10

SCIENCE
Quarter 2- Module 1
Electromagnetic Waves

Photo: Sunset
Location: Kiburiao, Quezon, Bukidnon
Captured by: Elmar M. Dongallo

ALTERNATIVE DELIVERY MODE
ADM

Department of Education ● Republic of the Philippines

Science – Grade 10
Alternative Delivery Mode
Quarter 2 – Module 1: Electromagnetic Waves
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This instructional material was collaboratively developed and reviewed by educators from public schools. We encourage teachers and other education stakeholders to email their feedback, comments, and recommendations to the Department of Education at bukidnon@ deped.gov.ph.

We value your feedback and recommendations.

Department of Education ● Republic of the Philippines

Table of Contents

What This Module Is About

Introductory Message:

Welcome to the Science 10 Alternative Delivery Mode (ADM) Module on Electromagnetic Waves! An electromagnetic (EM) wave refers to the disturbance in a field that carries energy and does not require a medium to travel. These EM waves are formed when an electric field comes in contact with a magnetic field. These include radio waves, microwaves, infrared, visible light, ultraviolet, X-rays and gamma rays.

To the Teachers:

This module was collaboratively designed, developed and reviewed by educators from public schools to assist you, the teacher or facilitator, in helping the learners meet the standards set by the K to 12 Curriculum while overcoming their personal, social, and economic constraints in schooling.

As a facilitator, you are expected to orient the learners on how to use this module. You also need to keep track of the learners' progress and allow them to manage their own learning for optimal development and understanding. Furthermore, you are expected to encourage and assist the learners as they do the tasks included in this module.

To the Parents:

This module was designed to provide your children with fun and meaningful opportunities for guided and independent learning at their own pace and time.

As vital partners in education, your support to your children’s learning at home is a great factor to ensure that they will become successful in what they do. As parents, you are expected to monitor your children’s progress as they accomplish the tasks present in this module and ensure that they will practice learning independently.

To the Learners:

This learning resource hopes to engage you into guided and independent learning activities at your own pace and time. This also aims to help you acquire the needed 21st century skills while taking into consideration your needs and circumstances.

It is our objective that you will have fun while going through this material. Take charge of your learning pace and in no time, you will successfully meet the targets and objectives set in this module which are intended for your ultimate development as a learner and as a person.

- ***From the Science 10 Module Development Team***

This module contains the following parts with their corresponding icons:

 ***What I Need to Know***	This gives you an idea on what skills or competencies you are expected to learn in each lesson.
 ***What I Know***	It includes an activity that aims to check your prior knowledge on the lesson you are about to take. If you get all the answers correct (100%), you may decide to skip the lesson.
 ***What's In***	This serves as a brief drill or review to help you link the current lesson with that to the previous one.
 ***What's New***	It offers a new lesson by introducing it interestingly through a story, a song, a poem, a problem opener, an activity or a situation.
 ***What Is It***	This provides a brief discussion of the lesson. This aims to help you discover and understand new concepts and skills.
 ***What's More***	This comprises activities for independent practice to solidify your understanding and skills on the current topic. You may check the answers to the exercises using the Answer Key found at the end of the module.
 ***What I Have Learned***	This includes questions or blank sentences/paragraphs to be filled in to process what you have learned from the lesson.
 ***What I Can Do***	It delivers an activity which will help you transfer your new knowledge or skill into real life situations or concerns.
 ***Assessment***	This aims to evaluate your level of mastery in achieving the learning competencies.
 ***Additional Activities***	This enriches your knowledge or skill of the lesson learned. It also tends to the retention of the learned concepts.
 ***Answer Key***	This contains all of the answers to all activities and exercises present in this module.

At the end of this module, you will also find:

References	This shows the list of all sources used in developing this module.

Before using this module, please take time to read the following guidelines and reminders:

1. Use the module with care. Do not put unnecessary mark/s on any part of the module. Use a separate sheet of paper in answering the exercises.
2. Do not forget to answer the *What I Know* section before moving on to the next activities included in this module.
3. Read the instructions carefully before doing each task.
4. Observe honesty and integrity in doing the tasks and in checking your answers.
5. Finish the task at hand before proceeding to the next.
6. Return this module to your teacher/facilitator once you are through with it.

If you encounter any difficulty in answering any of the activities, do not hesitate to consult your teacher or facilitator. Always bear in mind that you are not alone.

We hope that through this material, you will experience meaningful learning and be able to gain a deeper understanding of the relevant competencies. You can do it!

Module Overview

When this material was designed, your best interest as a learner was given the highest attention. For this specific module, you are expected to master the nature of electromagnetic waves. The scope of this module permits it to be used in many different learning situations. The language it uses recognizes the diverse vocabulary level of students. Moreover, the lessons are arranged to follow the standard sequence of the course. But the order in which you read them can be changed to correspond with the textbook you are now using.

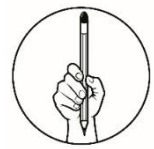
The module is divided into three lessons, namely:

- Lesson 1 – Nature of Electromagnetic Waves
- Lesson 2 – The Proponents of Electromagnetic Wave Theory
- Lesson 3 – EM Waves: Frequencies and Wavelengths

After going through this module, you are expected to:

1. Describe how an electromagnetic (EM) wave is produced and propagated;
2. Find out who the significant proponents are on the formulation of electromagnetic theory; and
3. Compare the relative frequencies and wavelengths of each EM wave.

Let us check first your understanding on the concept of electromagnetic waves by answering a pretest.



What I Know (Pretest)

Directions: Choose the CAPITAL LETTER of the best answer. Write the chosen letter on a separate sheet of paper.

1. How are electromagnetic waves produced?
   A. Any disturbance
   B. Currents
   C. Vibrating charge
   D. Voltage source

2. In the electromagnetic wave, what is the direction of the propagation of the wave?
   A. Always to the right
   B. Cannot be determined
   C. Parallel to electric and magnetic field directions
   D. Perpendicular to the electric and magnetic field directions

3. Which of the following forms of electromagnetic waves has the widest frequency range?
   A. Microwave
   B. Radio waves
   C. Ultraviolet
   D. X-ray

4. What happens to the frequency of the electromagnetic wave if its wavelength increases?
   A. It decreases.
   B. It increases as well.
   C. It remains the same.
   D. None of the above.

