Electromagnetic Radiation Cards

GAMMA RAYS

Wavelength	Frequency	Speed of travel
Less than 0.01 nm (*less than 10^{-11} m*) *Scale of an atomic nucleus*	Greater than 30,000,000,000 GHz (*greater than 3×10^{10} GHz*)	300,000,000 m/s (*3×10^{8} m/s*)

Artist's impression of GRB 190114C, a collapsing star exploding as a supernova, releasing gamma radiation.

Uses: In medicine, gamma rays are used in radiation therapy to destroy cancer cells. They are also used in a type of medical imaging with special cameras that create images by detecting the gamma rays emitted by radioactive particles injected into the patient's body. Gamma rays that are produced by cosmic events are used by astronomers to study the universe and its origins. In addition, gamma rays are useful for sterilizing medical equipment and food, detecting defects in metal, and monitoring and controlling nuclear power plants.

Interactions with matter: Gamma rays can transmit through dense materials, such as certain metals, without being absorbed much; but they can be absorbed by other types of molecules, which can cause their chemical bonds to separate. Gamma rays also have the ability to knock electrons out of individual atoms. This is called *ionization*, and it can be harmful to living cells.

Sources: In nature, gamma rays come from faraway, mysterious parts of our universe, such as exploding supernovas and black holes. Gamma radiation is also emitted during nuclear reactions, such as those in nuclear power plants.

NASA, ESA and M. Kornmesser

X-RAYS

Wavelength	Frequency	Speed of travel
0.01 nm to 10 nm (*10^{-11} m to 10^{-8} m*) *Scale of a complete atom*	30,000,000 GHz to 30,000,000,000 GHz *(3×10^{7} GHz to 3×10^{10} GHz)*	300,000,000 m/s *(3×10^{8} m/s)*

A hand under X-rays. In this case, the X-rays were absorbed by the bones because of their high density.

Uses: The medical applications of X-rays include imaging to diagnose broken bones, tumors, cavities, and other conditions inside the body, and radiation therapy to kill cancer cells. They are used in astronomy, but oxygen and nitrogen in the atmosphere absorb X-rays, so this work must be done with high-altitude balloons and satellites. Scientists also use X-rays to study the atomic structure of materials. In industry, they are used to inspect metal components for manufacturing flaws. X-rays are used in security checks at airports as well.

Interactions with matter: X-rays transmit through some less dense materials, such as air or water; however, denser materials, such as bone or metal, tend to absorb X-rays. X-rays also have the ability to knock electrons out of atoms. This is called *ionization*, and it can be harmful to living cells.

Sources: X-rays come from multiple natural sources, such as the Sun and other stars, as well as radioactive elements found on Earth. In medical imaging, they are typically produced by an X-ray tube. When a high voltage is applied to the tube, electrons are emitted from the positively charged side of the tube and accelerated toward the negatively charged side of the tube, producing X-rays in the process.

Trace Meek, Flickr

ULTRAVIOLET (UV) RADIATION

Wavelength	Frequency	Speed of travel
10 nm to 400 nm (*1×10^{-8} m to 4×10^{-7} m*) *Scale of molecules*	750,000 GHz to 30,000,000 GHz (*7.5×10^{5} GHz to 3×10^{7} GHz*)	300,000,000 m/s (*3×10^{8} m/s*)

A person lies inside a tanning bed. People usually wear protective goggles while they are inside these.

Uses: In medicine, ultraviolet (UV) radiation is used to visualize certain structures or molecules in tissues or cells. In astronomy, scientists use UV radiation to study temperatures and chemical compositions of space objects. In industry, UV light is used to harden specific resins in high-quality 3D printers. UV light is commonly used for disinfection purposes, such as in water treatment or air purification systems, to kill viruses and other microorganisms. UV light is also used in tanning beds and tooth-whitening treatments, though it has been shown to contribute to cancer risk.

