Definition:

Simply, radiation describes elementary particles, nuclei and electromagnetic waves as they propagate through space.

The term radiation is often used as a synonym for specifically those forms of electromagnetic radiation (light) that can cause considerable harm, or neutron radiation resulting from nuclear processes.

But in fact, radiation is typically broken up into two specific forms: ionizing (those forms normally associated with the term) and non-ionizing.

Ionizing Radiation

Ionization is the process by which electrons are removed from an atom. This happens all the time in nature, and it merely requires the atom to collide with a photon or particle of sufficient energy as to excite the election(s) to such an extent that the atom can no longer maintain its bond to the particle.

Certain forms of radiation will, by definition, carry enough energy to ionize various atoms or molecules. These ionizing forms of radiation can cause significant harm to biological entities as it can lead to cancer and other significant health problems. The extent of the radiation damage is a matter of how much radiation was absorbed by the organism.

The minimum threshold energy needed for radiation to be considered ionizing is about 10 electron volts (10 eV). There are several forms of radiation that naturally exist above this threshold:

- **Gamma-rays**: Gamma-rays (usually designated by the Greek letter γ) are a form of electromagnetic radiation, and represent the highest energy forms of light in the Universe. This radiation encompasses a broad range of wavelengths; essentially anything less than about 10 picometers (10 pm). Gamma-rays are created through a variety of processes ranging from nuclear reactors to supernovae. Since gamma-rays are electromagnetic radiation, they do not readily interact with atoms unless a head-on collision occurs. In this case the gamma-ray will "decay" into an electron-positron pair. However, should a gamma-ray be absorbed by a biological entity (e.g. a person) then significant harm can be done as it takes a considerable amount of energy to stop a gamma-ray. In this sense, gamma-rays are perhaps the most dangerous form of radiation to humans. Luckily, while gamma-rays can penetrate several miles into our atmosphere before they interact with an atom, our atmosphere is thick enough that most gamma-rays are absorbed before they reach the ground. However, astronauts in space lack protection from gamma-rays, and therefore are limited to the amount of time that they can spend "outside" a space craft or space station before they encounter too much radiation. There have even been some recent studies done to study the radiation levels of airline pilots and frequent fliers, to see how much extra radiation they are receiving by being so high about the Earth's surface for so long. While very high doses of gamma-rays can be fatal, the most likely outcome to repeated expose to above-average doses of gamma-rays (like experienced by astronauts, for instance) is an increased risk of cancer, but there is still only inconclusive data on this.
-

- **X-rays**: X-rays are, like gamma-rays, electromagnetic waves (light). They carry wavelengths between 10 nanometers (10 nm) and 10 picometers (10 pm). They are usually broken up into two classes: Soft X-rays (those with the longer wavelengths) and Hard X-rays (those with the shorter wavelengths). The shorter the wavelength (i.e. the *harder* the X-ray) the more dangerous it is. This is why lower energy X-rays are used in medical imaging. The X-rays will typically ionize smaller atoms, while larger atoms can absorb the radiation as they have larger gaps in their ionization energies. This is why X-ray machines will image things like bones very will (they have composed of heavier elements) while they are poor imagers of soft tissue (lighter elements). It is estimated that X-ray machines, and other derivative devices, account for between 35-50% of the ionizing radiation experienced by people in the United States.
-
- **Alpha Particles**: An alpha particle (designated by the greek letter α) consists of two protons and two neutrons; exactly the same composition as a helium nucleus. However, the academic literature uses the terms separately, arguing that their creation individual creation mechanisms is what sets them apart. Alpha particles are said to be created by by the alpha decay process by which a heavy nucleus ejects a helium nucleus, thereby lowering its mass number by 4 and atomic number by 2. However, there are said to be other mechanisms that can also produce an alpha particle, still distinguishing it from a helium nucleus, however there is some contention about this among academics. Ultimately the proper use of the term is rather ambiguous at best. In any case, the property that separates itself from the common helium nucleus is its kinetic energy; that is, its energy of motion. Focusing on the alpha decay process of creating these particles, by the very nature of the reaction, the alpha particle is ejected from the parent nucleus with very high speed (therefore high energy), usually in excess of 5% o the speed of light. While some alpha particles that come to Earth in the form of cosmic rays may achieve speeds in excess of 10% of the speed of light. Generally, however, alpha particles interact over very short distances, so on the surface of the Earth alpha particle radiation is not a direct threat to life as it is absorbed by our outer atmosphere. However, it *is* a danger for astronauts, and is a source of study as NASA considers sending humans beyond the protection of Earth's atmosphere and magnetosphere (the region of Earth's magnetic field).
-
- **Beta Particles**: The result of beta decay, beta particles (usually described by the greek letter B) are energetic electrons that escape when a neutron decays into a proton, electron and anti-neutrino. These electrons are given kinetic energy that makes them overall more energetic than alpha particles, but less so than high energy gamma-rays. Normally, therefore, beta particles are not of concern to human health as they are easily shielded. Artificially created beta particles (like in accelerators) can penetrate skin more readily as they have considerably higher energy. Some places use these particle beams to treat various kinds of cancer because of their ability to target very specific regions. However the tumor needs to be near the surface as not to damage significant amounts of interspersed tissue.
-
- **Neutron Radiation**: Very high energy neutrons can be created during nuclear fusion or nuclear fission processes. These neutrons can then be absorbed ban an atomic nucleus, causing the atom to go into an excited state and emit gamma-rays. These photons will then excite the atoms around them, creating a chain-reaction, leading to

