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Department of Education
National Capital Region
SCHOOLS DIVISION OFFICE
MARIKINA CITY

Science

Quarter 2 – Module 1

Properties of Electromagnetic Waves

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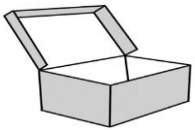


What I Need to Know

The purpose of this module is to help you demonstrate an understanding of the different regions and properties of the electromagnetic spectrum.

After going through this module, **you are expected to compare the relative wavelengths of different forms of electromagnetic waves**. **S10FE-IIa-b-47**

Specifically, you are expected to:

- compare the relative wavelengths, frequencies, and energies of the different regions of electromagnetic waves, and;
- solve problems involving wavelength, frequency, and energy of an electromagnetic wave.

What I Know

Read and understand each item carefully and encircle the letter of the correct answer.

1. Which electromagnetic wave has the highest energy?
   A. Radio wave
   B. Ultraviolet wave
   C. Visible light
   D. Gamma rays

2. How does an increase in frequency affect electromagnetic waves?
   A. Energy carried by the wave increases.
   B. Wavelength decreases.
   C. both A and B
   D. neither A nor B

3. What happens to the frequency and wavelength if the energy of the wave decreases?
   A. wavelength increases, frequency increases
   B. wavelength increases, frequency decreases
   C. wavelength decreases, frequency decreases
   D. wavelength decreases, frequency increases

4. Which electromagnetic wave has the longest wavelength?
   A. radio wave
   B. microwave
   C. gamma ray
   D. X – ray

5. What color in the visible spectrum carries the highest energy?
   A. red B. blue C. violet D. orange

6. Which shows the correct arrangement of the types of electromagnetic waves in increasing frequency?
   A. X-ray waves, gamma ray waves, infrared waves, radio waves
   B. Radio waves, infrared waves, microwaves, visible light waves
   C. Ultraviolet waves, infrared waves, visible light waves, gamma ray waves
   D. Microwaves waves, infrared waves, visible light waves, ultraviolet waves

7. Radio waves, X-ray waves, and microwaves are detected to be travelling in a vacuum. If the waves have a wavelength of 2×10^{3} m, 2×10^{-9} m, 2×10^{-1} m respectively, which of the three travels the fastest?
   A. X-ray waves
   B. microwaves
   C. radio waves
   D. They all travel at the same speed.

8. An FM radio station broadcasts at 90.5 MHz (9.05×10^{7} Hz). The radio wave travels at the speed of light, what is its wavelength?
   A. 0.04 m C. 2.72×10^{16} m
   B. 3.31 m D. 2.72×10^{10} m

For numbers 9 – 10, refer to the situation below.
A gamma ray with a frequency of 6.2×10^{19}Hz is fired on an unknown object in space. The value of Planck's constant is 6.626×10^{-34} Js.

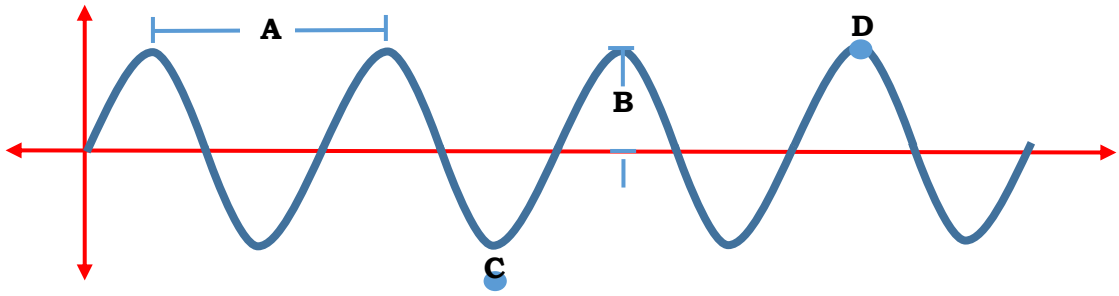
9. What is the wavelength of the wave?
   A. 0.05 m C. 4.8×10^{-12} m
   B. 0.15 m D. 4.8×10^{12} m

