Electromagnetic Waves: A Brief Introduction

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ABSTRACT

The Universe is filled with an enormous spectrum of electromagnetic radiation, of which the visible light is only a sliver. This paper looks at the history of the scientific research into the electromagnetic spectrum. There is only difference between light, radio waves, and all the other types of electromagnetic radiation is the length of the imaginary waves or, in other words, the energy of the photons involved. Because of these different energies, the different types of radiation are made and absorbed in different ways, which is what makes them act differently. In this paper, we will discuss the electromagnetic waves in general, as well as the electromagnetic spectrum, with an emphasis on the most common applications of different type of electromagnetic waves in electromagnetic spectrum. There is talk about radio waves, microwaves, infrared radiation, light, UV light, X-rays, and gamma rays

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INTRODUCTION

Electromagnetic (EM) waves are waves that are related with both electricity and magnetism where the magnetic field and electric field are perpendicular to each other. Electromagnetic (EM) waves are waves that alter periodically in an electric and magnetic field that propagates over space. These waves are known as electromagnetic (EM) fields. Lightning and captivity are always present when waves are present, and because they are waves, you can expect them to travel throughout space. Electromagnetic waves are produced whenever electric and magnetic fields interact with one another and when those interactions are subject to time-dependent change. Maxwell's equations eventually led to the development of the electromagnetic field equations. These electromagnetic waves with their unique properties have been introduced by Maxwell, and they can be applied to a wide variety of practical objectives. In contrast to time, the electric field is a magnetic field made up of electromagnetic waves that changes with time. Electromagnetic swells are associated with time-varying electric and magnetic fields that are able to spread through space.[1]

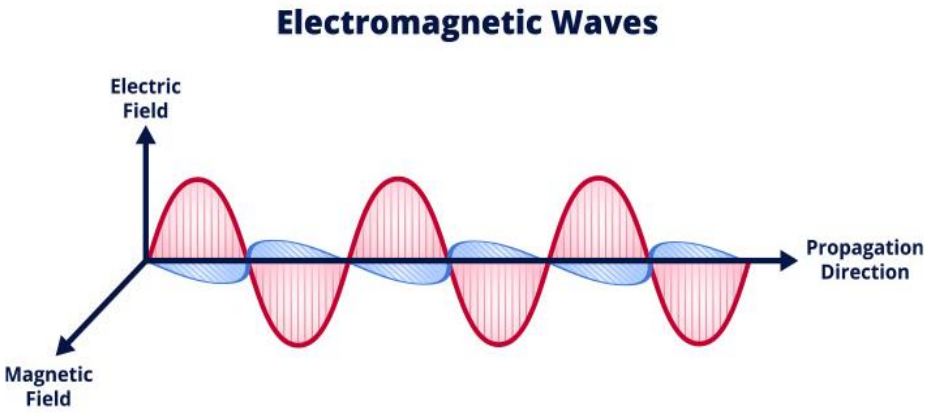

Figure.1. Electromagnetic waves

A BRIEF HISTORY OF ELECTROMAGNETIC WAVES

Starting in the middle of the 1800s, the Scottish physicist James Clerk Maxwell made twenty equations that explained how electromagnetism worked. These equations have since been boiled down to four simple formulas. The electric force field around the distribution of electrical charge is shown by the first equation. The second shows how magnetic field lines curl to make closed loops. The third and fourth equations show how an electromagnetic wave is made when electric and magnetic fields interact.[2]

Heinrich Hertz was born into a wealthy family in Hamburg. At the age of 23, he got his Ph.D. in physics, which was very early for that field. In 1886, just a few years later, he started studying electromagnetic waves and testing Maxwell's theories, which had not been widely accepted in continental Europe. Hertz's experiments showed that the electromagnetic effects that Maxwell had found spread at a certain speed. They didn't just happen all at once. Hertz came up with ways to measure the wavelength and speed of electromagnetic waves and wrote about how they reflect and bend. In the process, he found out that radio waves exist and found out that they act like light. Hertz's oscillator was made up of two rods that worked as a receiver and a spark gap that worked as an antenna for receiving signals. A spark would jump when the antenna picked up a radio wave. Hertz found that these signals were like electromagnetic waves in a lot of ways. The speed of these radio waves was the same as the speed of light.[3]

