
How does this help explain some of the macroscopic changes we observed in our microwave oven experiments?	The plastic didn't heat up on its own. This makes sense, because the particles don't move at all when the electric field changes.

All models have limitations. In the last question on the handout, students use a computer model as an introduction to the complex effects that various EM radiation frequencies can have on various types of matter, but we do not have enough information to refine our model yet. Instead, our goal is to note that our model is not complete, and that we may want to come back to it later to collect more evidence about other frequencies.

ADDITIONAL GUIDANCE Students may point to the simulation's "electrons in aluminum" setting in their discussion. This is fine, but don't dwell on it yet, as much of day 2 will be devoted to thinking about it in more detail.

Consider the limitations of our interactions model for explaining changes in frequency. Present **slide J**. Discuss how the water particle moves in response to higher frequencies, to encourage students to question the direct connection that higher frequency means greater energy transfer.

Suggested prompt	Sample student response
What did you notice about how water molecules respond when we increase frequency?	At higher frequencies, the arrows switch back and forth faster. The water molecule doesn't actually rotate very much. It kind of just jerks back and forth in place.
We have seen in the past that higher frequency transfers more energy when amplitude stays the same. Does this agree with the new model we see in this simulation? Why or why not?	It doesn't really agree. It seems like the water actually moves more when the frequency is slower, so more energy was transferred to the water. It still agrees. The frequency of the field changing is higher, so the energy in that field changes more.

As the class discusses this complex question, emphasize that we have only collected macroscopic evidence for a very specific frequency: the 2.5 GHz frequency inside the microwave oven. Say, *Even though the simulation lets us model a few different frequencies, we should be careful not to generalize too much about frequencies that we don't have evidence about. Let's note this as a limitation of our model to come back to later.* ✱

5 · NAVIGATE

5 min

MATERIALS: science notebook, *Field-Particle Interactions*

Complete an exit ticket about particle behavior in a changing electric field. Present **slide K**. Read the instructions aloud: *On your handout, circle an explanation or drawing that clearly helps explain:*

A. *Why does water heat up in the microwave oven?*

B. *Why doesn't the microwave-safe plastic heat up in the microwave oven?*

If you don't have something yet, sketch a quick model to show ideas about why some substances heat up in the microwave oven while others don't. Show key components, such as: fields, charges, interactions, forces. Collect the exit ticket before students leave.

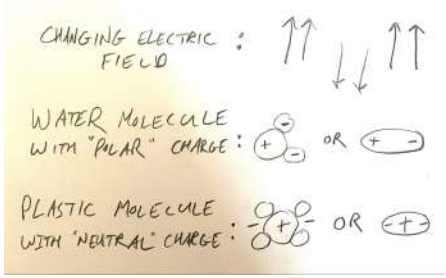
ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment: See the *Field-Particle Interactions Key* for additional guidance. (SEP: 2.3; CCC: 2.2; DCI: PS2.B.2, PS4.B.2)

What to do: The cause-effect connection between changing electric fields and particle-level forces is key to understanding why a microwave oven heats up food. Though this activity is framed as a simulation investigation and exit ticket, the work students produce is a crucial check of their ability to model this phenomenon.

If most students' work shows clear understanding of key ideas as described in the *Field-Particle Interactions Key*, then the beginning of day 2 can run as described in this *Teacher Guide*. Students will not need more individual practice modeling if this work shows they have developed this skill. Give them some targeted feedback on their exit tickets, and prepare to hand these back at the beginning of day 2.

However, if most students' work does not show understanding of those key ideas, do not simply push through to the consensus model without acknowledging their confusion. Instead, take additional class time to try the following strategy:



- Give targeted feedback on the exit tickets, highlighting places where their models **do** show clear understanding of key ideas described in the *Field-Particle Interactions Key*.
- At the beginning of day 2, answer the prompt on **slide M** as a class, drawing images of key components as shown in the image here. Make sure to include: changing electric fields, water molecule with polar charge, plastic molecule with neutral charge.

- Brainstorm and record a list of key ideas. Ask questions to prompt the following ideas: electric field pushes charged particles, unbalanced forces can make particles move, faster-moving molecules means heating up.
- Provide an opportunity on day 2 for students to work individually or in partners to sketch a model of why water heats up in the microwave oven, and why plastic does not heat up.