5. What is the speed of the electromagnetic wave in a vacuum?
   A. Zero
   B. Always the same as the speed of light
   C. Changing depending on the value of its wavelength
   D. none of the above

6. Who contributed in developing equations that showed the relationship of electricity and magnetism?
   A. André-Marie Ampere
   B. Heinrich Hertz
   C. James Clerk Maxwell
   D. Michael Faraday

7. Who showed the experimental evidence of electromagnetic waves and their link to light?
   A. André-Marie Ampere
   B. Heinrich Hertz
   C. James Clerk Maxwell
   D. Michael Faraday

8. Which type of wave has the shortest wavelength?
   A. Gamma ray
   B. Microwave
   C. Ultraviolet
   D. X-ray

9. What is the other term for electromagnetic waves?
   A. Electric waves
   B. Longitudinal waves
   C. Mechanical waves
   D. Transverse waves

10. All EM waves have the same speed.
   A. True B. False

11. Which of the following correctly lists electromagnetic waves in the order from the longest to the shortest wavelength?
   A. Gamma rays, ultraviolet, infrared, microwaves
   B. Microwaves, ultraviolet, visible light, gamma rays
   C. Radio waves, infrared, gamma rays, ultraviolet
   D. Radio waves, infrared, visible light, X-rays

12. How is the wavelength of infrared differs from the wavelength of ultraviolet waves?
   A. Longer
   B. Shorter
   C. The same
   D. None of the above

13. What is the main difference between a radio wave and a light wave?
   A. Speed
   B. Wavelength
   C. Both A and B
   D. None of the above

14. Which of the following is NOT an electromagnetic wave?
   A. Infrared
   B. Light
   C. Sound
   D. Radio

15. What is the frequency range of UV radiation?
   A. $3.5 \times 10^{9} – 3 \times 10^{11}$ Hz
   B. $3.5 \times 10^{11} – 4 \times 10^{14}$ Hz
   C. $7.5 \times 10^{14} – 3 \times 10^{16}$ Hz
   D. $7.5 \times 10^{16} – 3 \times 10^{19}$ Hz

Lesson 1 Nature of Electromagnetic Waves

What I Need to Know

In this lesson, you will be introduced to the **nature of electromagnetic waves** and on how they are produced and transmitted. You are also expected to be able to explain how these waves are considered to be comprised of both electric and magnetic fields.

The activities found in this lesson are crafted with the goal of allowing you to ponder easily and confidently on the concept of electromagnetic waves.

So, explore and have fun in learning!

What I Know

Check your understanding!

TRUE OR FALSE: Write the word **TRUE** if the statement is correct, and **FALSE** if it is not. (3 points each). Write your answer on a separate sheet of paper.

1. Electromagnetic waves transfer energy through a vacuum.
2. A wave is a disturbance that transfers energy.
3. EM waves travel at the speed of $4x10^8$ m/s.
4. Electromagnetic waves are transverse waves consisting of changing electric fields and changing magnetic fields.
5. Most EM waves have the same speed.

What's In

In the previous lesson, you have learned about the interrelationship between electricity and magnetism. You were also able to discover how an electric field could create a magnetic field and vice versa.

As a review, a magnetic field is created around a wire that conducts electric current. A coiled wire, known as a **solenoid**, acts as a magnet when current flows through it. A **solenoid** with a core of iron acts as a strong magnet which is called as **electromagnet**.

Based on what you have learned previously, how can you describe electromagnetism?

Notes to the Teacher

You may instruct the students to write down their answers on their activity notebook.

What's New

This time, you will be introduced to the nature of an electromagnetic (EM) wave. As its name suggests, it is considered to be of both electric and magnetic in nature. In other words, an electromagnetic wave contains an electric field and a magnetic field. These fields are not made up of matter similar to what is in a football field. Instead, electric and magnetic fields are the regions through which the push or pull of charged particles and magnets is exerted. Charged particles and magnets can push or pull certain objects without even touching them.

To understand this idea further, the next activity can help you out. Try making this wave machine to see how all the different kinds of waves move!

Activity 1.1: Building a Wave Machine

Objective:

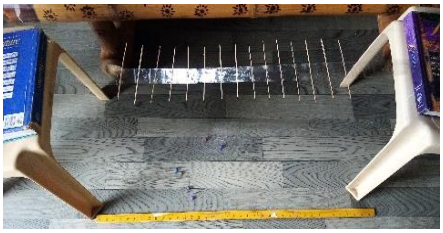
To observe the propagation of a wave.

Materials:

Monobloc Chairs– 2 pcs
Scotch Tape or Masking tape
Sticks (from stickbroom or BBQ sticks) – 15 pcs
Modelling Clay- 30 pcs (alternative NIPS candy or any softy small circle objects with same size and weight that can hold the sticks)
Any books to hold the tape– 2 pcs

Procedure:

1. Gather all materials needed for the activity and then place the two chairs about 1 meter apart from each other.
2. Stretch a piece of scotch tape or masking tape to both sides of the chair and place any books to hold the ends of the tape. Make sure that the sticky part of the tape is facing upward.
3. Leaving about one (1) foot of tape empty on each end, center the sticks from the stickbroom or barbecue sticks along the tape, placing each one 1 ½ inches away from the one.
4. Make a 30 small circles of modelling clay with the same size and weight that can hold the sticks or if you don't have a modelling clay you can use Nips candy or any softy small circle objects with same size and weight that can still hold the sticks. Then, place the circled modeling clay/nips into the ends of the stick by pushing them through the stick.
5. Tap the stick on one end of the tape.
   Do tapping for five times or at your own desires. Observe what happen.



Actual Photos of the Activity
Performed and Captured by: Elmar M. Dongallo

Guide Questions:

1. When you tapped the stick on one end of the tape, did you see a wave that formed and rolled down the line? Write your observations.
2. How is a wave propagated and produced?
3. Remove half of the circled modelling clay/nips from both ends of the line. Now, tap one stick. Does the wave still travel along the line? Write your observations on a separate sheet of paper.

You may check your answers after performing all the activities in this lesson.

What Is It

Nature of Electromagnetic Waves

How are electromagnetic waves produced?

Electromagnetic waves are produced by a charge that changes its direction or speed. Electrons are charged particles that can produce electric and magnetic fields. But in order to create the vibrating electric and magnetic fields that are the characteristics of an electromagnetic wave, electrons must move. A charged particle, such as an electron, moves back and forth, or vibrate. A changing magnetic field produces an electric field and in the same manner, a changing electric field produces a magnetic field.

After knowing about how electromagnetic waves are produced, this time, read on to be informed on how they move into different directions.

An **electromagnetic wave** is made up of an electric field and a magnetic field positioned at right angles to each other and to the direction of motion of the wave (see *Figure 1.1*). Since these fields are located at the right angles to the direction of motion of the wave, electromagnetic waves are considered as transverse waves. This means that both electric and magnetic fields oscillate perpendicular to each other and to the direction of the propagating wave.