10. How much energy does the wave carry?
   A. 4.11×10^{-14} J C. 4.11×10^{14} J
   B. 4.11×10^{-14} J·s D. 4.11×10^{14} J·s

Lesson Properties of Electromagnetic Waves

What's In

As discussed in your Grade 7 Physics, there are different parts and properties of a transverse wave. Answer the guide question on a separate sheet of paper using the diagram below.



Guide Question:

Which letter represents the:

1. wavelength _____
2. trough _____
3. amplitude _____
4. crest _____

What's New

Activity 1: The Electromagnetic Spectrum

Objectives:

1. Discuss the different properties of EM waves.
2. Compare the relative wavelength and frequency of the types of EM waves.

Procedure:

1. Examine Figure A.
2. Study the wavelength and frequency that corresponds to the type of EM wave.

3. Answer the questions on a separate sheet of paper.

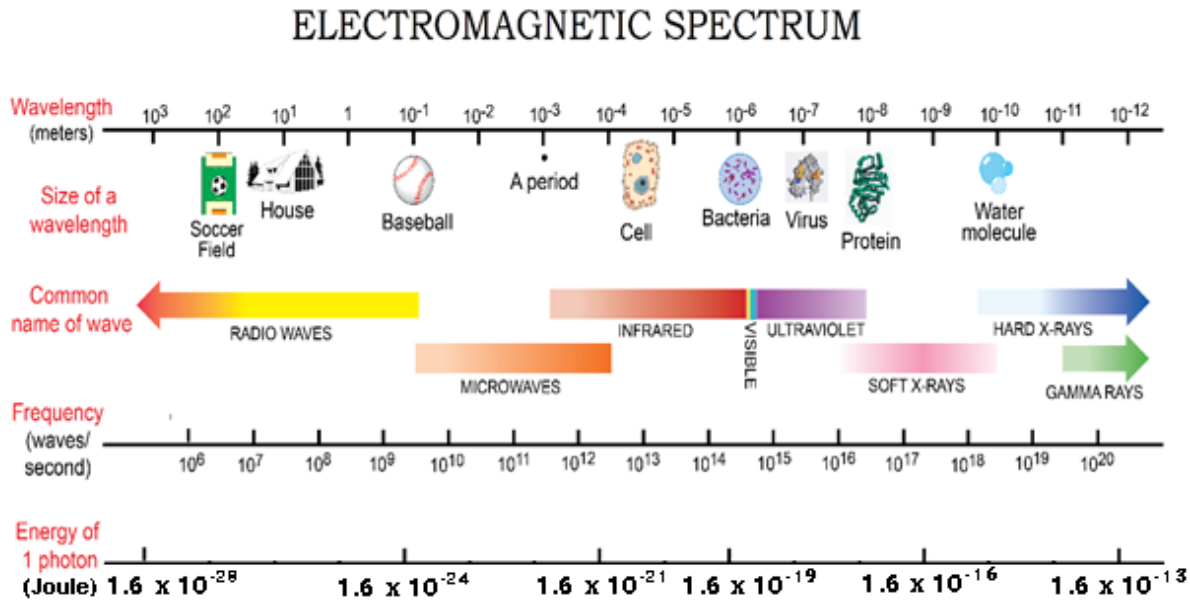


Figure A.

Guide Questions:

1. Are the divisions of the electromagnetic spectrum distinct? Explain your answer.

2. What properties of EM waves enabled scientists to come up with the divisions in the electromagnetic spectrum?

3. If you will arrange the types of EM waves based on their wavelength, which has the longest wavelength? the shortest wavelength?

4. Which among the types of EM waves has the highest frequency? the lowest frequency?

5. Which among the types of EM waves has the highest energy? the lowest energy?

6. What relationship exists between wavelength and frequency? between frequency and energy? between wavelength and energy?