CHARACTERISTICS OF ELECTROMAGNETIC WAVES

Some of common characteristics of electromagnetic waves are follows:

- As time passes, the electric field varies, which in turn gives rise to a magnetic field. Similarly, the magnetic field shifts with time and, in turn, gives rise to the electric field. This cycle continues until the electric field no longer exists.
- These electric and magnetic fields go through periodic changes and interact with each other when they are simultaneously travelling across space, which results in the generation of electromagnetic waves.
- The electric field will have the shape of a sine wave, but the magnetic field will have a wave direction that is perpendicular to the electric field. Both of these things contribute to the progression of the electromagnetic field.[4]
- If, on the other hand, the electric field is parallel to the x-axis, then the wave will also travel down the z-axis if the magnetic field is aligned along the y-axis.
- Both the electric and magnetic fields are separate from one another and run in a direction that is perpendicular to the direction in which the surge is propagating.
- In an electromagnetic wave, the oscillating electric and magnetic fields have the same phase and proportional magnitudes. The ratio of electric and magnetic field amplitudes is equal to the speed of the electromagnetic wave.[5]

- Electromagnetic waves are produced when electric and magnetic fields interact with one other in a way that causes them to move in opposite directions in time.

ELECTROMAGNETIC SPECTRUM

The electromagnetic spectrum is a range of frequencies, wavelengths, and photon energies that covers frequencies from below 1 hertz to above 1025 Hz. This corresponds to wavelengths that range from a few kilometres to a fraction of the size of an atomic nucleus in the spectrum of electromagnetic waves. The electromagnetic spectrum is also known as the electromagnetic band. Electromagnetic waves have a tendency to travel at speeds that are comparable to the speed of light when they are present in a vacuum. Nevertheless, they do so throughout a very broad spectrum of wavelengths, frequencies, and photon intensities. The electromagnetic spectrum is made up of a broad range that includes all forms of electromagnetic radiation. Within this range, there are also a great number of sub-ranges, which are more often known as portions. These can be further broken down into categories such as infra-red radiation, visible light, or ultraviolet radiation.[6]

Electromagnetic Waves in Electromagnetic Spectrum

In increasing order of frequency and decreasing order of wavelength, the complete range (electromagnetic spectrum) is given by radio waves, microwaves, infrared radiation, visible light, ultra-violet radiation, X-rays, gamma rays, and cosmic rays. Following is a list of different kind of radiation and the frequencies and wavelengths they produce:

Type of Radiation	Frequency Range (Hz)	Wavelength Range
gamma-rays	$10^{20} – 10^{24}$	< 10^{-12} m
x-rays	$10^{17} – 10^{20}$	1 nm – 1 pm
ultraviolet	$10^{15} – 10^{17}$	400 nm – 1 nm
visible	$4 \times 10^{14} – 7.5 \times 10^{14}$	750 nm – 400 nm
near-infrared	$1 \times 10^{14} – 4 \times 10^{14}$	2.5 μm – 750 nm
infrared	$10^{13} – 10^{14}$	25 μm – 2.5 μm
microwaves	$3 \times 10^{11} – 10^{13}$	1 mm – 25 μm
radio waves	< 3×10^{11}	> 1 mm

Table.1. Wavelengths and frequencies of different kind of radiation

The electromagnetic spectrum can be illustrate as follows:

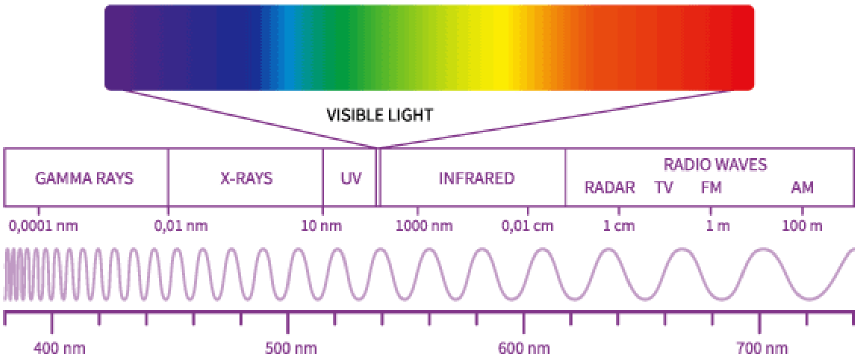

Figure.2. Illustration of Electromagnetic spectrum

Gamma rays: They are the ones with the shortest wavelengths and the highest frequencies. They are waves with a lot of energy that can travel a long way through the air and are the most penetrating waves. It can be used in many different ways in the medical field. Using gamma-ray imaging, doctors can look inside our bodies. The universe is the biggest source of gamma rays, which is an interesting fact.

X-rays: X-rays have longer wavelengths than gamma rays but shorter wavelengths than ultraviolet radiation, so they have more energy. They've been used in a lot of different ways in science and business, but mostly in medicine, for example in radiography. Since they are a type of ionizing radiation, they can be harmful. Electrons outside of the nucleus give off X-rays, while the nucleus gives off gamma rays.[7]

Ultraviolet: UV radiation is the part of the electromagnetic spectrum between X-rays and light that we can see. Most ultraviolet light comes from the sun. It makes your skin burn and tan. UV rays are also given off by hot things in space.

Visible light: Visible light, also called the visible spectrum, is the part of the electromagnetic spectrum that people can see with their eyes. It goes from blue light at 400 nanometres to red light at 700 nanometers. Blue light has more energy than red light.

Infrared (IR) radiation: IR is the part of the electromagnetic spectrum between visible light and microwaves. It is also called thermal radiation. The sun is the most important natural source of infrared light.

Microwaves: Microwaves are electromagnetic waves with wavelengths that can be as long as one meter or as short as one millimeter. Their frequencies range from 300 MHz

(0.3 GHz) to 300 GHz. This kind of radiation is found in microwaves, which can be used to cook food at home or at work. Astronomers also use it to figure out and understand how nearby galaxies and stars are put together.

Radio waves: They have long wavelengths that can be as short as a few centimeters or as long as tens of thousands of kilometers. They are used for TV, cell phone, and radio communications, among other things.

Significant of electromagnetic Spectrum

Depending on how they are generated, how they engage with matter, and the applications that they find in the real world, the electromagnetic waves that may be found in these various bands each have their own unique set of characteristics. The equations of Maxwell

predicted that there would be an endless number of frequencies of electromagnetic waves, and that these waves would all move at the speed of light. This is the first piece of evidence suggesting that the complete electromagnetic spectrum actually exists. In spite of this, the most important aspect of the electromagnetic spectrum is the fact that it can be applied to the process of categorizing electromagnetic waves and organizing them in accordance with the various frequencies or wavelengths at which they occur.[8]

APPLICATIONS OF ELECTROMAGNETIC WAVES

The electromagnetic waves offers a number of practical uses. The following is a list of some of its applications:

- Hertz's discovery of radio waves and microwaves made it possible for TV, radio, and cell phones to work without wires.
- The part of the electromagnetic spectrum that deals with visible light is the reason why we can see things. This part of the electromagnetic spectrum lets us see all the things around us, including their colors.
- Roentgen's discovery of X-rays turned out to be useful in medicine because they could be used to find many diseases or problems in bones.
- High-energy ultraviolet light can ionize atoms, which can lead to chemical reactions.
- Paul Villard found that gamma rays can be used to make things ionized and for nuclear medicine.[9]

CONCLUSIONS

The advancement of technology has led to an increase in the application of electromagnetic waves, which is only expected to continue. In this study, the radiations of electromagnetic fields were looked into. From gamma rays to radio waves, the electromagnetic spectrum is made up of the order of all known electromagnetic waves. As told before, because of improvements in technology, people have been exposed to high levels of electromagnetic emissions nowadays. The effects of electromagnetic radiation (EMR) on people's health are now one of the most concerned issues.

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