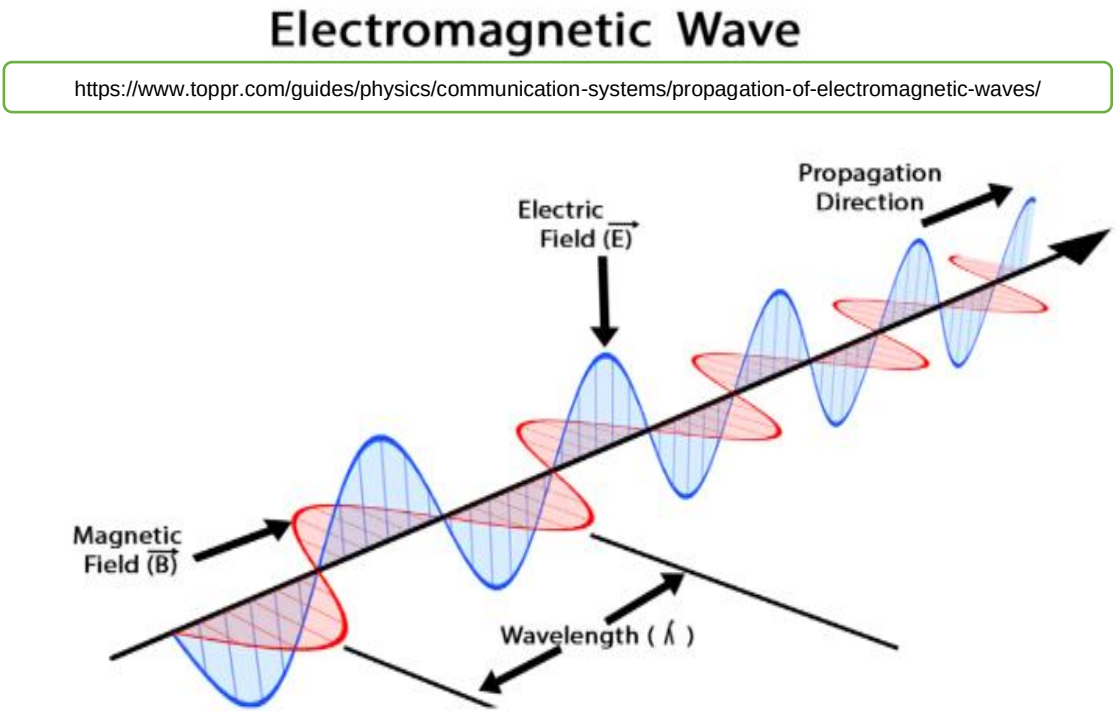


Figure 1.1 In a transverse wave, the direction of the wave energy moves into a right angle to the electric and magnetic fields.

Like other waves, such as water waves and waves on a rope, electromagnetic waves carry energy from one place to another. But unlike other waves, electromagnetic waves do not carry energy by causing matter to vibrate. It is the electric and magnetic fields that vibrate. This explains why electromagnetic waves can travel in a vacuum (where there is no matter). But it does not mean that electromagnetic waves cannot travel through a medium. They certainly can. Light, for example, can be transmitted with a medium - as through the atmosphere - or without a medium - as through space.

Electromagnetic waves travel in a vacuum at a speed of **$3x10^8$ m/s** and denoted as ***c***, the speed of light. The speed is slightly slower in air, glass, and any other material. To appreciate just how great this speed is, consider this: Light from the sun travels 150 million kilometers to Earth in about 8 minutes!

Nothing known in the universe travels faster than the speed of light. Since all EM waves have the same speed which is equal to the speed of light, this means that as the wavelength decreases, the frequency of the wave increases.

Properties of Electromagnetic Waves

Electromagnetic waves are known to possess the following properties:

1. They are produced by accelerated or oscillating charge.
2. They do not require any material or medium for propagation.
3. They travel in free space at the speed of $3x10^8$ m/s.

What's More

Directions: Unscramble the words in Box B and match this words to fill them into the appropriate blanks in Box A to complete the statements below. Write the answer on a separate sheet of paper. (3pts each)

Box A

1. A moving charge creates _____.
2. A changing magnetic field causes a changing _____
3. The successive production of electric and magnetic fields results to the creation of _____ wave.
4. An EM wave propagates _____ from the source.
5. Electromagnetic waves do not need _____ to transfer energy.

Box B
Scrambled Word/s

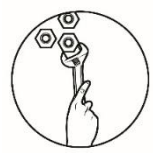
A. ME
B. PEEDS
C. OESTCJB
D. WARDOUT
E. CTNGMAEI LDFIE
F. EEILCTRC IEDFL

What I Have Learned

Check your understanding!

Answer the following questions.

1. What is an electromagnetic field?
2. How is an EM wave produced and propagated?



What I Can Do

Let's apply what you have learned!

Electromagnetic Waves in Your Life

1. How do electromagnetic waves play an important role in your life? Explain your answer. Write your answer on a separate sheet of paper.

Assessment

Check your understanding!

TRUE OR FALSE: Write the word **TRUE** if the statement is correct, and **FALSE** if it is not. (3 points each). Write your answer on a separate sheet of paper.

1. Most EM waves have the same speed.
2. EM waves travel at the speed of $4x10^8$ m/s.
3. Electromagnetic waves are transverse waves consisting of changing electric fields and changing magnetic fields.
4. Electromagnetic waves transfer energy through a vacuum.
5. A wave is a disturbance that transfers energy

Additional Activities

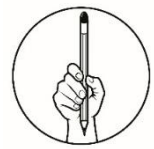
Let’s extend what you have learned!
Directions:

1. Inside your house, look around four devices and appliances that you use everyday.
2. Name four (4) objects that you see which can produce electromagnetic waves.
3. Write the uses/applications of the objects that you have listed.
4. Write your answer on a separate sheet of paper.

Lesson 2 The Proponents of Electromagnetic Wave Theory

What I Need to Know

In this lesson, you will learn how the study of electromagnetic waves came to be. It is here that you will find out who were the proponents on the formulation of the **electromagnetic theory**. Furthermore, this lesson will enable you to gain more information about the scientists who made great contributions to the development of this theory.



What I Know

Check your understanding!

MATCHING TYPE

Directions: Match the scientists given below to their significant contributions. Write the LETTER only of your answer on a separate sheet of paper. (3pts each)

Scientists	Contribution
_____1. André-Marie Ampere	A. Contributed in developing equations that showed the relationship of electricity and magnetism
_____2. Michael Faraday	B. Showed experimental evidence of electromagnetic waves and their link to light
_____3. Heinrich Hertz	C. Demonstrated the magnetic effect based on the direction of a current
_____4. James Clerk Maxwell	D. Formulated the principle behind electromagnetic induction
_____5. Hans Christian Oersted	E. Showed how a current - carrying wire behaves like a magnet

What's In

In the previous lesson, you have learned about the nature of an electromagnetic wave. You were also able to discover how accelerating electrons can produce electromagnetic waves and that these waves are a combination of electric and magnetic fields. In addition, you have also studied that EM waves transfer energy through a vacuum at the speed of **$3x10^8$ m/s** which is the same as the speed of light.

From what you have learned, what again is an electromagnetic wave?

Notes to the Teacher

You may instruct the students to write down their answers on their activity notebook.

What's New

The history of **Electromagnetic Wave Theory** begins with ancient measures to understand atmospheric electricity, in particular, lightning. People then had little understanding of electricity and were unable to explain the phenomena. Scientific understanding about the nature of electricity grew throughout the eighteenth and nineteenth centuries through the work of researchers.

