# Electromagnetic Waves: The Different Types and Importance for Our Daily Lives

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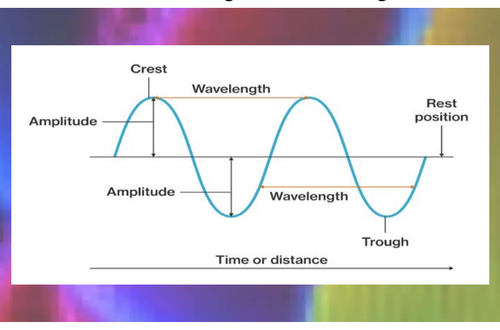
## Introduction:

This research paper will cover electromagnetic (EM) waves and their uses specifying on microwaves and ultraviolet waves. Electromagnetic waves have many common uses in your daily life that you might not even realize. The point is to outline the EM spectrum and how it all works and comes together. Almost everyone uses a microwave daily, but do they understand the application of these microwaves to heat food along with their other very important uses. Another electromagnetic wave that is important and contributes to our existence is ultraviolet waves. All types of electromagnetic waves are tremendously important and contribute to how we live our lives daily.

## Electromagnetic Waves:

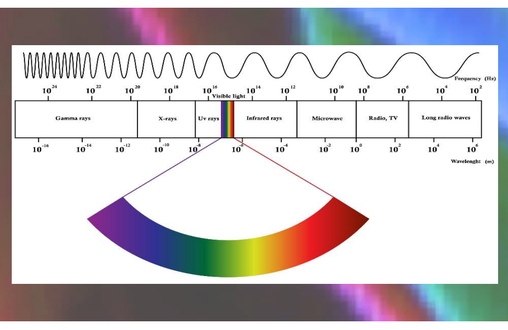
Description:

Electromagnetic waves are one of the ways that energy travel in the world around us. Unlike magnetic waves, electromagnetic waves do not require a medium to propagate. This means that electromagnetic waves can travel through air, solids, and vacuum of space. Electromagnetic waves have both crests and troughs somewhat like ocean waves. The distance between the crests or troughs is called the wavelengths, which vary tremendously depending on what type of electromagnetic waves it is. Below is a diagram of electromagnetic waves:



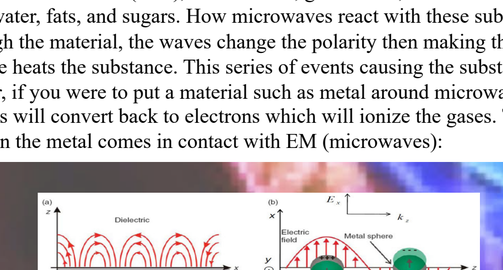

Electromagnetic Spectrum:

The electromagnetic spectrum is the range of frequencies of electromagnetic radiation and their respective wavelengths and photon energies. The seven types of electromagnetic waves on the spectrum from the longest to shortest wavelength are; radio waves, microwaves, infrared (IR), visible light, ultraviolet (UV), X-rays, and gamma rays. Out of the seven EM wave types on the spectrum, visible light is the most important since it allows us to see. In simpler terms, the electromagnetic spectrum is the term scientist use to describe the entire range of light that exists. The longer the wavelength of an electromagnetic wave the smaller the frequency is. For example, radio waves have a wavelength of $10^{6}$ (m) and a frequency of $10^{2}$ (Hz) where gamma rays have a wavelength of $10^{-16}$ (m) and a frequency of $10^{24}$ (Hz). Below is a diagram of the electromagnetic spectrum:




How EM waves are created:

Before 1873, magnetism and electricity were thought to be separate forces. However, James Clerk Maxwell, a Scottish physicist developed a theory of electromagnetism in 1873. The study regarding electromagnetism is about how electrically charged particles behave with one another and magnetic fields. In electromagnetism there are four main interactions; 1) the force of attraction or repulsion between electric charges is inversely proportional to the square of the distance between them, 2) magnetic poles come in pairs that attract and repel each other, much as electric charges do, 3) an electric current in a wire produces a magnetic field whose direction depends on the direction of the current, 4) and a moving electric field produces a magnetic field and vice versa. James Maxwell developed multiple formulas to describe these scenarios called Maxwell's equations. Electromagnetic waves are specifically created by oscillating magnetic and electric fields. In more detail, electromagnetic radiation is formed when an atomic particle (e.g an electron) is accelerated due to an electric field which makes it move. This movement creates oscillating magnetic and electric fields, that move at right angles to one another in a cluster of light energy (i.e photon). Photons travel at the fastest speed possible in the universe approximately 300,000,000 m/sec n harmonic waves, which is known as the speed of light. Depending on what type of electromagnetic wave it is the frequency, and wavelength will differ. This is a diagram explaining how magnetic and electric fields work together to create EM waves:




## Microwaves:

Introduction to microwaves:

Microwaves are a type of electromagnetic wave on the electromagnetic spectrum. Microwaves have a wavelength of 30 cm to 1 mm and frequencies from 1 GHz to 300 GHz. This kind of electromagnetic radiation, microwaves, is basically extremely high-frequency radio waves. With the use of his equation, James Clerk Maxwell first predicted microwaves in the year 1864. However, it was in the year 1888 when Heinrich Hertz was the first physicist to prove the existence of microwaves by designing and manufacturing a device that produced and detected microwave radiation. Microwaves will travel in straight lines and will be reflected by the conducting surfaces. An advantage of using microwaves is that they support larger bandwidth hence more information is transmitted along with higher data rates being transmitted since the bandwidth is more. However, some disadvantages are; electromagnetic interference may occur, variations in dielectric properties with temperatures may occur, and inherent inefficiency of electric power. Overall the pros overwait the cons since we still use microwaves daily in multiple ways. Below is a diagram showing some more pros and cons to the electromagnetic wave, microwaves:




How they function:

Microwaves can be produced in multiple ways, but the fundamentals are the same as for electromagnetic waves hence magnetic and electric fields combine. There are also many different types of emitters for microwaves such as; cavity magnetron, klystron, traveling-wave tube (TWT), gyrotron, and all-stars. These devices that emit microwaves use density modulated mode meaning they work based on clumps of electrons flying ballistically through them. As stated, there are many ways to produce microwaves some ways to produce lower power microwaves include; field-effect transistor (FET), tunnel diode, gunn diode, and IMPATT diode. Microwaves will react with substances like water, fats, and sugars. How microwaves react with these substances is as follows, when the microwaves pass through the material, the waves change the polarity then making them vibrate extremely fast which causes friction, hence heats the substance. This series of events causing the substance to heat up is called dielectric heating. However, if you were to put a material such as metal around microwaves, the metal will act as an antenna and the microwaves will convert back to electrons which will ionize the gases. This diagram shows and explains what happens when the metal comes in contact with EM (microwaves):




**Surface effect depicted for EM radiation interacting with metal. The figure-a depicts plane surface interaction, and figure-b depicting the Surface effect is bounded by small spherical metal spheres, where the Electron cloud oscillates in synchronism with the oscillating E-field. The principal mode $n$=1 is depicted as dipole formation**

Uses for daily life:

Microwaves have several important uses in our daily lives. One of these uses is microwaves the metal box that heats your food when you are in a rush or for convenience. This wasn't the original use for microwaves at all, it was in 1946 when Percy Spencer an American engineer was walking past microwaves and realized that the chocolate bar in his pocket had melted which lead him to design the first microwave called the radarange. It was in the year 1955 when Tappan first introduced a microwave for home use, yet it was still too big and expensive for general home use. In the year 1967, was when microwaves truly started coming into homes after Amana Corporation introduced the countertop microwave. From 1946 to 2020 microwaves have evolved a lot and have become a more essential part of our daily life. There are a lot of other uses for microwaves other than the obvious microwave such as; long-distance wireless transmission, satellite communication, cell phone communication, wi-fi, global positioning system (GPS), radar, Bluetooth, medical uses, and military weapons. Most wireless transmission systems are based on microwaves since they can transmit signals over a long distance. Satellites can transmit signals to earth from space by using microwaves because they can bypass the atmosphere through the ionosphere to relay information. Other uses for microwaves with satellites include radio, television, and international phone calls. Sending a text, voice call, video clip, or picture are all transformed into signals which are sent through microwaves to the nearest cell tower where the signal gets transmitted to the planned destination. Microwaves are also used for wi-fi, hence wi-fi is short for wireless fidelity which refers to the ability for wi-fi microwaves to operate at various frequencies. GPS uses satellites orbiting the earth to broadcast microwave signals along with determining the exact location of an object. Radar guns work by sending out short bursts of microwaves that hit the vehicle and get reflected which then are detected by the gun receiver. Bluetooth uses short-range microwaves signals to allow two devices to connect which removes any cables or wires from the equation. X-rays are not the only type of EM used in the medical field, microwaves are also used, one of these ways being targeted dielectric thermal desiccation of human tissue known as microwave ablation. Microwaves can also be used as a solution to drone threats, this high-powered microwave weapon would be directed towards the sky were several blasts or microwave radiation will be released causing all drones in its path to fry. Although the microwave oven is the most known use of microwaves there are various other uses as stated that are truly innovational and things, we use daily without realizing the science behind. I know I use my phone, Bluetooth, and GPS daily, but I had not understood that it was using the same thing I heat my food with called microwaves. Below is an image of the 1955 microwave oven compared to a current modern one:

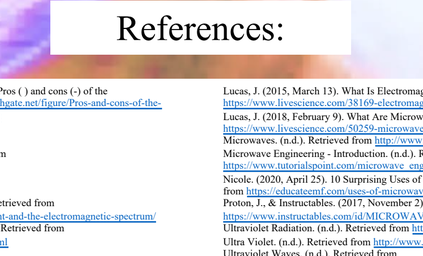
## UV Waves:

Explanation:

Ultraviolet light is also known as UV is a type of electromagnetic radiation that has wavelengths from 10 nm to 400 nm and frequencies from 30 PHz to 750THz. Ultraviolet has shorter wavelengths than visible light but longer wavelengths compared to x-rays. These UV waves are invisible to human eyes however, some insects such as bees can see them. The ultraviolet part of the electromagnetic spectrum is divided into three regions; near ultraviolet, far ultraviolet, and extreme ultraviolet. These three regions are distinguished by the wavelength of the ultraviolet light, and by how energetic the ultraviolet radiation is. Near ultraviolet (NUV), is the ultraviolet light closest to visible light on the electromagnetic spectrum. Extreme ultraviolet (EUV), is the ultraviolet light closest to x-rays on the electromagnetic spectrum, along with being the most energetic of the three regions. Far ultraviolet (FUV), is what is between the near ultraviolet and extreme ultraviolet regions and is also the least explored out of the three types. Down below is a diagram that outlines the different regions and where they are located:

The pros and cons:

Ultraviolet light can come from both the sun and manmade sources which can both have positive and negative effects. To start with the pros of ultraviolet light from the sun, UV light specifically UV-A triggers our bodies to produce vitamin D. Vitamin is needed for our bones, muscles, immune system, and is even suspected to lower the risk of colon cancer. UV light also has positive effects on skin conditions such as psoriasis since it slows the growth of skin cells hence reduces the symptoms. Exposure to ultraviolet light stimulates the production of tryptamines which will improve your mood. UV is also really good for sterilizing and disinfecting by killing the bacteria and viruses so they can no longer reproduce or multiply. Animals also have pros from UV light including, navigation and helping things stand out more clearly. The negatives of ultraviolet light include, UV rays cause sunburn which damages the skin cells causing extra blood flow to the area, hence reddened skin typical of a sunburn. Another negative effect that is more serious is increasing the risk of skin cancer. Almost 90% of skin cancers are caused by UV radiation specifically UV-B but UV-A is a reason too. It is suspected that ultraviolet radiation suppresses the immune system which protects the body from pathogens to a certain extent. Along with the function and distribution of white blood cells being affected for up to a day later after exposure to ultraviolet light. Your eyes can also get affected by UV light since it can hurt the tissues in your eyes which will burn them and can cause an eye condition called photokeratitis. UV-B light can hurt the process of photosynthesis which will reduce the size, productivity, and quality of different types of plants. This type of ultraviolet light UV-B has been thought to increase a plants chances of getting diseases. There are a lot of pros to UV light along with a lot of cons but since ultraviolet normally comes from the sun which is already mostly blocked because of the atmosphere there is nothing you can really do to prevent UV rays. Being aware that there can be negative effects is an important step so you can try what you can to prevent them like wearing sunscreen, etc.. This diagram shows the different types of UV rays UV-A, UV-B, and UV-C rays leaving the sun and were they end:




Uses from natural to manmade:

Ultraviolet radiation has many uses which can be both natural and manmade. Natural uses of UV rays include; getting a tan, producing vitamin D, and improving your mood. Manmade uses of ultraviolet light consist of; tanning beds, blacklights, detecting fake money, hardening dental fillings, kill microbes and sterilize things. For the natural uses of ultraviolet radiation, they are all because of the UV rays that the sun gives off so hence being outside would give those benefits and uses of UV. However, for the manmade uses most of them require a manmade UV light, these UV rays can be made artificially by passing an electric current through a gas or vapor, such as mercury vapor. UV light is very helpful in the medical field since will sterilize and kill microbes. One-way hospitals use UV waves is by using germicidal lamps that produce the same waves to sterilize the equipment, water, and even air in the operating rooms. UV light can have many uses from not the most important things like making your white clothes glow in a club to very important things like sterilizing items in the food and drug, and medical industries. Here is an image of an artificial ultraviolet lamp used for sterilization:



## Conclusion:

In conclusion, the electromagnetic waves and spectrum are used far more often in our lives than most people will realize. I hope you were able to learn about all the physics with electromagnetic waves with an emphasis on microwaves and ultraviolet waves. Next time you turn on your phone, go tanning, use a microwave, etc. think about how all these electromagnetic waves are working to make your life easier and more desirable. Electromagnetic waves have been around for a long time, but it wasn't until recently when it was discovered to what extent we can put these different types of EM waves to use. The electromagnetic spectrum is very complex, and each piece plays a very important role. Even though with our bare eyes we cannot see some types of EM waves they are constantly around us.

## References:

Ambrozic, G., Orel, Z. C., & Zigon, M. (2018, August 1). Figure 2: Pros ( ) and cons (-) of the microwave-assisted synthesis.... Retrieved from https://www.researchgate.net/figure/Pros-and-cons-of-the-microwave-assisted-synthesis-Slika-2-Prednosti-in_fig3_283837760

Anatomy of an Electromagnetic Wave. (n.d.). Retrieved from https://science.nasa.gov/ems/02_anatomy

Detecting Ultraviolet Light Using Tonic Water. (n.d.). Retrieved from https://scied.ucar.edu/activity/learn/ultraviolet-light-tonic-water

How UV Light is Used in Air Purification. (n.d.). Retrieved from https://www.oransi.com/page/uv-light

Inc. (n.d.). Properties of Light and the Electromagnetic Spectrum. Retrieved from https://www.coursehero.com/sg/organic-chemistry/properties-of-light-and-the-electromagnetic-spectrum/

Johnson, L. (2019, July 31). UV Light: Positive & Negative Effects. Retrieved from https://sciencing.com/uv-light-positive-negative-effects-8108855.html

Libretexts. (2019, June 5). Electromagnetic Waves. Retrieved from https://chem.libretexts.org/Bookshelves/Physical_and_Theoretical_Chemistry_Textbook_Maps/Supplemental_Modules_(Physical_and_Theoretical_Chemistry)/Quantum_Mechanics/Gen_Chem_Quantum_Theory/Electromagnetic_Waves

Lucas, J. (2015, March 13). What Is Electromagnetic Radiation? Retrieved from https://www.livescience.com/38169-electromagnetism.html

Lucas, J. (2018, February 9). What Are Microwaves? Retrieved from https://www.livescience.com/50259-microwaves.html

Microwaves. (n.d.). Retrieved from http://www.darvill.clara.net/emag/emagmicro.htm

Microwave Engineering - Introduction. (n.d.). Retrieved from https://www.tutorialspoint.com/microwave_engineering/microwave_engineering_introduction.htm

Nicole. (2020, April 25). 10 Surprising Uses of Microwaves That will Amaze You. Retrieved from https://educateemf.com/uses-of-microwaves/

Proton, J., & Instructables. (2017, November 2). MICROWAVE RADIATION. Retrieved from https://www.instructables.com/id/MICROWAVE-RADIATION/

Ultraviolet Radiation. (n.d.). Retrieved from https://www.showmethephysics.com/uv_1.htm

Ultra Violet. (n.d.). Retrieved from http://www.darvill.clara.net/emag/emaguv.htm

Ultraviolet Waves. (n.d.). Retrieved from https://www.univie.ac.at/geographie/fachdidaktik/FD/site/external_html5/imagers.gsfc.nasa.gov/ems/uv.html