Electromagnetic Waves

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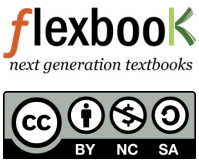

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CONCEPT 1 Electromagnetic Waves

- Define electromagnetic wave and electromagnetic radiation.
- Describe the electric and magnetic fields of an electromagnetic wave.
- Explain how electromagnetic waves begin and how they travel.
- State how electromagnetic waves may interact with matter.
- Identify sources of electromagnetic waves.

Did you ever wonder how a microwave works? It directs invisible waves of radiation toward the food placed inside of it. The radiation transfers energy to the food, causing it to get warmer. The radiation is in the form of microwaves, which are a type of electromagnetic waves.

What Are Electromagnetic Waves?

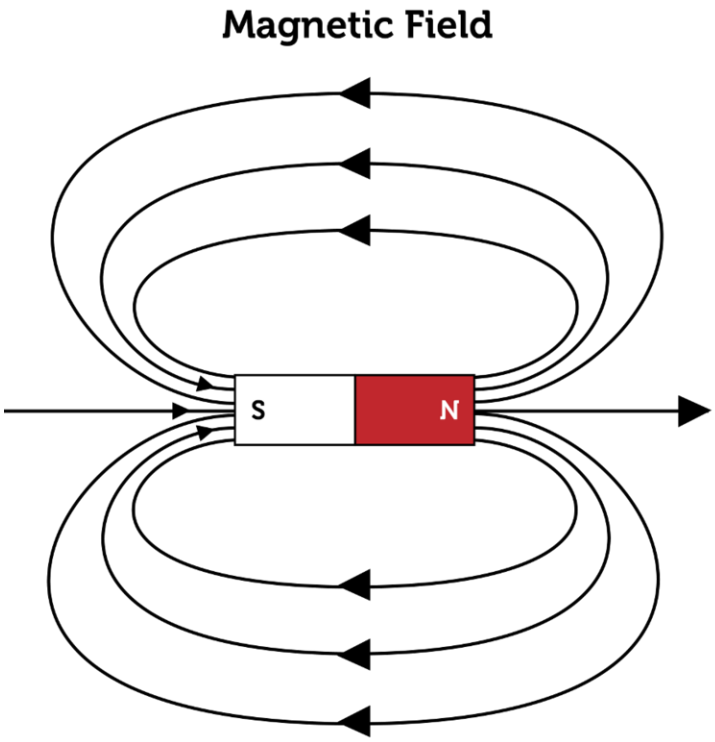
Electromagnetic waves are waves that consist of vibrating electric and magnetic fields. Like other waves, electromagnetic waves transfer energy from one place to another. The transfer of energy by electromagnetic waves is called **electromagnetic radiation**. Electromagnetic waves can transfer energy through matter or across empty space. For an excellent video introduction to electromagnetic waves, go to this URL: http://www.youtube.com/watch?v=cfXzwh3KadE

Q: How do microwaves transfer energy inside a microwave oven?

A: They transfer energy through the air inside the oven to the food.

May the Force Be with You

A familiar example may help you understand the vibrating electric and magnetic fields that make up electromagnetic waves. Consider a bar magnet, like the one in the **Figure** 1.1. The magnet exerts magnetic force over an area all around it. This area is called a magnetic field. The field lines in the diagram represent the direction and location of the magnetic force. Because of the field surrounding a magnet, it can exert force on objects without touching them. They just have to be within its magnetic field.



Field Lines Around a Bar Magnet

FIGURE 1.1

Q: How could you demonstrate that a magnet can exert force on objects without touching them?

A: You could put small objects containing iron, such as paper clips, near a magnet and show that they move toward the magnet.

An electric field is similar to a magnetic field. It is an area of electrical force surrounding a positively or negatively charged particle. You can see electric fields in the following **Figure** 1.2. Like a magnetic field, an electric field can exert force on objects over a distance without actually touching them.

How an Electromagnetic Wave Begins

An electromagnetic wave begins when an electrically charged particle vibrates. The **Figure** 1.3 shows how this happens. A vibrating charged particle causes the electric field surrounding it to vibrate as well. A vibrating electric field, in turn, creates a vibrating magnetic field. The two types of vibrating fields combine to create an electromagnetic wave. You can see animations of electromagnetic waves at these URLs: http://www.youtube.com/watch?v=Qju7QnbrOhM&feature=related http://www.phys.hawaii.edu/ teb/java/ntnujava/emWave/emWave.html