Activity 2: Calculating Wavelength, Frequency, and Energy of EM Waves

Objective:

Solve problems involving the wavelength, frequency, and energy of an EM wave.

Procedure:

1. Keep in mind that the speed of all types of electromagnetic waves is ***c***, which is equal to 3.0 x 10^8 m/s.
2. To solve for the frequency, use the formula:
$$f = \frac{c}{\lambda}$$
3. To solve for the wavelength, use the formula:
$$\lambda = \frac{c}{f}$$
4. To solve for the energy, use the formula:
$$E = hf \text{ or } E = h\frac{c}{\lambda}$$
where *h* is the Planck's constant which is equal to 6.626 × 10^{-34} J•s.
5. Use **GUFSA** (given, unknown, formula, substitution, answer) pattern.
6. Take note that the unit of the wavelength should be in meters (m) and the frequency is in (cycle/s or Hz). The unit of energy (E) is Joule (J).
7. The first problem is already solved for you. Use it as your guide in answering the remaining problems. Write your answers on a separate sheet of paper.

Guide Questions:

1. A radio wave is travelling in space and has a wavelength of 2.0 x 10^3 m. (A) What is the frequency of the wave? (B) How much energy does it carry?

Given:
λ = 2.0 x 10^3 m
c = 3.0 x 10^8 m/s

Unknown
f = ___ Hz
E = ___ J

Formula:
$$f = \frac{c}{\lambda}$$
$$E = h\frac{c}{\lambda}$$

(A) Substitution:
$$f = \frac{3.0 \times 10^8 \frac{m}{s}}{2.0 \times 10^3 \cancel{m}}$$

Answer:
f = 150,000 Hz or 1.5 x 10^5 Hz

(B) Substitution:
$$E = 6.626 \times 10^{-34} \text{ J} \cdot \cancel{s}\left(\frac{3.0 \times 10^8 \frac{\cancel{m}}{\cancel{s}}}{2.0 \times 10^3 \cancel{m}}\right)$$

Answer:
E = 9.9 x 10^{-29} J

2. Miss A is listening to the news on the radio broadcasting at 780kHz (780,000 Hz). What is the wavelength of the radio wave?

3. How much energy is in an ultraviolet light if it has a frequency of 3.6×10^{16} Hz? What is its wavelength?

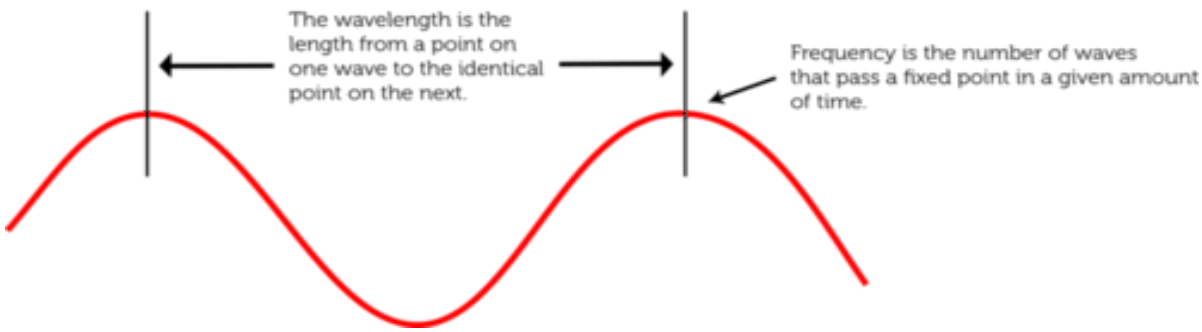
What Is It

Speed, Wavelength, Frequency, and Energy of Electromagnetic Waves

The electromagnetic spectrum is an arrangement of the different types of electromagnetic waves according to its wavelength and frequency. According to decreasing wavelength, the arrangement of the electromagnetic waves is radio wave, microwave, infrared, visible light, ultraviolet, X-ray, and gamma ray. These waves do not have an exact division in the electromagnetic spectrum. Therefore, *the electromagnetic spectrum has no distinct divisions.*

All electromagnetic waves travel at the same speed through empty space or vacuum. The speed of all electromagnetic waves is about 300,000,000 meters per second (3.0×10^8 m/s) – this is called the **speed of light**.

