The Electromagnetic Spectrum

We all know the waves the sea makes or the ones the wind creates on a flag. We can touch them, interact and interfere with them. Even sound travels in waves which we can hear with the help of our ear drums. These waves need a medium in which they create a molecular recreation and thereby propagate through space. Light is different in this respect. It is still understood as a wave but it does not need a medium to move through space. These types of waves are called Electromagnetic Radiation (EM radiation). Electromagnetic radiation is generally described as a self-propagating wave in space with electric and magnetic components. These components oscillate at right angles to each other and to the direction of propagation, and are in phase with each other. Electromagnetic radiation is classified into types according to the frequency of the wave, these types include (in order of increasing frequency) radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, X-rays and gamma rays. In some technical contexts the entire range is referred to as just "light".

EM radiation exhibits both wave properties and particle properties at the same time. However, these characteristics are mutually exclusive and appear separately in different circumstances: the wave characteristics appear when EM radiation is measured over relatively large timescales and over large distances, and the particle characteristics are evident when measuring small distances and timescales. Both characteristics have been confirmed in a large number of experiments.

Wavelength & Frequency

Radio waves, television waves, and microwaves are all types of electromagnetic radiation. They only differ from each other in wavelength. Wavelength is the distance between one wave crest to the next.

Microwaves

1.5 GHz–0.3 THz | 20 cm–1000 μm

Oven
Wifi
Mobile phone
Satellite
Cloud Cover, Ice
Atmospheric Temperature

Microwaves are absorbed by molecules that have a dipole moment in liquids. In a microwave oven, this effect is used to heat food. Low-intensity microwave radiation is used in Wi-Fi.

This super high-frequency (SHF) and extremely high frequency (EHF) of Microwaves come next up the frequency scale. Microwaves are waves which are typically short enough to employ tubular metal waveguides of reasonable diameter. Microwave energy is produced with klystron and magnetron tubes, and with solid state devices such as Gunn and IMPATT devices. Microwaves are widely used in modern technology, for example in point-to-point communication links, wireless networks, microwave radio relay networks, radar, satellite and spacecraft communication, medical diagnostic imaging and tumor treatment, remote sensing and weather forecasting, and in numerous home and business products such as microwave ovens and microwave radio receivers for satellite television or broadband Internet access.

Typical uses of microwaves are: point-to-point communication links, wireless networks, microwave radio relay networks, radar, satellite and spacecraft communication, medical diagnostic imaging and tumor treatment, remote sensing and weather forecasting, and in numerous home and business products such as microwave ovens and microwave radio receivers for satellite television or broadband Internet access.

There are many different sources of microwaves; for example, hot objects or objects made of highly conductive materials can be used for this purpose. Microwaves occur naturally from certain astronomical objects, and are used in various kinds of devices and communication systems. This broad use is because they easily penetrate the earth's atmosphere with little interference, unlike other wavelengths, and because they can be focused into narrow beams more easily than radio waves. Unlike higher frequencies, such as infrared and light, microwaves can penetrate through most clouds and fog. Some molecules strongly absorb microwaves, and this is how they heat up food in microwave ovens. Microwaves are also used in radar because they can be reflected by many kinds of objects.

There are concerns that some of the microwave radiation used in modern life may have some biological effects on some of the things that it passes through, because microwaves can induce electric currents in conductive materials, which may cause some biological effects. Although microwaves are a kind of ionizing radiation, the photons by themselves are not energetic enough to ionize molecules or break chemical bonds, or cause chemical reactions such as those involved in sunburn or photosynthesis, but they can still cause heating effects when they are absorbed by molecules that can rotate or vibrate at the microwave frequencies. At very high intensities, they can heat up any material to which they are applied, and so they are used in microwave ovens to cook food, and in microwave diathermy devices to heat tissue for medical treatment. Microwave radiation is also used in various kinds of devices and systems, such as in microwave ovens and in microwave radio receivers for satellite television or broadband Internet access.

TW = Frequency Modulation AM = Amplitude Modulation

Radio

12 Hz – 1.5 GHz | 30 000 000 km – 0.2 m

Radio, AM, FM
Television
Satellite
Cell phone
Wireless Lans
Pager, Walkie Talkie
Toy Radio Controls
Medical Diagnostics
Astronomy Observations
Atmospheric Temperature

Radio frequency refers to that portion of the electromagnetic spectrum in which electromagnetic waves can be generated by alternating current fed to an antenna.

Radio waves generally are utilized by antennas of appropriate size with wavelengths ranging from hundreds of metres to about one millimetre. They are used for transmission of data, via modulation. Television, mobile phones, satellite communications and computer networks are all using this. Over 500 GHz, the absorption of electromagnetic radiation by Earth's atmosphere is so great that the atmosphere is effectively opaque to higher frequencies of electromagnetic radiation, until the atmosphere becomes transparent again in the so-called infrared and optical window frequency ranges.

Infrared

0.3 THz–375 GHz | 1000 μm–780 nm

Heating
Thermography
Night vision
Spectroscopy
Infrared Data Association (IrDA)

The name Infrared means "below red", from the Latin infra, "below", and red being the color of visible light of longest wavelength.

The boundary between visible and infrared light is not precisely defined. The human eye is markedly less sensitive to light above 700 nm wavelength, so longer frequencies make insignificant contributions to scenes illuminated by common light sources. But particularly intense light (e.g., from lasers, or from bright daylight with the visible light removed by coloured gels) can be detected up to approximately 780 nm, and will be perceived as red light. The cones of the eye respond to infrared (also to different standards) at various values typically between 700 nm and 780 nm.