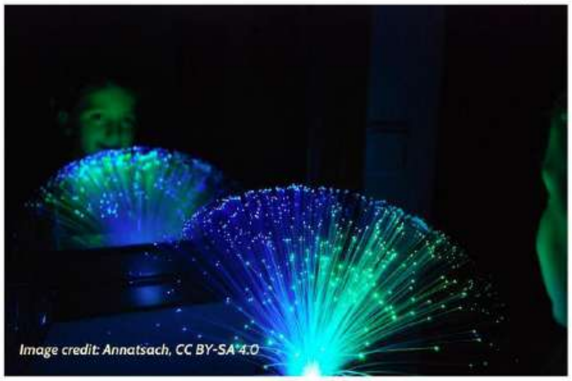
Interactions with matter: Some UV light is absorbed into the ozone layer of Earth's atmosphere, while some transmits through. UV rays can cause molecules in a material to vibrate or rotate, which can lead to increases in temperature, or even changes in the color, texture, and strength of the material. UV rays also have the ability to knock electrons out of atoms. This is called *ionization*, and it can be harmful to living cells.

Sources: UV light comes from multiple natural sources, such as the Sun and other stars, as well as radioactive elements found on Earth. It can also be produced by artificial sources, such as UV lamps or lasers, which generate this radiation by putting extra energy into certain materials, which then emit UV light.

Tho-Ge, Pixabay

VISIBLE (OPTICAL) LIGHT

Wavelength	Frequency	Speed of travel
400 nm to 700 nm (*4×10^{-7} m to 7×10^{-7} m*) *Scale of a single-celled organism*	400,000 GHz to 750,000 GHz *(4×10^{5} GHz to 7.5×10^{5} GHz)*	300,000,000 m/s *(3×10^{8} m/s)*



A person looking at optical fibers in the dark. Optical fibers are made of ultra-pure glass or plastic, and they use internal reflection to transmit light signals over long distances. These light signals can store information, making optical fibers essential for modern communication networks.

Uses: In medicine, visible light is used to activate drugs that kill cancer cells. Scientists also use it to analyze the chemical composition of materials. Until rather recently, all observations in astronomy were made with visible light. In industry, it is used to measure the concentration of a substance in foods and beverages. Visible light can transmit data through fiber-optic cables. Though it can cause heating effects in living organisms, it is not harmful. In fact, visible light is essential for the survival of most living organisms on Earth.

Interactions with matter: Molecules absorb or transmit visible light based on their chemical structure. When an object appears to be a certain color, this usually means that the object has reflected radiation of that color toward our eyes. Though many colors appear naturally, humans have figured out how to artificially create many specific colors by carefully controlling which visible light frequencies are absorbed and reflected.

Sources: "Visible light" is visible to humans and animals because it's the most common EM radiation emitted by our Sun, so animals and plants have evolved to use it. Other natural sources include stars, lightning, and bioluminescent organisms, such as fireflies. Through human history, sources of visible light have evolved from candles to incandescent light bulbs, fluorescents, and LEDs. As technology improves, bulbs produce more visible light and waste less energy as infrared radiation.

INFRARED RADIATION (IR)

Wavelength	Frequency	Speed of travel
700 nm to 1,000,000 nm (*10^{-6} m to 10^{-3} m*) *Scale of a needle point*	300 GHz to 400,000 GHz (*3×10^2 GHz to 4×10^5 GHz*)	300,000,000 m/s (*3×10^8 m/s*)

Image credit: Evan-Amos, Public domain

Remote controls use IR radiation to transmit signals. Most remote controls have a range of about 5-10 meters (16-33 feet).

Uses: Infrared (IR) light is used in medical imaging technologies to diagnose injuries. IR light can travel more easily through dense cosmic dust clouds than visible light, allowing astronomers to study objects farther out in space. It is common in short-range communication, such as some TV remote controls. It is also used in the food industry to keep food warm. Though IR can heat up matter in living organisms and cause burns, it is not considered harmful.

