# UNIT STORYLINE

**Unit Question:** How do we use radiation in our lives, and is it safe for humans?

## Lesson Set 1: How does a microwave oven heat up food?

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| How do microwave ovens function, and why does their structure affect wireless signals? | Wireless communication signals are affected when they pass through the walls and door of a microwave oven. The microwave oven cooks food quickly and without an obvious heat source. | We read an article about an interesting trend: people are storing their phones, keys, and other electronic devices in their microwave ovens. We observe a Bluetooth speaker paired to a device inside a closed microwave oven, read the *Microwave Oven Manual*, and then safely heat food and make additional observations. We model the structure and function of the microwave oven, build a Driving Question Board, and brainstorm future investigations and data we need. We figure out:  
  - The structure of a microwave oven blocks or somehow affects wireless signals, but not completely.  
  - The function of a microwave oven is to heat (transfer energy into) liquid/food.  
  - Using a microwave oven requires attention to safety. | |
| Anchoring Phenomenon |                            |                          |                   |

**Navigation to Next Lesson:** We have a lot of questions about microwave ovens and wireless technology, and a lot of ideas for investigations we want to do to answer our questions.

## Lesson 2

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<th>Lesson Set 1</th>
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<th>How does a microwave oven use electricity to produce microwave radiation?</th>
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| How does a microwave oven use electricity to produce microwave radiation? | When a microwave oven is taken apart, we find a magnetron with an antenna. This antenna probably changes fields inside the cooking area, but to be sure we need to know more about how the magnetron works. | We integrate information from our *Microwave Oven Manual*, a video of a magnetron being dissected, a reading, and a brief investigation to identify a relationship between moving electrons and changing electric fields. We figure out:  
  - Electrons vibrate inside the antenna of a magnetron.  
  - Vibrating charged particles change electric fields.  
  - Changing electric fields carry energy across space.  
  - The microwave oven is designed so the magnetron antenna changes electric fields near the oven's cooking area. This energy transfers across space and somehow reaches the food. |

**Navigation to Next Lesson:** We have many ideas about how the changing electric fields emitted from the magnetron transfer energy from the antenna to the food. We recognize that we need to know more about waves to investigate these ideas in more detail.
### LESSON 3
**Lesson Set 1**

**3 days**

**How does energy transfer through a wave?**

**Investigation**

*Shaking the end of a slinky creates a wave pattern. A computer simulation of a wave on a string produces similar patterns.*

We recall examples of physical waves and produce waves with a spring. We develop a model of how physical waves transfer energy through solids. We use a computer simulation to plan and carry out four investigations. Using our results, we make claims for how various wave properties affect energy transfer. We develop a mathematical model of the relationship between some of these properties. We figure out:

- Energy is transferred through waves on a string by the stretching of electric fields (bonds) and by the forces between these fields and the matter of the string.

- A larger amplitude transfers more energy along the wave.

- A larger frequency transfers more energy along the wave.

- The wavelength of a wave can be determined by the wave speed across the medium and its frequency.

### LESSON 4
**Lesson Set 1**

**2 days**

**How does an antenna transfer energy to matter at a distance?**

**Investigation**

*Electromagnetic radiation can be visualized as changing electric and magnetic fields rippling outward from a moving charge.*

We investigate how moving electrons in an antenna cause energy to transfer. We use and evaluate different representations of electromagnetic radiation propagating through space, and read about the mechanism that generates electric and magnetic fields from a vibrating charged particle. We develop a mechanistic explanation of electromagnetic radiation and use it to predict its interactions with matter inside the microwave oven. We figure out:

- Moving electrons create electric fields that change.

- These changing electric fields, in turn, create changing magnetic fields, which generate changing electric fields again. This wavelike cycle continues, resulting in the formation of electromagnetic radiation.

- Electromagnetic radiation can travel through empty space without needing matter to move through.

- The energy in changing electric and magnetic fields spreads out as waves travel, becoming weaker the farther they go.

**Navigation to Next Lesson:** We think that the multiple perspectives (M-E-F) we have used to explain energy transfer in physical waves could also help us make sense of how energy transfers from the magnetron to the food inside the microwave oven.