Infrared radiation is popularly known as "heat" or sometimes "heat radiation," since many people (even physics teachers) attribute all radiant heating to infrared light. Infrared radiation from the Sun accounts for roughly 49% of the heating of any frequently sell heat surfaces which absorb them. IR light from the sun only accounts for 30% of the heating of the Earth, the rest bestagassed by visible light. Cones (or cones UV) lower (on that paper, secondarily) but objects put out visible radiation, and ice cubes emit mostly microwaves. Light from very hot objects (thousands of degrees) occasionally is felt as heat, mostly concentrated in the 8–12 micron band. Unlike near heat, which exists only in matter, infrared radiation can propagate through a vacuum.

Visible

375 THz–790 THz | 780 nm–380 nm

Photos
Photosynthesis
Color Theory
Light Therapy
Optical Fibers

The visible spectrum (or optical spectrum) is the portion of the electromagnetic spectrum that is visible to the human eye. Electromagnetic radiation in this range of wavelengths is called visible light or simply light.

There are no exact bounds to the visible spectrum, a typical human eye will respond to wavelengths from 700 to 400 nm, although some people may be able to perceive wavelengths as long as 780 nm or as short as 380 nm, especially with the maximum sensitivity at around 555 nm, in the green region of the optical spectrum (yes: luminosity function). The spectrum does not, however, contain all the colors that the human eyes and brain can distinguish. Brown and pink are absent, for example. See Color to understand why.

The eyes of many species perceive wavelengths different from the spectrum visible to the human eye. For example, many insects, such as bees, can see light in the ultraviolet, which is useful for finding nectar in flowers. For this reason, plant species whose life cycles are linked to insect pollination may owe their reproductive success to the appearance in ultraviolet light. Thus, the star color of flowers may be in the ultraviolet spectrum.

Optical Window

In astronomy, the optical window is that portion of the electromagnetic spectrum that passes through the atmosphere all the way to the ground. Most EM energy never reaches the ground because it falls outside like a window that lets in just a little of what is out there. It is called "optical" because the wavelengths we can see are all in this range. The window runs from around ultraviolet (300 nm) at the short end up into the range that eye can see, roughly 400–700 nm and continues up through the visual infrared to around 1100 nm, which is thermal infrared.

There is another absorption window called the "radio window" that lets through some (not all) radio waves. The radio window runs from about one centimeter to about eleven meter waves.

Can one touch light?

If a little glass bead is put on top of a powerful laser, the bead remains suspended in mid-air. The heaviest object that has been levitated with a laser had a mass of 20 g; the laser used to levitate the object was 10 watts in power. With additional effects, such as shock waves, to keep the object in the air. This means that light has momentum. Therefore images can be touched! In fact, the sun with which objects can be pushed even has a special name. For stars, it is called "light pressure" and for lasers it is called "optical tweezers". Take each type of electromagnetic field, and the even kind of wave, light carries energy.

Ultra-Violet

790 THz–24 PHz | 380 nm–13 nm

Black Light
Medical Diagnostics
Tan Lamps
Spectroscopy
Forensics
Astronomy Observations
Atmospheric Temperature
Vitamin D Production

In humans, prolonged exposure to solar UV radiation may result in acute and chronic health effects on the skin, eye, and immune system.

As a defense against UV radiation, the body turns when exposed to sunlamps (depending on skin type) levels of radiation by releasing the brown pigment melanin. This helps to block UV penetration and prevent damage to the vulnerable skin tissue deeper down. A positive effect of UV light is that it induces the production of vitamin D in the skin.

Extreme UV is characterized by a transition in the physics of interaction with matter: wavelengths longer than about 30 nm interact mainly with the chemical valence electrons of matter, while wavelengths shorter than that interact mainly with inner shell electrons and nuclei.

X-Ray

24 PHz–120Hz | 13 nm–24 pm

Radio, AM, FM
Television
Satellite
Cell phone
Wireless Lans
Medical Diagnostics
Astronomy Observations
Atmospheric Temperature

X-rays are a form of ionizing radiation and as such can be dangerous. In manyapplications, exposure to an intense X-ray beam can cause damage of the radiation, Wilhelm Röntgen.

When modeled X-rays are being produced, a thin metallic sheet is placed between the emitter and the target, efficiently filtering out the lower energy (soft) X-rays. This is done because the soft X-rays are not X-rays overlapping with the rest of the spectrum. The wavelength of hard X-rays overlaps with that of soft X-rays, and the wavelength is shorter. Hard X-rays are a subset of "long" wavelength (lower energy) gamma rays, however the distinction between the two terms depends on the source of the radiation, not its wavelength. X-ray photons are generated by energetic electron processes, gamma rays by transitions within atomic nuclei.

The basic production of X-rays is by accelerating electrons in order to collide with a metal target (usually tungsten, but sometimes molybdenum). Then the electrons suddenly decelerate upon colliding with the metal target and if enough energy is contained within the electron it is able to knock out an electron from the inner shell of the metal atom and as a result electrons from higher energy levels then fill up the vacancy and X-ray photons are emitted.

Gamma Rays

Medical Isotopes

<3 PHz | > 3 pm

Gamma rays (often denoted by the Greek letter gamma) are an energetic form of electromagnetic radiation produced by radioactive decay or other nuclear or subatomic processes such as electron-positron annihilation.

Gamma rays form the highest-energy end of the electromagnetic spectrum. They are used for a range of applications in both medicine and industry. It is important to note that there is no physical difference between gamma rays and X-rays of the same energy — they are two names for the same electromagnetic radiation, just as sunlight and moonlight are two names for visible light. Rather, gamma rays are distinguished from X-rays by their origin. Gamma rays are the term for high-energy electromagnetic radiation produced by energy transitions due to accelerating electrons. Because it is possible for some electron transitions to be of higher energy than some nuclear transitions, there is an overlap between what we call low energy gamma rays and high energy X-rays.