After students have made models individually or in partners, then move on to the class consensus model, using ideas students generated through their own models.

Building toward: 7.A.2 Develop and revise a model to illustrate absorption of microwave radiation as movement of charged particles in response to particle-level forces from changing electric fields. (SEP: 2.3; CCC: 2.2; DCI: PS2.B.2, PS4.B.2)

End of day 1

6 · NAVIGATE

5 min

MATERIALS: science notebook, exit ticket from day 1

Examine exit ticket responses for similarities and differences. Return the exit tickets from last time to students. Present **slide L**. Say, *I noticed some differences in how we're thinking about polar and nonpolar particles interacting with microwave radiation.*

Read the instructions on the slide aloud:

- *Compare sketches on our exit ticket from last class with a partner.*
- *Brainstorm key components we would need in a consensus model to clearly explain:*
    - *Why does water heat up in the microwave oven?*
    - *Why doesn't the microwave-safe plastic heat up in the microwave oven?*
- *Write your ideas in your science notebook.*

Give partners about 5 minutes to look at each other's models and record key components in their notebooks.

7 · DEVELOP A CONSENSUS MODEL

10 min

MATERIALS: science notebook, chart paper, markers

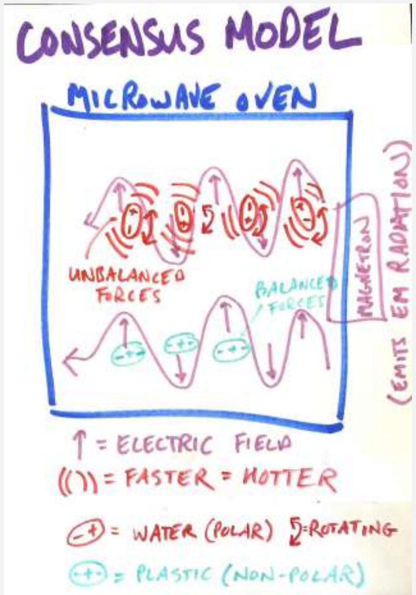
Develop a class consensus model. Present **slide M**. Title a piece of chart paper “Matter Changes in the Microwave Oven”. Elicit student ideas with the prompt:

- *What key components will we need in our consensus model?*

Accept all responses. Consider making an informal checklist to guide the process of building the consensus model. ✱

Present **slide N**. Elicit 1-2 ideas in response to the prompts:

A. *What changes or interactions between these components do we need to show?*
B. *What connection to macroscopic evidence are we trying to explain?* ✱



At the end of this discussion, the model on the poster may look like the image shown here, although it will vary from class to class.

Make sure your model includes responses to the two questions on **slide N**, such as:
(A) the difference in charge at the particle level between water (polar) and plastic (nonpolar)
(A) the direction of forces acting on different parts of the system
(A) how these particles interact with microwave radiation inside the microwave oven
(B) how the particle motion relates to the observed changes in temperature

Apply the model to the behavior of aluminum foil in the microwave oven. Present **slide O**. Say, *Let’s test the usefulness of our model by using it to explain another observation we’ve made about microwave ovens.* Ask students to consider and respond to these prompts:

- *Can our model help explain why aluminum foil is safer to use in the microwave oven under certain conditions but dangerous in others?*

Accept all responses for the first prompt. Highlight that whatever is happening with the foil in the microwave oven, our findings do not help us answer this question yet. Consider asking students to share their own experience to help navigate to the next question by asking, *Where have you seen information or evidence about metal in the microwave?*

Proceed to the slide’s second prompt:

- *What other products have you seen with metal in them that are designed to go in the microwave oven?*

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING CAUSE AND EFFECT

Encourage students to use particle representations that don’t necessarily look like the water or ethylene molecules. A more abstract representation of polar and nonpolar particles (such as an oval with charges) highlights the importance of charge distribution rather than shape in helping to explain a particle’s interaction with a changing electric field. Ask what the particle model’s most important characteristic is for representing our ideas.

✱ STRATEGIES FOR THIS CONSENSUS DISCUSSION

As students share their answers, use some of these prompts to expand the range of ideas represented in the consensus model:

- *How should we represent it? Are we OK with that?*
- *How could we modify what we have, so we account for the evidence that we agree is important to consider?*
- *What modifications might you make to clarify confusion or address the discontent that this group feels?*

Listen for students to suggest the foil on the inside of toaster pastry packets, metal rims on microwave-safe cooking dishes, metal racks, and so forth. If they can't think of examples, that is fine.