**Navigation to Next Lesson:** We figured out how electromagnetic waves transfer energy through space, but we wonder how microwaves interact with the matter inside the microwave oven.
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<tr>
<td>3 days</td>
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<tr>
<td>How does radiation interact with the parts of the microwave oven system?</td>
<td><img src="image" alt="Microwave Oven Diagram" /></td>
<td>We argue for, plan, and carry out investigations to determine what happens to microwave radiation when it reaches the material(s) in the microwave oven door and walls. We develop a model to explain the results of our investigations, showing what happens to the energy transferred by these waves when they interact with these parts of the system. We figure out:</td>
<td><img src="image" alt="Energy Transfer Diagram" /></td>
</tr>
<tr>
<td>Investigation</td>
<td>When bowls of water wrapped in foil or in foil with small holes are in a running microwave oven for 15 seconds, their temperature does not increase.</td>
<td>- The energy transferred by microwave radiation can be absorbed (food heating up), reflected (off metal walls), and/or transmitted by matter.</td>
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<td>- We all have an ethical responsibility to consider the possible personal, societal, and environmental impacts of any scientific investigation we plan or engineering solution we design.</td>
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<td>- The window in the microwave oven door transmits one type of EM radiation (visible light) through it, but transmits none (or very little) of another type of EM radiation (microwave radiation).</td>
<td><img src="image" alt="Energy Transfer Diagram" /></td>
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</table>

**Navigation to Next Lesson:** Though we were able to determine how microwave radiation interacts with some materials, we still have questions about why it interacts the way it does and how other materials (e.g., different foods) interact with it.

| **LESSON 6**    |                             |                          |                     |
| Lesson Set 1    |                             |                          |                     |
| 1 day           |                             |                          |                     |
| How can we use interactions between matter and electromagnetic radiation to explain the increase in global temperatures? | ![Global Temperature Graph](image) | We add new questions to the Driving Question Board and use our science ideas about the interactions of different types of EM radiation with different types of matter to explain how an increase in greenhouse gases could be contributing to the overall increase in global temperatures. We figure out: | ![Energy Flow Diagram](image) |
| Putting Pieces Together | Greenhouse gases and global temperatures have increased over the last century, but the amount of solar radiation has not. | - 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 the prevalence and longevity of carbon in the atmosphere, carbon has contributed to the increased temperatures globally and will continue to do. | ![Energy Flow Diagram](image) |

**Navigation to Next Lesson:** We revisited our Driving Question Board and realized we still have many questions about other types of EM radiation, their safety, and their interactions with various types of matter, such as food and other objects.
**Lesson Question**
Why do some substances heat up faster than other materials in a microwave oven?

**Phenomena or Design Problem**
What we do and figure out
How we represent it

**LESSON 7**
Lesson Set 1

2 days

**Investigation, Putting Pieces Together**

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

**Phenomena or Design Problem**

**What we do and figure out**

Different materials respond differently when heated inside the microwave oven. Water heats up, plastic doesn't, and aluminum foil creates sparks.

We use simulations to model how matter of different materials (water, plastic, metal) interact with changing electric fields of different frequencies. We connect this particle-scale evidence to macroscopic evidence about materials heating up in 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 these claims. We figure out:

- The forces from changing electric fields in the microwave oven will cause polar molecules, like water, to rotate in the direction of the fields.
- The interaction between the microwave radiation and the water molecules will transfer energy out of the fields and into thermal or kinetic energy of the water.
- Electrons can move inside conductors like metal when pushed by changing electric fields in microwave radiation, which can cause reflection, or dangerous arcing in some cases.

**How we represent it**

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- Electrons can move inside conductors like metal when pushed by changing electric fields in microwave radiation, which can cause reflection, or dangerous arcing in some cases.

**Navigation to Next Lesson:** We wonder what causes the patterns of melted and unmelted cheese when we heat nachos in the microwave oven.

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**LESSON 8**
Lesson Set 1

3 days

**Investigation, Putting Pieces Together**

**Lesson Question**
Why do we see patterns of hot and cold spots in the microwave oven?

**Phenomena or Design Problem**

**What we do and figure out**

When many small light bulbs are placed across the microwave oven while it is running, some light up and some do not.

We observe a pattern when light bulbs are placed in the microwave oven. We use simulations to make sense of wave interference. We model wave interference from an energy perspective to explain hot and cold spots in the microwave oven. We revise our initial consensus model from the anchor phenomenon and our Driving Question Board. We figure out:

- When two waves meet in space, they can produce a new wave through either constructive or destructive interference, but the total combined energy of the original waves is conserved.
- The microwave oven produces hot and cold spots due to constructive and destructive wave interference between the waves emitted from the magnetron and those reflected off of the oven’s interior walls.
- The turntable in the microwave oven is designed to move food between hot and cold spots to provide more even heating.

**How we represent it**

We observe a pattern when light bulbs are placed in the microwave oven. We use simulations to make sense of wave interference. We model wave interference from an energy perspective to explain hot and cold spots in the microwave oven. We revise our initial consensus model from the anchor phenomenon and our Driving Question Board. We figure out:

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- The microwave oven produces hot and cold spots due to constructive and destructive wave interference between the waves emitted from the magnetron and those reflected off of the oven’s interior walls.
- The turntable in the microwave oven is designed to move food between hot and cold spots to provide more even heating.