the area to become radioactive. This is one of the primary ways in which human can be injured while working around nuclear reactors without proper protective gear.

Non-ionizing Radiation

While ionizing radiation (above) gets all the press about being harmful, non-ionizing radiation can also have significant biological effects. For instance non-ionizing radiation can cause things like sunburns, and is capable of cooking food (hence microwave ovens). However, since this radiation doesn't actually cause an atom to fully *ionize* it is classified differently. (This is, actually, not strictly true. Non-ionizing radiation can come in the form of thermal radiation, which can heat material (and hence atoms) to high enough temperatures to cause ionization. However, this process is considered different than kinetic or photon ionization processes which define the above group.)

- **Radio Waves**: Radio waves are the longest wavelength form of electromagnetic radiation (light). They span 1 millimeter to 100 kilometers. This range, however, overlaps with the microwave band (see below). Radio waves are produced naturally by active galaxies (specifically from the area around their supermassive black holes), pulsars and in supernova remnants. But they are also created artificially for the purposes of radio and television transmission.
-
- **Microwaves**: Defined as wavelengths of light between 1 millimeter and 1 meter (1,000 millimeters), microwaves are sometimes considered to be a subset of radio waves. In fact, radio astronomy is generally the study of the microwave band, as longer wavelength radiation is very difficult to detect as it would require detectors of immense size; hence only a few peer beyond the 1 meter wavelength. While non-ionizing, microwaves can still be dangerous to humans as it can impart a large amount of thermal energy to an item due to its interactions with water and water vapor. (This is also why microwave observatories are typically placed in high, dry places on Earth, as to lessen the amount of interference that water vapor in our atmosphere can cause to the experiment.
-
- **Infrared Radiation**: Infrared radiation is the band of electromagnetic radiation that occupies wavelengths between 0.74 micrometers up to 300 micrometers. (There are 1 million micrometers in one meter.) Infrared radiation is very close to optical light, and therefore very similar techniques are used to study it. However, there are some difficulties to overcome; namely infrared light is produced by objects comparable to "room temperature". Since electronics used to power and control infrared telescopes will run at such temperatures, the instruments themselves will give off infrared light, interfering with data acquisition. Therefore the instruments are cooled using liquid helium, so as to lessen extraneous infrared photons from entering the detector. Most of what the Sun emits that reaches the surface of the Earth is actually infrared light, with the visible radiation not far behind (and ultraviolet a distant third).
-
- **Visible (Optical) Light**: The range of wavelengths of visible light is 380 nanometers (nm) and 740 nm. This is the electromagnetic radiation that we are able to detect with our own eyes, all other forms are invisible to us without electronic aids. Visible light is actually only a very small part of the electromagnetic spectrum, which is why it is important to study all other wavelengths in astronomy as to get a complete picture of

the Universe and to understand the physical mechanisms that govern the heavenly bodies.

-
- **Blackbody Radiation**: A blackbody is any object that emits electromagnetic radiation when it is heated, the peak wavelength of light produced will be proportional to the temperature (this is known as Wien's Law). There is no such thing as a perfect blackbody, but many objects like our Sun, the Earth and the coils on your electric stove are pretty good approximations.
-
- **Thermal Radiation**: As particles inside of a material move due to their temperature the resulting kinetic energy can be described as the total thermal energy of the system. In the case of a blackbody object (see above) the thermal energy can be released from the system in the form of electromagnetic radiation.