Interactions with matter: IR can be absorbed by most solid matter, making particles vibrate, which we feel as heat. This is greatly affected by the particle structure of the substance. For example, the molecular structure of "greenhouse gases", such as carbon dioxide and methane, absorb IR; but other common gases in Earth's atmosphere, such as nitrogen and oxygen, allow IR to transmit through unaffected. IR can also cause electron movement in materials like metals, in which electrons can move freely.

Sources: When matter particles vibrate, they emit IR. Therefore, an object at any temperature emits IR radiation--even freezing-cold ice. However, the hotter the substance, the more the particles move, and the higher the frequency of the IR emitted. If the substance is hot enough, the radiation emitted reaches high enough frequencies that it can be seen by the human eye. This is why we see very hot things glow red, orange, or even white.

Evan-Amos

MICROWAVE RADIATION

Wavelength	Frequency	Speed of travel
1,000,000 to 100,000,000 nm (*10^{-3} to 10^{-1} m*) *Scale of a small or large insect*	3 GHz to 300 GHz (*3×10^{0} GHz to 3×10^{2} GHz*)	300,000,000 m/s (*3×10^{8} m/s*)

A satellite dish receives microwave radiation from a satellite thousands of miles above Earth, allowing TV companies to send programs to specific households.

Uses: In medicine, microwave radiation can be used to kill tumors; when tumor cells have a higher water content than healthy cells, microwave radiation can heat and kill the tumor cells. It can also be used to create images of the body's internal structures. In astronomy, measuring and tracking the "cosmic microwave background" (CMB) has taught us much about the origin of our universe. In industry, microwave radiation is used for drying, hardening, and heating materials. It is used in satellite communication as well as wireless networks, such as Bluetooth and Wi-Fi. Microwave radiation is not considered harmful.

Interactions with matter: When microwave radiation interacts with matter, it can cause electrons to vibrate, and it can increase the rotation of polar molecules. In general, polar substances, such as water and biological tissues, absorb more energy from microwave radiation than nonpolar molecules, such as microwave-safe plastics.

Sources: The "cosmic microwave background" can be detected coming from every direction in the universe--this is evidence that the universe has expanded since the Big Bang. Human-made sources of microwave radiation include microwave ovens, radar systems, and telecommunication systems.

Pxfuel

RADIO WAVES

Wavelength	Frequency	Speed of travel
Larger than 100,000,000 nm (*longer than 0.1 m*) *Scale of a person up to a large city*	Less than 3 GHz (*less than* 3×10^{0} *GHz*)	300,000,000 m/s (3×10^{8} *m/s*)

Antennas of the Atacama Large Millimeter/submillimeter Array (ALMA) in Chile are used by scientists to study distant stars, galaxies, and planets in great detail.

Uses: Radio waves are used in some medical imaging, such as magnetic resonance imaging (MRI). In astronomy, radio telescopes are sometimes enormous, made of many separate receiving antennas to collect from a larger area. Like microwave radiation, radio waves heat specific types of matter differently, so they are used in "radio ovens" for industrial applications. Radio waves are also used for radio and TV broadcasting as well as mobile phone and satellite communication. They are used in radar systems for navigation, weather forecasting, and air traffic control. Radio waves are non-ionizing and therefore not considered harmful.

Interactions with matter: Most absorption of radio waves occurs from interaction with charged particles. When a radio wave passes through a material, the wave's electric field component exerts a force on charged particles, such as electrons, causing them to move back and forth. Otherwise, radio waves transmit through most matter, which is one reason why they travel so far on Earth.

Sources: Some natural sources of radio waves include space objects that have a changing magnetic field, like the Sun and other objects in deep space. Artificial sources include radio and TV broadcasting stations and radar and satellite communication systems. The longest radio waves that humans create are used to communicate with submarines in the ocean.

European Southern Observatory (ESO)/C. Malin