**Navigation to Next Lesson:** We can explain how electromagnetic radiation can transfer energy to food in a microwave oven, but we cannot explain how it can be used to transfer information between wireless devices.
Lesson Set 2: How do we use electromagnetic radiation safely in our lives?

Lesson Question

LESSON 9
Lesson Set 2
2 days
What other types of EM radiation are there, and how do we use them?

Investigation, Problematizing

The electromagnetic spectrum includes various types of radiation with a wide range of frequencies, wavelengths, and uses, such as communication and medical imaging, but some types can also pose health risks.

We examine the remaining categories of DQB questions and construct the EM spectrum using the wavelength and frequency of various types of EM radiation. 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. We figure out:

- The EM radiation spectrum is arranged from high- to low-frequency (short to long wavelength) EM waves.
- Different types of EM radiation have different interactions with matter, including heating it up, 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 10
Lesson Set 2
2 days
Does all electromagnetic radiation cause damage?

Investigation

Not all frequencies and amplitudes of light are linked to skin cancer.

We question whether higher frequency or higher amplitude EM radiation leads to an increase in skin cancer. We use multiple sources of evidence to try to identify patterns in frequency, amplitude, and skin cancer. We use both a wave model and a photon model to try to explain our evidence. We figure out:

- The photons of high-frequency EM radiation have enough energy to knock out electrons, causing changes in the molecular structure of the DNA molecule.
- More high-frequency, ionizing radiation puts you at greater risk of cancer, but how much the risk increases depends on the type of radiation and the total exposure time.
- The photon model of EM radiation can better explain the interactions of high-frequency EM radiation and matter.
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<td>Lesson Set 2</td>
<td>How can we use EM radiation to create and store digital images?</td>
<td>We wonder how EM radiation is used to create and store digital images. We read about how the interactions of X-rays with matter can be harnessed to create images of the internal structure of our body, and about the advantages and disadvantages of digital versus conventional radiography. We wonder how EM radiation is used in wireless communication to transmit information. We figure out:</td>
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<tr>
<td>Investigation</td>
<td>Digital radiography uses electronic detectors to capture X-rays for creating and storing digital images of our bodies' internal structures.</td>
<td>- Sensors that respond to EM radiation are very sensitive and can trigger electric currents that can be used to create digital images.</td>
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<td>- Digital images can be reliably stored in our computers.</td>
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<td>- Digital technologies can reduce the time of exposure to the ionizing radiation necessary in medical applications.</td>
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<td>We figure out that the interactions of X-rays with matter can be harnessed to create digital images for medical applications while reducing the time of exposure needed, and thus, reducing the potential harm they can cause us. We wonder how the interactions between EM radiation and matter are used in communication technologies.</td>
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LESSON 12 | Lesson Set 2 | How are our wireless electronic devices designed to use EM waves to reliably communicate different types of information? | We develop ways to send messages with EM waves using a simulation. We develop a model for how this system works and compare it to digital communication systems. We gather information from multiple sources in various formats from four different stations. We integrate this information with our model to summarize how our wireless electronic devices are designed to use EM waves to reliably communicate various types of information. We figure out: | | | | | |
| Investigation | Pulses of sound, light, and other EM waves have been used in the past to communicate text messages over long distances. | - The majority of modern wireless communication uses binary code (digital transmission) to represent information, such as text, audio, photos/video, and location. | | | | | | |
| | | - Binary code is a combination of “on” and “off” states; it can be represented in EM radiation by varying the energy in the wave, using changes in the wave’s amplitude or frequency to communicate “on” and “off”. | | | | | | |
| | | - If a wireless message is encrypted, only the intended receiver can decode the information. | | | | | | |
| | | We consider the argument that scientists and engineers are making that using even higher frequency EM radiation in future wireless communication technologies could provide some advantages. We can already see some trade-offs related to doing this. | | | | | |
LESSON 13
Lesson Set 2
1.5 days

Is communication technology that uses radiation safe?

Putting Pieces Together

We return to the Driving Question Board to take stock of where we have been and what questions we have answered. We work through an assessment task in which we evaluate two social media posts about 5G radiation, and we use our model for EM radiation to argue from evidence about whether this technology is safe. We figure out:

- We have answered many of our questions about EM radiation.
- 5G technology is most likely not dangerous because it is not a form of ionizing radiation, but long-term exposure could lead to potential health consequences.

EM radiation affects different materials in different ways.

Navigation to Next Lesson: This is the last lesson in the unit.

LESSONS 1-13
27 days total