Say, *A lot of companies claim that their products are safe to use in a microwave oven. Let's read some claims about the safety of these kinds of products, and that might give us some ideas about how our model can explain the foil.*

- *Is more evidence or clarification needed before we can come to an agreement? What is that?*

8 · EVALUATE THE VALIDITY AND RELIABILITY OF CLAIMS

25 min

MATERIALS: *Evaluating Information Checklist*, *Metal in Microwave Ovens*, science notebook, https://www.openscied.org/general/fieldparticleinteractions/

Introduce the *Evaluating Information Checklist*. Present **slide P**. Distribute the *Evaluating Information Checklist* to each student. Ask them to work with a partner to answer the slide prompts:
Read through each row of the Evaluating Information Checklist with a partner.

- *Which categories do you think will be easy to identify from an article?*
- *Which categories do you think will be more difficult?*
- *Why do you think that?*

Invite a few volunteers to share their ideas, and accept all responses. Say, *It might help us understand how to use this checklist if we evaluate a short part of one of the readings together.* ✱

Model how to use the *Evaluating Information Checklist*. Present **slide Q**. Ask a volunteer to read the paragraph:

- *When you use a microwave oven, radiation passes through materials like paper, glass, and plastic, but it gets absorbed by the water content in food. The radiation makes the water molecules inside the food wiggle around, which creates heat and cooks the food.*

As a class, use the *Evaluating Information Checklist* to determine the validity and reliability of the claims in the paragraph. Discuss whether the paragraph fulfills each of the criteria on the checklist.

Evaluate the validity and reliability of the reading. Present **slide R**. Distribute *Metal in Microwave Ovens* to each student. Assign half of the partner pairs to read the handout's Part A: Company Website, and the other half to read Part B: Local Newspaper (on the other side).

Tell students to evaluate the validity and reliability of their assigned reading in partners using the *Evaluating Information Checklist*. Draw their attention to the slide to show them how to fill in the checklist. Give them about 12 minutes to complete this task.

✱ SUPPORTING STUDENTS IN ENGAGING IN OBTAINING, EVALUATING, AND COMMUNICATING INFORMATION

It is not important whether students can define *reliability* and *validity*. In fact, it is very likely at this point that they will be confused by what the distinction is. What is important is that they become confident in using different criteria to evaluate the validity and reliability of claims they encounter in various contexts.

✱ SUPPORTING STUDENTS IN DEVELOPING AND USING STRUCTURE AND FUNCTION

The *Metal in Microwave Ovens* reading refers explicitly to the design of the lid of the pot as an explanation for why this lid will not arc in the microwave oven. To clarify this point, try asking what shape of lid would be an ineffective design for this reason. Encourage students to consider that the behavior of this

Explain choices about validity and reliability. Present **slide S**. Direct the class to individually write their answers to the slide's prompts in their science notebook:

- *Based on your evaluation, are the claims made in the reading:*
  - *reliable?*
  - *valid?*
- *Explain your answers, using evidence from the Evaluating Information Checklist and the reading.*
- *Why is it important to pay attention to the validity and reliability of the claims we read?*

Give students a few minutes before inviting them to share. Accept all responses. Make sure you hear from students who read Part A and from those who read Part B.

Use a computer model of electrons in aluminum to verify that claims are reliable. Present **slide T**. Point out that the simulation we used earlier also has a simulation of a single electron, and another of electrons in aluminum foil. Ask for a show of hands to see whether anybody got a chance to play around with those settings. Discuss the slide's prompts with the class, as shown in the tables below.

Suggested prompt	Sample student response
How could we use the simulation of electrons in aluminum to verify claims made in the readings?	We could look at our simulation to see if it makes sense with the claims that the authors make.

Run the simulation of an electron and give students a few moments to observe.

Suggested prompt	Sample student response
What do you notice when we run the simulation of an electron?	The electron moves back and forth in the direction that it's pushed by the electric field. It moves back and forth at the same frequency as the electric field flips.

Run the simulation of electrons in aluminum and give students a few moments to observe.

lid is affected by not only the lid's material but also its structure (shape, thickness).