During the19th century, it had become clear that electricity and magnetism were related, and their theories were unified: Whenever charges are in motion, electric current results, and magnetism is due to electric current. The source for electric field is electric charge, whereas that for magnetic field is the electric current (charges in motion).

Through the years, the advancement on the knowledge regarding electromagnetic waves led us to a modern technological world.

The next activity will help you find out the distinguished scientists who made great contributions in the development of the Electromagnetic Wave Theory.

Activity 2.1: Electromagnetic Wave Theory Comic Strip

Directions: Read the comic strip below and answer the questions that follow on a separate sheet of paper.

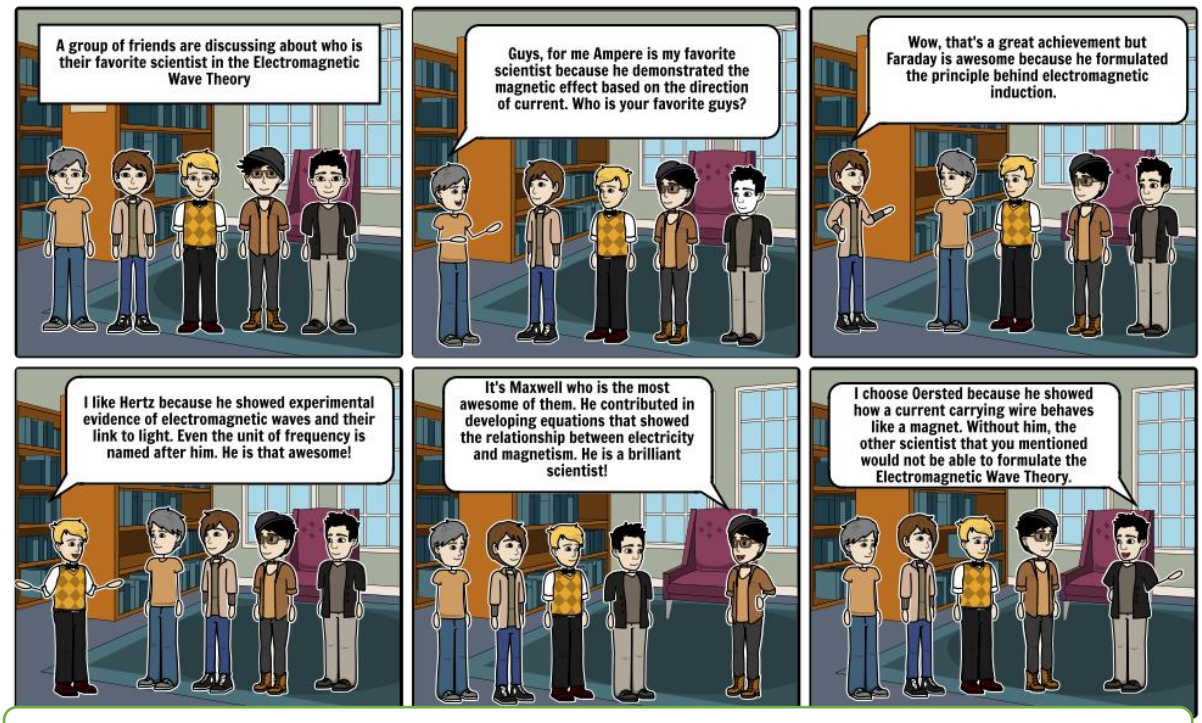


Figure 2.1 EM wave theory comic strip
Source: https://www.storyboardthat.com/storyboards/ahmad33294/electromagnetic-wave-theory-comic-strip

Guide Questions:

1. What is the contribution of Ampere in the Electromagnetic Wave Theory?
2. If you were one of the group of friends talking in this comic strip, who do you think would be your favorite scientist? Why?

What Is It

ELECTROMAGNETIC WAVE THEORY

When you studied wave motion, you have known that a disturbance produces waves that can be transmitted through a medium. In the same way, **electromagnetic waves** are also produced by a disturbance caused by a vibrating charge. When the charge is moved, the electric field around it is changed.

Recall **Oersted's** discovery which states that "A changing electric field produces a magnetic field". A changing magnetic field is therefore produced around the vibrating charge. In turn, this changing magnetic field produces an electric field.

Do you remember **Faraday's Law**? The cycle goes on. The changing magnetic and electric fields are perpendicular to each other and to their direction of propagation. Therefore, they are seen as transverse waves.

About 150 years ago, **James Clerk Maxwell** theorized that this mutual generation and propagation of electric field and magnetic field can be conceived as a form of moving energy carried by what he called as electromagnetic wave. So, if this is just like any wave, does it mean that it travels through a medium? No. Electromagnetic wave traverses empty space! However, Maxwell did not believe that electromagnetic wave propagates in space under any condition. He supposed that it must move at a certain speed. He calculated the speed of the wave based on Faraday's theoretical assumptions and experiments and concluded that the speed is **3.0×10^8 m/s** and denoted as ***c*** – the same as the speed of light! He therefore proposed that light is a form of electromagnetic wave. Unfortunately, at that time, no experiment was done to verify his accounts. But after Faraday's death, **Heinrich Hertz** designed an experimental set-up that enabled him to generate and detect electromagnetic waves.

Proponents on the Formulation of EM Wave Theory

The following prominent scientists each made a significant contribution in resolving how electromagnetic waves behave.

James Clerk Maxwell (1876), an English scientist who developed a scientific theory to better explain electromagnetic waves. When Maxwell used this field theory to assume that light was an electromagnetic wave, and then correctly deduced the finite velocity of light, it was a powerful logical argument for the existence of the electromagnetic force field.

He noticed that electrical fields and magnetic fields can couple together to form electromagnetic waves. Maxwell discovered that a changing magnetic field will induce a changing electric field and vice versa.

Heinrich Hertz, a German physicist who applied Maxwell's theories to the production and reception of radio waves. The unit of frequency of a radio wave - one cycle per second - is named the hertz, in honor of Heinrich Hertz. He proved the existence of radio waves in the late 1880s. He used two rods that served as a receiver and a spark gap as the receiving antennae. Where the waves were picked up, a corresponding spark would jump. Hertz showed in his experiments that these signals possessed all of the properties of electromagnetic waves.

Michael Faraday (1791-1867) is probably best known for his discovery of electromagnetic induction. His contributions to electrical engineering and electrochemistry or due to the fact that he was responsible for introducing the concept of field in physics to describe electromagnetic interaction are enough for him to be highly recognized. But perhaps, it is not so well known that he had also made fundamental contributions to the **electromagnetic theory of light**.

André-Marie Ampère made the revolutionary discovery that a wire carrying electric current can attract or repel another wire next to it that's also carrying electric current. The attraction is magnetic, but no magnets are necessary for the effect to be seen. He went on to formulate Ampere's Law of Electromagnetism and produced the best definition of electric current during his time.

