Fundamentals of Optical Radiation

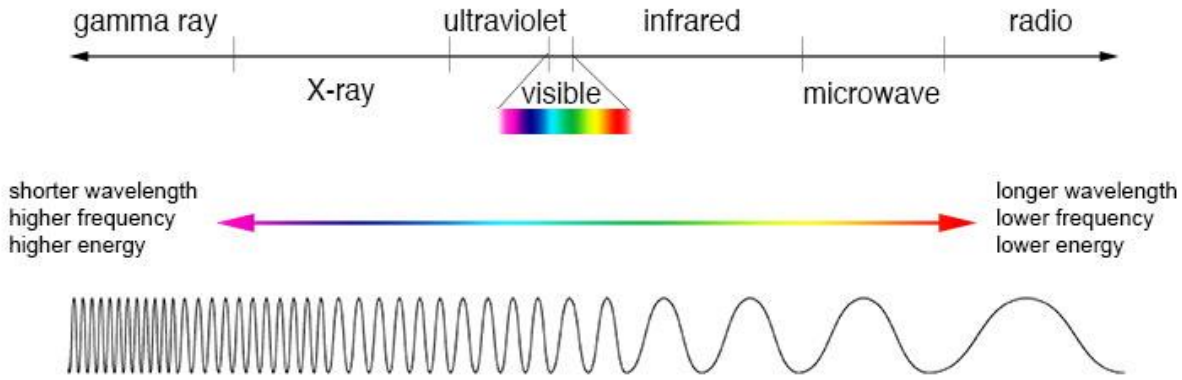
Electromagnetic Spectrum:

Light is of dual nature having particle and wave nature, regarding its wave properties it is a **wave** of alternating electric and magnetic fields and has variant range of wavelength [not single wavelength], hence EM spectrum defined as:

"'the entire range of wavelengths or frequencies or photon energy of **electromagnetic radiation** extending from gamma rays to the longest radio waves and including visible light.'"

The electromagnetic spectrum includes, from longest wavelength to shortest:

- **radio waves**
- **Microwaves**
- **infrared radiation**
- **optical(visible light)**
- **ultraviolet radiation**
- **X-rays**
- **Gamma-rays**



Non-Ionizing Radiation:

Non-ionizing (or **non-ionizing**) **radiation** refers to any type of electromagnetic radiation that does not carry enough energy per quantum (photon energy) to ionize atoms or molecules—that is, to completely remove an electron from an atom or molecule. Instead of producing charged ions when passing through matter, non-ionizing electromagnetic radiation has sufficient energy only for **excitation**, the movement of an electron to a higher energy state.

The usual definitions have suggested that radiation with particle or photon energies less than **10 electronvolts (eV)** be considered non-ionizing. Another suggested threshold is 33 electronvolts,

which is the energy needed to ionize water molecules. The light from the Sun that reaches the earth is largely composed of non-ionizing radiation.

It's located at the low end of the electromagnetic spectrum. Non-ionizing radiation sources include power lines, microwaves, radio waves, infrared radiation, visible light and lasers. Although considered less dangerous than ionizing radiation, overexposure to non-ionizing radiation can cause health issues.

Types of non-ionizing electromagnetic radiation:

1. Near ultraviolet radiation:

Ultraviolet is classified into **near, medium** and **far UV** according to energy, where near and medium ultraviolet is technically non-ionizing, but where all UV wavelengths can cause photochemical reactions that to some extent mimic ionization (including DNA damage and carcinogenesis). UV radiation above **10 eV** (wavelength shorter than **125 nm**) is considered ionizing. However, the rest of the UV spectrum from **3.1 eV (400 nm)** to **10 eV**, although technically non-ionizing, can produce photochemical reactions that are damaging to molecules by means other than simple heat.

2. Visible light:

Light, or visible light, is the very narrow range of electromagnetic radiation that is visible to the human eye (about **400–700 nm**), or up to **380–750 nm**. More broadly, physicists refer to light as electromagnetic radiation of all wavelengths, whether visible or not.

3. Infrared:

Infrared (IR) light is electromagnetic radiation with a wavelength between **0.7 and 300 micrometers**, which equates to a frequency range between approximately **1 and 430 THz**. IR wavelengths are longer than that of visible light but shorter than that of terahertz radiation microwaves.