Even though all the types of electromagnetic waves move at the same speed across space, these waves all differ in wavelength, frequency, and energy they carry.



The **wavelength** of an electromagnetic wave is the distance between two successive crests or troughs or the distance between two corresponding points of adjacent waves. The **frequency** describes the number of waves that pass a fixed point in a given value of time. The energy carried by an electromagnetic wave depends on its frequency. You can calculate the wavelength and frequency of an electromagnetic wave using the following formula:

$$f = \frac{c}{\lambda};\ \lambda = \frac{c}{f}$$

where:

- c is the speed of light (300,000,000 m/s)
- f is the frequency in the unit of cycle per second or Hertz (name after Heinrich Hertz), and;
- λ (pronounced as ***lambda***) is the wavelength of the wave in meters (SI unit).

Each property of electromagnetic waves is related to one another. For instance, a radio wave has the longest wavelength, but it has the lowest frequency and the lowest energy. Gamma ray, on the other hand, has the shortest wavelength but it has the highest frequency and the highest energy. In the activity, you have discovered the relationship of these properties.

The wavelength of any electromagnetic wave is inversely proportional to the frequency and energy it carries. Meaning, the longer the wavelength, the lower the frequency and the energy and vice versa.

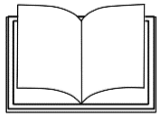
The different types of electromagnetic waves can also be compared by the energy carried by the photon. The energy is given by the equation:

$$E = hf$$

where

- h is Planck's Constant which is equal to 6.626×10^{-34} J•s, and;
- f is the frequency of the EM wave

Among the types of electromagnetic waves, gamma rays have the highest frequency; therefore, it also has the highest energy. Radio waves have the lowest energy.



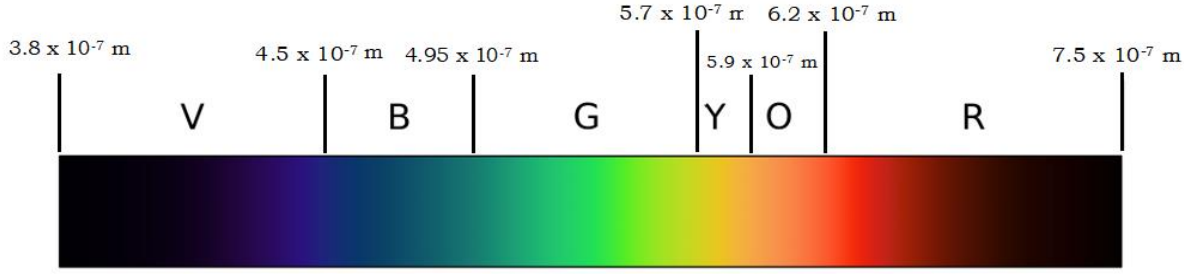
What's More

Visible light, a form of electromagnetic wave, has its color spectrum. The spectrum is divided into different colors as shown in the figure below. Complete the

table by calculating the frequency and energy ranges of each color. The wavelength range of each color of the visible light is already given. You may use the following sets of equations in completing the table. Note that the average values for frequency, energy, and wavelength can be calculated by adding the minimum and maximum values and divide it by two.

$$f = \frac{c}{\lambda};\ \lambda = \frac{c}{f};\ E = h\frac{c}{\lambda};\ E = hf$$