Hans Christian Oersted, a Danish physicist and chemist who discovered that the electric current in a wire can deflect a magnetized compass needle, a phenomenon the importance of which was rapidly recognized and which inspired the development of electromagnetic theory.

The Basic Principles of EM Wave Theory

After years of rigorous studies and experiments, the following principles came about to explain the Electromagnetic Wave Theory.

1. Many natural phenomena exhibit wave-like behaviors. All of them – water waves, earthquake waves, and sound waves require a medium to propagate. These are examples of mechanical waves.
2. Light can also be described as a wave – a wave of changing electric and magnetic fields that propagate outward from their sources. These waves, however, do not require a medium to propagate.
3. They propagate at 300,000,000 meters per second through a vacuum.

4. Electromagnetic waves are transverse waves. In simpler terms, the changing electric and magnetic fields oscillate perpendicular to each other and to the direction of the propagating waves.

   These changing electric and magnetic fields generate each other through Faraday's Law of Induction and Ampere's Law of Electromagnetism. These changing fields dissociate from the oscillating charge and propagate out into space at the speed of light.

5. When the oscillating charge accelerates, the moving charge's electric fields change, too.

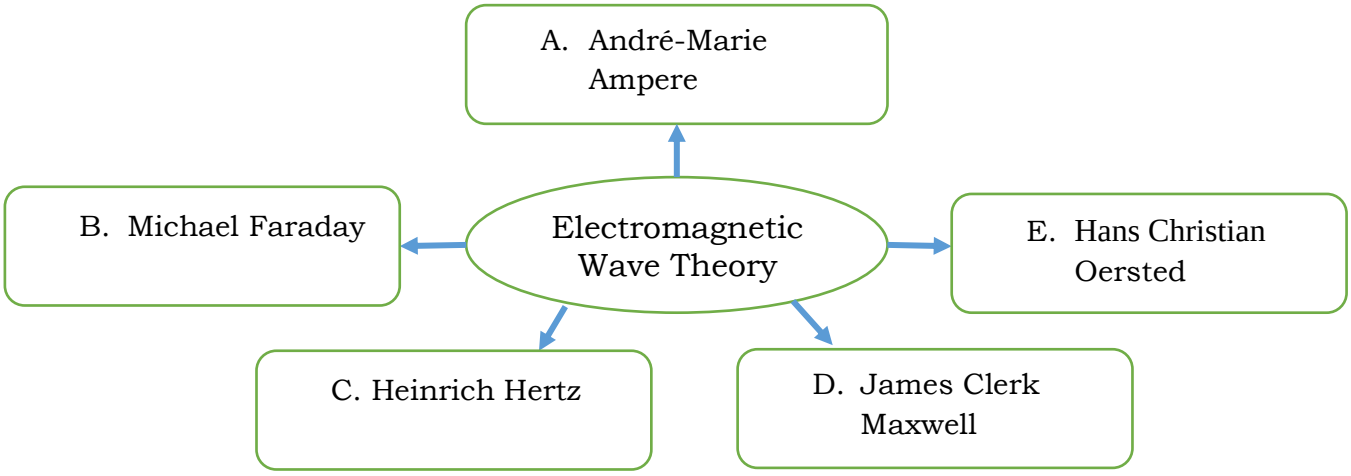
What's More

Activity 2.2: CONCEPT WEB

Directions: Using the information you have gathered previously, make a concept web showing the contributions of the scientists listed below. Write your answers on a separate sheet of paper.

A. André-Marie Ampere
B. Michael Faraday
C. Heindrich Hertz
D. James Clerk Maxwell
E. Hans Christian Oersted

Concept Web

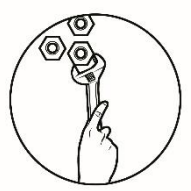


What I Have Learned

Let's check your understanding!

Answer this question.

1. How did the Electromagnetic Wave Theory result to the advancement of a modern technological world? Explain your answer and write it on a separate sheet of paper.



What I Can Do

Answer the question below.

If you are one of the scientists mentioned in this lesson, how can you prove to other people that your theory should become a law? Write your opinion on a separate sheet of paper.

_____
_____
_____
_____
_____
_____
_____
_____
_____
_____
_____.

Assessment

MATCHING TYPE

Directions: Match the scientists listed below to their corresponding contributions. Write the LETTER only of your answer on a separate sheet of paper. 3pts each

Scientists	Contribution
_____1. André-Marie Ampere	A. Contributed in developing equations that showed the relationship of electricity and magnetism
_____2. Michael Faraday	B. Showed experimental evidence of electromagnetic waves and their link to light
_____3. Heinrich Hertz	C. Demonstrated the magnetic effect based on the direction of a current
_____4. James Clerk Maxwell	D. Formulated the principle behind electromagnetic induction
_____5. Hans Christian Oersted	E. Showed how a current-carrying wire behaves like a magnet

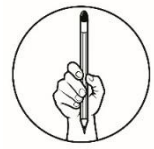
Additional Activities

Create your own comic strips citing the scientists' contribution to the development of the Electromagnetic Wave Theory.

Lesson 3 EM Waves: Frequencies and Wavelengths

What I Need to Know

In this lesson, you will learn about the characteristics of EM waves. You will also find here their physical wave features: **frequency** and **wavelength**. Moreover, this lesson enables you to gain more information on how the different types of EM waves are arranged according to its wavelength and frequency.



What I Know

Check your understanding!

MULTIPLE CHOICE

Direction: Choose the letter of the best answer. Write the CAPITAL LETTER only of your answer on a separate sheet of paper. 3pts each.

1. Which EM wave has the highest frequency than others?
   A. Microwaves C. UV radiation
   B. Radio waves D. Visible light

2. What is the frequency range of UV radiation?
   A. $3.5 \times 10^{9} - 3 \times 10^{11}$ Hz C. $7.5 \times 10^{14} - 3 \times 10^{16}$ Hz
   B. $3.5 \times 10^{11} - 4 \times 10^{14}$ Hz D. $7.5 \times 10^{16} - 3 \times 10^{19}$ Hz

3. What is the wavelength of a wave with a frequency of $3x10^9$ Hz?
   A. $1.0x10^{-1}$ m
   B. $1.0x10^{-2}$ m
   C. $1.0x10^{2}$ m
   D. $3.5x10^{1}$ m

4. Radio wave is _____ in wavelength than the gamma ray.
   A. Higher
   B. Longer
   C. Lower
   D. Smaller

5. What happens to the frequency of the electromagnetic wave if its wavelength increases?
   A. It decreases.
   B. It increases as well.
   C. It remains the same.
   D. None of the above.

What's In

In the previous lesson, you have learned about the Electromagnetic Wave Theory and its significant proponents who made its development possible.

Before we will proceed to the next lesson, jot down your new insights or learning about the Electromagnetic Wave Theory. Write your answer on a separate sheet of paper.