The reading also refers explicitly to the use of food containers with a thin metallic layer under a non-metallic lid to speed up cooking. Encourage students to consider how the structure of this container can affect how energy transfers into the food when assessing the validity and reliability of this claim.

Suggested prompt	Sample student response
What do you notice when we run the simulation of electrons in aluminum?	Electrons move somewhat freely within the aluminum. The electrons start to bunch up.

Ask students to consider the last prompt:

- *What does this tell us about the validity of claims in the readings?*

Listen for ideas about how the structure of the aluminum at a particle scale, which allows electrons to move freely, allows for arcing, just like the readings describe.
✱

ADDITIONAL GUIDANCE

Use probing questions to get students thinking about how the particle structure of aluminum helps us explain the macroscopic behavior of aluminum in the microwave oven. Quite a few details in the *Evaluating Information Checklist* reading provide opportunities to discuss *Structure and Function*: Part A refers explicitly to the design of the lid of the pot as an explanation for why this lid will not arc in the oven; Part B refers to food containers with a thin metallic layer under a nonmetallic lid to speed up the cooking of the food inside, and uses electron vibration to explain the reflective nature of metal. Students may also notice how the designed macroscopic structure of the microwave-safe dishware allows it to function in the oven despite the fact that some of its electrons move freely.

ASSESSMENT OPPORTUNITY

What to look for/listen for in the moment:

- Mention specific pieces of evidence used by the author to justify whether the claims in the reading are valid or reliable. (SEP: 8.4)
- Mention specific investigations or ideas developed by the class that provide evidence of validity and reliability of claims about the interactions of charged particles within aluminum foil and electromagnetic radiation. (SEP: 8.4; CCC: 6.2; DCI: PS2.B.2)
- Include particle-level interactions in the aluminum foil structure with changing electric fields to determine whether the claims are valid and reliable. (SEP: 8.4; CCC: 6.2; DCI: PS2.B.2)
- Describe an investigation that can be carried out with materials in the classroom to test the reliability of claims about the role of aluminum foil in influencing electromagnetic radiation within the

microwave oven. (SEP: 8.4; CCC: 6.2; DCI: PS2.B.2)

What to do: You might want to encourage students to read the article aloud with their partner. Encourage them to actively use the strategies listed in italics below each checklist item, such as:

- *Underline sections where the author presents evidence related to claims.*
- *List relevant experiences you have had or relevant terms you understand.*
- *Using a different color, underline the science ideas that each author uses to support their claims.*

When students begin to consider the reliability of claims, encourage them to describe possible experiments or places where you would look for more evidence.

If time permits, you can carry out some of the experiments students suggest. **Do not** perform any suggested experiments that do not meet the safety precautions indicated in the *Microwave Oven Manual*, and **do not** suggest that they conduct experiments on their own for home learning.

Building toward: 7.B Evaluate multiple claims from advertisement media to determine the validity and reliability of claims made about the relationship between the structure, shape, and molecular substructure of aluminum foil and its interaction with electromagnetic radiation. (SEP: 8.4; CCC: 6.2; DCI: PS2.B.2)

9 · NAVIGATE

5 min

MATERIALS: science notebook

Update Personal Glossary and *Progress Tracker*. Present **slide U**. Give students a couple of minutes to record a definition for *polar molecules* in their Personal Glossaries using words and/or pictures. Circulate around the room to glance at their definitions, and look for them to record something like “a molecule that has a positive side and a negative side.” Then ask them to record our new ideas in their *Progress Tracker*. They may sketch a version of the consensus model, or simply write an explanation of the behavior of polar and nonpolar molecules in response to microwave radiation.

Navigate into the next lesson. Present **slide V**. Have students use our current model in a Turn and Talk in response to the prompt:

- *Does our particle-scale model for what heats up and what stays cool in the microwave oven explain the patterns we observed of hot and cool spots when we heated nachos in the oven?*

Accept all responses, and tell students we want to look further into this question next time.

Additional Lesson 7 Teacher Guidance

SUPPORTING STUDENTS IN MAKING CONNECTIONS IN ELA	This is the CCSS-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 evaluate information from two sources regarding the use of aluminum foil inside a microwave oven. The evaluation focuses on the validity and reliability of the claims presented, and the *Molecule Cutouts* is provided to support student engagement with this CCSS-related idea throughout the unit.