The Color Spectrum of the Visible Light



Color Spectrum	Wavelength Range (m)	Frequency Range (Hz)	Energy Range (J)
Violet	$3.8 \times 10^{-7} - 4.5 \times 10^{-7}$	*6.67×10^{14} - 7.89×10^{14}*	*4.42×10^{-19} - 5.23×10^{19}*
Blue	$4.5 \times 10^{-7} - 4.95 \times 10^{-7}$		
Green	4.95×10^{-7} - 5.7×10^{-7}		
Yellow	5.7×10^{-7} - 5.9×10^{-7}		
Orange	5.9×10^{-7} - 6.2×10^{-7}		
Red	$6.2 \times 10^{-7} - 7.5 \times 10^{-7}$		

Guide Questions:

1. Which color has the highest average energy? the lowest average energy?

2. Which color has the longest average wavelength? the shortest average wavelength?

3. Which color has the highest average frequency? the lowest average frequency?

4. How would you compare the wavelength of the colors of the visible spectrum to its frequency? to its energy?

What I Have Learned

Fill in the blanks with the appropriate word/s to complete the paragraph below. Write your answers on a separate sheet of paper.

Electromagnetic waves are characterized by wavelength, frequency, and energy. The 1) _____ is the distance between corresponding points of adjacent waves. 2)_____ is the number of waves that pass a fixed point in a given amount of time. Each photon carries 3) _____ which is dependent on the frequency of the wave.

There are different types of electromagnetic waves that vary in wavelength, frequency, and energy. The EM wave with the longest wavelength and lowest energy is 4)_____ and the wave with the shortest wavelength and highest energy is 5)_____.

In the color spectrum of light, 6)_____ has the highest energy and highest frequency while 7)_____ has the lowest energy and lowest frequency, therefore having the longest wavelength.

What I Can Do

The average distance of the Earth from the Sun is 1.5×10^{11} m. If the Sun's electromagnetic radiation travels at the speed of light (3.0×10^{8} m/s), how long would it take for the sun's EM radiation to reach the Earth? Show your solution and answer on a separate sheet of paper.

Additional Activities

Identify three (3) devices or appliances in your home that emit electromagnetic radiation. Write the wavelength and frequency of the emission and classify the type of EM radiation it produces. Draw the table below with your answers on a separate sheet of paper.

Device/Appliance	Type of EM Wave	Frequency Range	Wavelength Range

Posttest

Read and understand each item carefully and encircle the letter of the correct answer.

1. How does a decrease in the frequency affect the electromagnetic wave?
   A. Energy carried by the wave decreases.
   B. Wavelength decreases.
   C. neither A nor B
   D. both A and B

2. Which electromagnetic waves has the shortest wavelength?
   A. X – ray waves
   B. microwave
   C. radio wave
   D. gamma ray

3. What color in the visible spectrum carries the lowest energy?
   A. red
   B. blue
   C. violet
   D. orange

4. Radio wave, X-ray waves, and microwave are observed to be travelling in a vacuum. If the waves have a wavelength of 2×10^{3} m 2×10^{-9} m, 2×10^{-1} m respectively, which of the three travels the fastest?
   A. X - ray waves
   B. microwave
   C. radio wave
   D. They all travel at the same speed.

5. What will happen to the frequency and wavelength if the energy of the waves decreases?
   A. wavelength increases, frequency increases
   B. wavelength increases, frequency decreases
   C. wavelength decreases, frequency decreases
   D. wavelength decreases, frequency increases

6. A certain FM radio station broadcasts at 90.5 MHz or 9.05×10^{7} Hz. The radio wave travels at the speed of light, what is its wavelength?
   A. 0.05 m
   B. 3.31 m
   C. 2.72×10^{16} m
   D. 2.72×10^{10} m

7. What electromagnetic wave has the highest energy?
   A. Gamma ray
   B. Radio wave
   C. Ultraviolet wave
   D. Visible light

8. Which shows the correct arrangement of the electromagnetic wave in increasing frequency?
   A. radio waves, infrared waves, microwaves, visible light waves
   B. Infrared waves, visible light waves, ultraviolet waves, gamma ray waves
   C. microwave, infrared waves, visible light waves, ultraviolet waves
   D. x-ray waves, gamma ray waves, infrared waves, radio waves

For numbers 9 – 10, refer to the situation below.
A radio wave with a frequency of 6.2 x 10^{9}Hz is detected to be travelling in space. The value of Planck's constant is 6.626 x 10^{-34} Js.