Notes to the Teacher

You may instruct the students to write down their answers on their activity notebook.

What's New

Now that you have acquired a deeper understanding on what electromagnetic waves are, you might be wondering how sunlight is different from X-rays if both are electromagnetic waves that travel at the same speed. Electromagnetic waves, like all types of waves, are described by their physical wave features: amplitude, wavelength, and frequency. These are the characteristics that can vary and thereby produce many different kinds of electromagnetic waves.

An electromagnetic wave is arranged according to its wavelength and frequency. The term **frequency** describes how many waves per second a wavelength produces. On the other hand, the **wavelength** measures the length of an individual wave in meters.

The next activity will enable you to explore the different types of EM waves based on their wavelengths and frequencies.

Activity 3.1: When Frequency and Wavelength Matters!

Objective:

- Determine the frequency and wavelength ranges of the different types of electromagnetic waves

Material:

- EM wave images, activity notebook, pen

Procedure:

1. Study the image of the electromagnetic spectrum very closely.
2. Determine the frequency and wavelength ranges of the different types of electromagnetic waves.

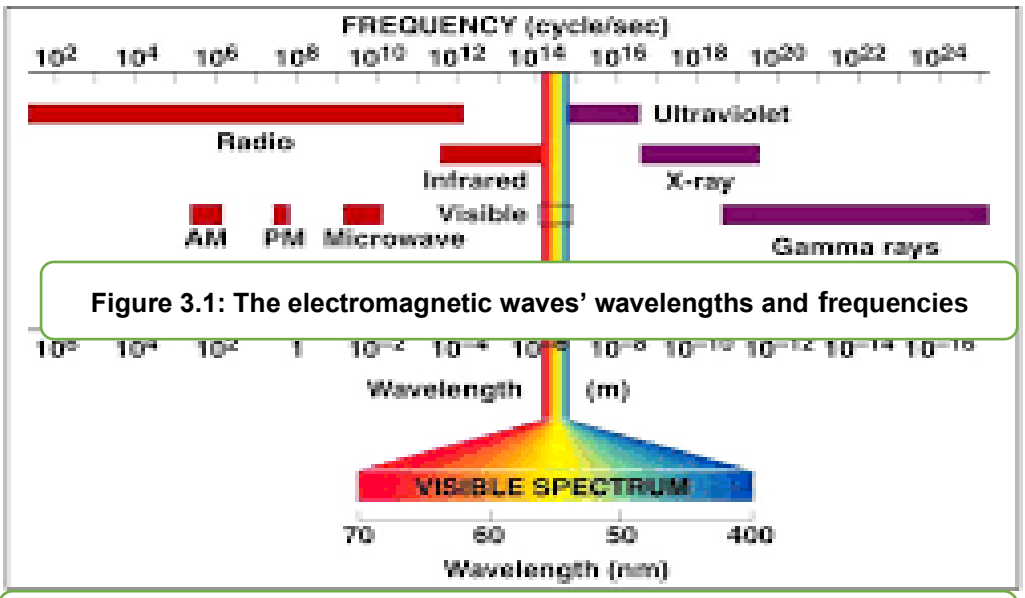


Figure 3.1: The electromagnetic waves' wavelengths and frequencies

Figure 3.1 The EM Waves' wavelength and frequency
Source: https://www.slideshare.net/dionesioable/module-17-wireless-communication

Copy the table and enter your data on a separate sheet of paper.

Table 3.1 Electromagnetic Waves' Wavelength and Frequency

EM Wave	Frequency Range (hertz)	Wavelength Range (meters)
Radio Waves		
Microwaves		
Infrared		
Visible Light		
Ultraviolet		
X-rays		
Gamma rays		

What is It

EM Waves: Frequencies and Wavelengths

The **electromagnetic waves (EM)** are often arranged in the order of wavelength and frequency in what is known as the **electromagnetic spectrum**. Because all EM waves travel at the same speed, if the frequency of a wave changes, then the wavelength must change as well. Waves with the longest wavelengths have the lowest frequencies while the waves with the shortest wavelengths have the highest frequencies. The amount of energy carried by an electromagnetic wave increases with its frequency.

Arranged according to increasing frequency, the EM spectrum displays the following waves: **radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays** at the high-frequency (short wavelength) end. It is important to note that these waves do not have an exact dividing region.

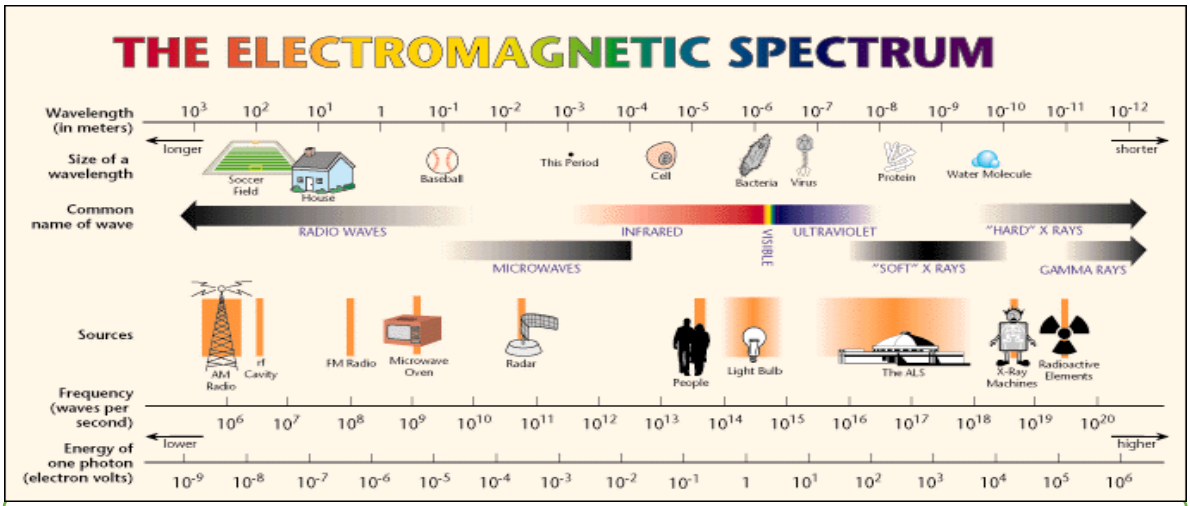


Figure 3.2: The EM spectrum (Source: https://www2.lbl.gov/MicroWorlds/ALSTool/EMSpec/EMSpec2.html)

Since **all EM waves** travel at the speed of **light**, then the spectrum of wavelengths is exactly opposite to the spectrum of frequencies. In other words, wavelength and frequency are inversely proportional to each other. As frequencies increase on the EM spectrum, wavelengths decrease. So, that means radio waves have the longest wavelengths and gamma rays have the shortest.