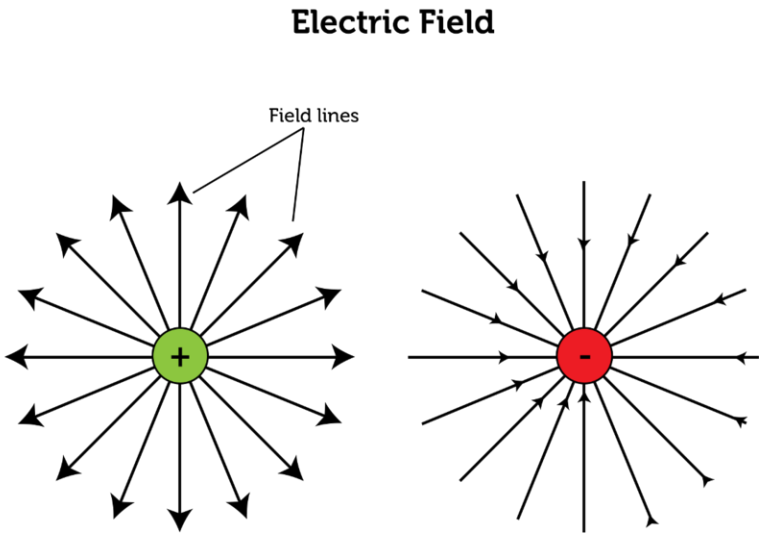


FIGURE 1.2

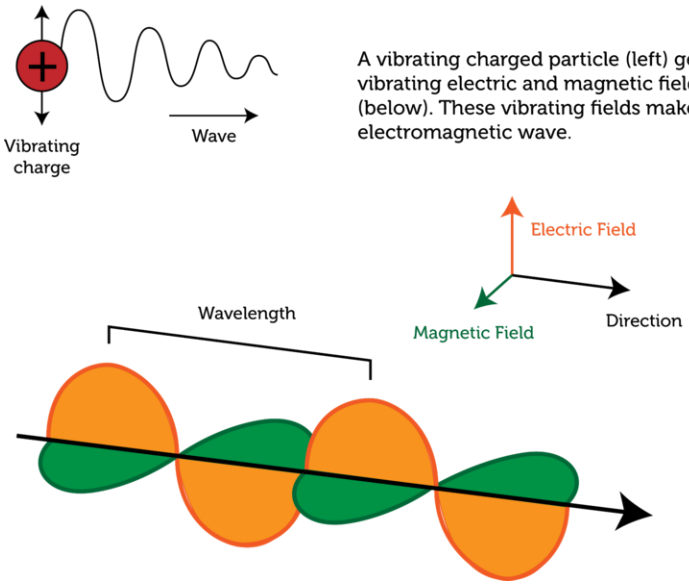


FIGURE 1.3

How an Electromagnetic Wave Travels

As you can see in the diagram above, the electric and magnetic fields that make up an electromagnetic wave are perpendicular (at right angles) to each other. Both fields are also perpendicular to the direction that the wave travels. Therefore, an electromagnetic wave is a transverse wave. However, unlike a mechanical transverse wave, which can only travel through matter, an electromagnetic transverse wave can travel through empty space. When waves travel through matter, they lose some energy to the matter as they pass through it. But when waves travel through space, no energy is lost. Therefore, electromagnetic waves don't get weaker as they travel. However, the energy is "diluted" as it travels farther from its source because it spreads out over an ever-larger area.

Electromagnetic Wave Interactions

When electromagnetic waves strike matter, they may interact with it in the same ways that mechanical waves interact with matter. Electromagnetic waves may:

- reflect, or bounce back from a surface;
- refract, or bend when entering a new medium;
- diffract, or spread out around obstacles.

Electromagnetic waves may also be absorbed by matter and converted to other forms of energy. Microwaves are a familiar example. When microwaves strike food in a microwave oven, they are absorbed and converted to thermal energy, which heats the food.

Sources of Electromagnetic Waves

The most important source of electromagnetic waves on Earth is the sun. Electromagnetic waves travel from the sun to Earth across space and provide virtually all the energy that supports life on our planet. Many other sources of electromagnetic waves depend on technology. Radio waves, microwaves, and X rays are examples. We use these electromagnetic waves for communications, cooking, medicine, and many other purposes.

Summary

- Electromagnetic waves are waves that consist of vibrating electric and magnetic fields. They transfer energy through matter or across space. The transfer of energy by electromagnetic waves is called electromagnetic radiation.
- The electric and magnetic fields of an electromagnetic wave are areas of electric or magnetic force. The fields can exert force over objects at a distance.
- An electromagnetic wave begins when an electrically charged particle vibrates. This causes a vibrating electric field, which in turn creates a vibrating magnetic field. The two vibrating fields together form an electromagnetic wave.
- An electromagnetic wave is a transverse wave that can travel across space as well as through matter. When it travels through space, it doesn't lose energy to a medium as a mechanical wave does.
- When electromagnetic waves strike matter, they may be reflected, refracted, or diffracted. Or they may be absorbed by matter and converted to other forms of energy.
- The most important source of electromagnetic waves on Earth is the sun. Many other sources of electromagnetic waves depend on technology.

Vocabulary

- **electromagnetic radiation**: Transfer of energy by electromagnetic waves across space or through matter.
- **electromagnetic wave**: Transverse wave consisting of vibrating electric and magnetic fields that can travel across space.

Practice

Watch the electromagnetic wave animation at the following URL, and then answer the questions below. http://www.youtube.com/watch?v=4CtnUETLIFs

1. Identify the vibrating electric and magnetic fields of the wave.
2. Describe the direction in which the wave is traveling.

Review

1. What is an electromagnetic wave?
2. Define electromagnetic radiation.
3. Describe the electric and magnetic fields of an electromagnetic wave.
4. How does an electromagnetic wave begin? How does it travel?
5. Compare and contrast electromagnetic and mechanical transverse waves.
6. List three sources of electromagnetic waves on Earth.