9. What is the wavelength of the wave?
   A. 0.05 m
   B. 0.40 m
   C. 2 x 10^{-18} m
   D. 1.861 x 10^{18} m

10. How much energy does the wave carry?
   A. 4.11 x 10^{24} J
   B. 4.11 x 10^{-24} J
   C. 4.11 x 10^{24} J·s
   D. 4.11 x 10^{-24} J·s

Answer Key

What I Know
1. D
2. C
3. B
4. A
5. C
6. D
7. D
8. B
9. C
10. A

Additional Activity

Device/Appliance	Type of EM Wave	Frequency Range	Wavelength Range
TV Remote	Infrared	300 GHz to 430 GHz	0.000007 m - 0.00001 m
Microwave oven	Microwave	2.45 GHz – 2.5 GHz	0.120 m – 0.122 m

What's In
1. A
2. C
3. B
4. D

What's New
Activity 1
1. No, they may overlap.
2. wavelength, energy, and frequency
3. Radio wave, gamma ray
4. Gamma ray, radio wave
5. Gamma ray, radio wave
6. Inverse relationship, direct relationship, inverse relationship

What's New
Activity 2

1. Already answered
2. 384.62 m
3. 2.39 x 10^{-17} J, 8.33 x 10^{-9} m

What's More

Frequency Range
1. 6.67 x 10^{14} - 7.89 x 10^{14}
2. 6.06 x10^{14} - 6.67 x 10^{14}
3. 5.26 x 10^{14} - 6.06 x10^{14}
4. 5.08 x 10^{14} - 5.26 x 10^{14}
5. 4.84 x 10^{14} - 5.08 x 10^{14}
6. 4.0 x 10^{14} - 4.84 x 10^{14}

Energy Range
1. 4.42 x 10^{-19} - 5.23 x 10^{-19}
2. 4.02 x 10^{-19} - 4.42 x 10^{-19}
3. 3.48 x 10^{-19} - 4.02 x 10^{-19} 4. 3.36 x 10^{-19} - 3.48 x 10^{-19}
5. 3.2 x 10^{-19} - 3.36 x 10^{-19}
6. 2.65 x 10^{-19} - 3.2 x 10^{-19}

What's More
Questions
1. violet, red
2. red, violet
3, violet, red
4. The energy and frequency are directly proportional to each other but both are inversely proportional to the wavelength.

What I have Learned
1. wavelength
2. frequency
3. energy
4. radio wave
5. gamma ray
6. violet
7. red

What I Can Do
1. 500 seconds or 8 minutes and 20 seconds

References

Brainard, Jean. "Electromagnetic Waves," May 18, 2020. https://www.ck12.org/c/physical-science/electromagnetic-wave-and-properties/lesson/Properties-of-Electromagnetic-Waves-MS-PS/?referrer=concept_details.

khanacademymedicine. "Electromagnetic Waves and the Electromagnetic Spectrum: Physics: Khan Academy." YouTube. khanacademymedicine, May 18, 2020. https://youtu.be/7eutept5h0Q.

Khan Academy. "Light: Electromagnetic Waves, the Electromagnetic Spectrum and Photons (Article)." Khan Academy. Khan Academy. Accessed May 18, 2020. https://www.khanacademy.org/science/ap-chemistry/electronic-structure-of-atoms-ap/bohr-model-hydrogen-ap/a/light-and-the-electromagnetic-spectrum.

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