The different types of electromagnetic waves are defined by the amount of energy carried by their photons. **Photons** are bundles of wave energy. From among the EM waves, gamma rays carry photons of high energies while radio waves own photons with the lowest energies. With regard to the wavelength properties, radio waves can be likened to the size of a football field while gamma rays are as small as the **nuclei** of an atom. Gamma rays, X-rays, and high ultraviolet are classified as ***ionizing radiation*** as their photons have enough energy to ionize atoms, causing chemical reactions.

All electromagnetic waves can travel through a medium but unlike other types of waves, they can also travel in a vacuum or empty space. They travel in a vacuum at the speed of **$3x10^8$ m/s** and denoted as **c**, the speed of light. The wave speed, frequency and wavelength are related as shown in the following equation:

$$\mathbf{v = \lambda f}$$

where **v** is the wave speed, expressed in meters per second, the frequency **f** is expressed in Hertz and the wavelength **λ** is expressed in meters.

Sample Problems:

(Assume that the waves propagate in a vacuum.)

1. What is the frequency of radio waves with the wavelength of 20 m?

   Given: $v = c = 3x10^8$ m/s (constant)

   $\lambda = 20$ m ($2.0x10^1$ m)

   f =?

   Solution:

   Formula: $v = c = f$

   Derived: $f = \frac{c}{\lambda}$

   $= \frac{3x10^8 m/s}{2.0x10^1 m}$

   $= 1.5x10^{(8-1)}$ Hz

   (Answer) $f = 1.5x10^7$Hz

2. What is the frequency of light waves with the wavelength of $5x10^{-7}$ m?
   Given: v = c = $3x10^8$ m/s (constant)
   λ = $5x10^{-7}$ m
   f =?

Solution:

Formula: v = c = f

Derived: $f = \frac{c}{\lambda}$

$= \frac{3x10^8 m/s}{5x10^{-7} m}$

$= 0.6x10^{(8-(-7)} Hz$

$= 6x10^{(15-1)} Hz$

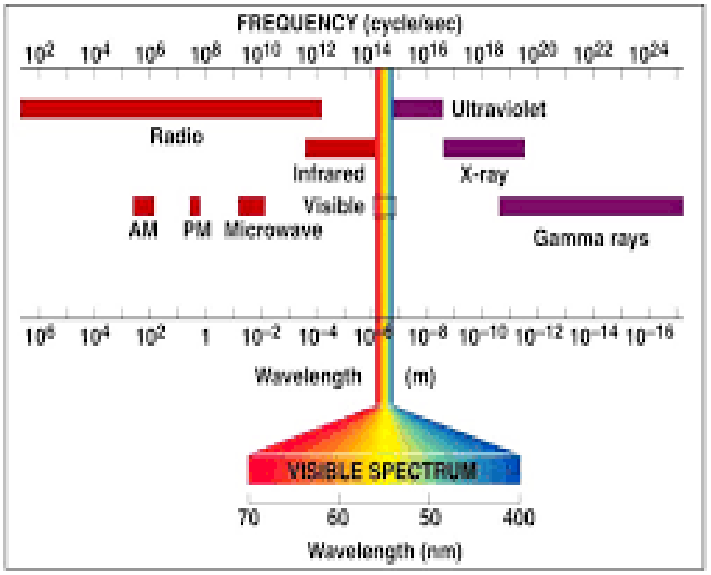
(Answer) $f = 6x10^{14}$Hz

What's More

Direction: Compare the following EM waves and fill in the missing word to complete the statement. Use the descriptions such as lower, higher, shorter and longer. Write your answer on a separate sheet of paper.

1. Radio wave is _____ in wavelength than the gamma ray.
2. Microwave is _____ in frequency than infrared.
3. Infrared is _____ in wavelength than visible light.
4. X-ray is _____ in wavelength than gamma ray.
5. Gamma ray is _____ in frequency than microwave.

Fig.3.3. The EM waves wavelengths and frequencies

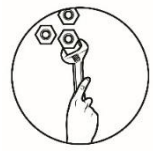


Source: https://www.slideshare.net/dionesioable/module- 17-wireless-communication

What I Have Learned

Say something on this!
Write your answer on a separate sheet of paper.

1. How is an electromagnetic spectrum organized in terms of its frequency and wavelength?
2. What happens to the wavelength of an electromagnetic wave if its frequency increases?



What I Can Do

Try to solve this problem!
Show your solutions on a separate sheet of paper.
(Assume that the waves propagate in a vacuum.)

1. What is the frequency of a micro wave that has a wavelength of $1.5x10^2$ m?
   Given: v = c = $3x10^8$ m/s (constant)
   λ = $1.5x10^2$ m
   f =?

Assessment

MULTIPLE CHOICE

Direction: Choose the letter of the best answer. Write the CAPITAL LETTER only on a separate sheet of paper. 3pts each

1. What happens to the frequency of the electromagnetic wave if its wavelength increases?
   A. It decreases.
   B. It increases as well.
   C. It remains the same.
   D. None of the above.

2. What is the wavelength of the wave with a frequency of $3x10^9$ Hz?
   A. $1.0x10^{-1}$ m
   B. $1.0x10^{-2}$ m
   C. $1.0x10^2$ m
   D. $3.5x10^1$ m

3. Which EM wave has the highest frequency among the others?
   A. Microwaves
   B. Radio waves
   C. UV radiation
   D. Visible light

4. Radio wave is _____ in wavelength than the gamma ray.
   A. Higher
   B. Longer
   C. Lower
   D. Smaller

5. What is the frequency range of UV radiation?
   A. $3.5x10^{9} – 3x10^{11}$ Hz
   B. $3.5x10^{11} – 4x10^{14}$ Hz
   C. $7.5x10^{14} – 3x10^{16}$ Hz
   D. $7.5x10^{16} – 3x10^{19}$ Hz

Additional Activities

The EM spectrum is the ENTIRE range of EM waves in the order of increasing frequency and decreasing wavelength.

As you go from **left → right**, the wavelength gets smaller and the frequencies get higher. This is an inverse relationship between wave size and frequency. (As one goes up, the other goes down.) This is because the speed of ALL EM waves is the speed of light ($3x10^{8}$m/s).

For this activity, arrange the EM spectrum in the order from the longest wavelength to the shortest wavelength. Write down the answer on your activity notebook.

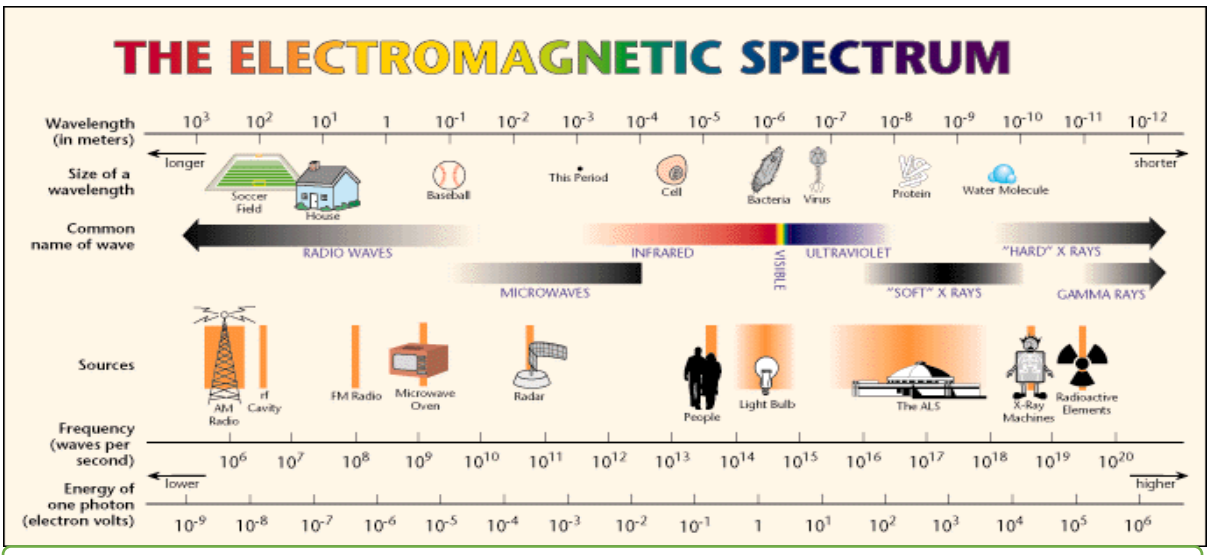


Figure 3.4: The EM spectrum (Source: https://www2.lbl.gov/MicroWorlds/ALSTool/EMSpec/EMSpec2.html)

Summary

- *A wave is a disturbance that transfers energy.*
- *James Clerk Maxwell formulated the Electromagnetic Wave Theory which says that an oscillating electric current should be capable of radiating energy in the form of electromagnetic waves.*
- *Heinrich Hertz discovered the Hertzian which is now known as radio waves. Hertz is the unit used to measure the frequency of waves.*
- *An electromagnetic wave comprises of an electric field and a magnetic field at right angles to each other and to the direction of motion of the wave.*
- *Electromagnetic waves can travel through a vacuum because they do not require matter to exist.*
- *Electromagnetic waves are produced by a charge that is changing direction or speed.*
- *All electromagnetic waves travel at the same speed in a vacuum - $3x10^8$ m/s.*
- *The EM waves are often arranged in the order of wavelength and frequency in what is known as the electromagnetic spectrum.*
- *Frequency describes how many waves per second a wavelength produces.*
- *Wavelength measures the length of individual wave in meters.*
- *Waves with longest wavelengths have the lowest frequencies.*
- *Waves with the shortest wavelengths have the highest frequencies.*

Post Test

MULTIPLE CHOICE

Direction: Choose the letter of the best answer. Write the CAPITAL LETTER only on a separate sheet of paper.

1. What is the speed of the electromagnetic wave in a vacuum?
   A. Zero
   B. Always the same as the speed of light
   C. Changing depending on the value of its wavelength
   D. None of the above

2. How are electromagnetic waves produced?
   A. Any disturbance
   B. Currents
   C. Vibrating charge
   D. Voltage source

3. What happens to the frequency of the electromagnetic wave if its wavelength increases?
   A. It decreases.
   B. It increases as well.
   C. It remains the same.
   D. None of the above.

4. In the electromagnetic wave, what is the direction of the propagation of the wave?
   A. Always to the right
   B. Cannot be determined
   C. Parallel to electric and magnetic field directions
   D. Perpendicular to the electric and magnetic field directions

5. Which of the following forms of electromagnetic waves has the widest frequency range?
   A. X-ray
   B. Microwave
   C. Ultraviolet
   D. Radio waves

6. Who contributed in developing equations that showed the relationship of electricity and magnetism?
   A. André-Marie Ampere
   B. Heinrich Hertz
   C. James Clerk Maxwell
   D. Michael Faraday

7. Who showed experimental evidence of electromagnetic waves and their link to light?
   A. André-Marie Ampere
   B. Heinrich Hertz
   C. James Clerk Maxwell
   D. Michael Faraday

8. Which type of wave has the shortest wavelength?

A. Gamma ray
B. Microwave
C. Ultraviolet
D. X-ray

9. What is the other term for electromagnetic waves?

A. Electric waves
B. Longitudinal waves
C. Mechanical waves
D. Transverse waves

10. Which of the following correctly lists electromagnetic waves in the order from the longest to the shortest wavelength?

A. Gamma rays, ultraviolet, infrared, microwaves
B. Microwaves, ultraviolet, visible light, gamma rays
C. Radio waves, infrared, gamma rays, ultraviolet
D. Radio waves, infrared, visible light, X-rays

11. How is the wavelength of infrared differs from the wavelength of ultraviolet waves?

A. Longer
B. Shorter
C. The same
D. None of the above

12. All EM waves have the same speed.

A. True B. False

13. What is the main difference between a radio wave and a light wave?

A. Speed
B. Wavelength
C. Both A and B
D. None of the above

14. Which of the following is NOT an electromagnetic wave?

A. Infrared
B. Light
C. Sound
D. Radio

15. What is the frequency range of UV radiation?

A. $3.5 \times 10^{9} – 3 \times 10^{11}$ Hz
B. $3.5 \times 10^{11} – 4 \times 10^{14}$ Hz
C. $7.5 \times 10^{14} – 3 \times 10^{16}$ Hz
D. $7.5 \times 10^{16} – 3 \times 10^{19}$ Hz

Answer Keys

What I Know (Pre-test)

1. A
2. D
3. D
4. A
5. B
6. C
7. B
8. A
9. D
10. A
11. D
12. A
13. B
14. C
15. C

Lesson 1

What I Know

1. True
2. True
3. False
4. True
5. False

What's In

Answers may vary

What's More

1. Magnetic field
2. Electric Field
3. EM
4. Outward
5. Objects

What I Have Learned

Answers may vary

What I Can Do

Answers may Vary

Assessment

1. False
2. False
3. True
4. True
5. True

Lesson 2

What I Know

1. C
2. D
3. B
4. A
5. E

What's In

Answers may vary

What's More

Answers may vary

What I Have Learned

Answers may vary

What I Can Do

Answers may Vary

Assessment

1. E
2. D
3. B
4. A
5. C

Lesson 3

What I Know

1. C
2. C
3. A
4. B
5. A

What's In

Answers may vary

What's More

1. Longer
2. Lower
3. Longer
4. Longer
5. higher

What I Have Learned

Answers may vary

What I Can Do

Answer: $2x10^6$ Hz

Assessment

1. A
2. A
3. C
4. B
5. C

Post Test

1. B
2. C
3. A
4. D
5. A
6. C
7. B
8. A
9. D
10. D
11. A
12. A
13. B
14. C
15. C

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