4. Microwave:

Microwaves are electromagnetic waves with wavelengths ranging from as long as one meter to as short as one millimeter, or equivalently, with frequencies between **300 MHz (0.3 GHz)** and **300 GHz.**

5. Radio waves:

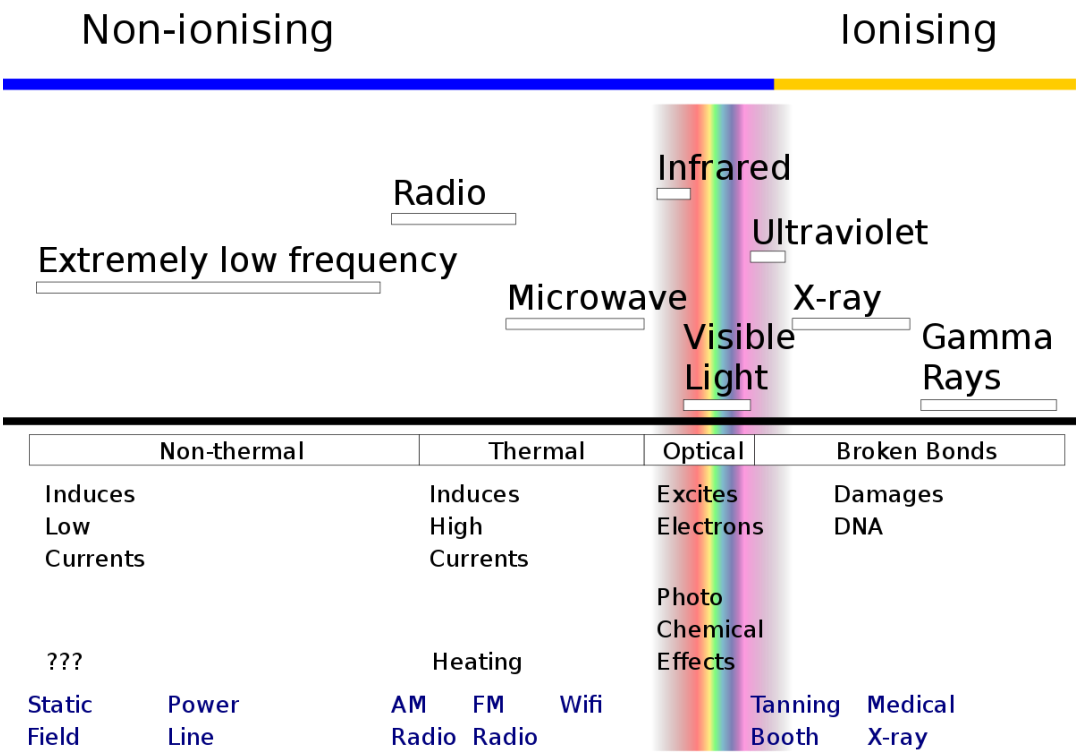
Radio waves are a type of electromagnetic radiation with wavelengths in the electromagnetic spectrum longer than infrared light. Like all other electromagnetic waves, they travel at the speed of light.

6. Very low frequency (VLF):

Very low frequency or VLF is the range of frequency of **3 to 30 kHz**. Since there is not much bandwidth in this band of the radio spectrum, only the very simplest signals are used, such as for radio navigation.

7. Extremely low frequency (ELF):

Extremely low frequency (ELF) is the range of radiation frequencies from **300 Hz to 3 kHz**. In atmosphere science, an alternative definition is usually given, from **3 Hz to 3 kHz.**



Optical Radiation:

It is a part of the electromagnetic spectrum that ranges between wavelengths of **100 nm** to **1 mm**. The range of spectrum includes the following:

- Ultraviolet radiation
- Visible light
- Infrared radiations

They obey the laws of optics i.e. they are focused and refracted with lenses.
There are two main sources:

- Artificial sources such as **UV lights, common light bulbs,** and **radiant heaters**
- The primary source of exposure for most people is the **sun**.

Optical radiation vs EMF:

Electromagnetic fields(EMF) are part of the electromagnetic spectrum and they belong to "non-ionising radiation". More accurately it is defined as:

"The spatial distribution of a **force** which can act upon electric charges and currents”

Over its entire range, the spectrum extends from **static electric and magnetic fields** to very **energetic gamma radiation.**
They differ from optical radiation in the following aspects:

Composition:

- Optical radiation comprises typical **waves** of longitudinal nature and comprises Electric and Magnetic components. These radiations are produced when it has "detached" from its source and propagates on its own through space.

- EMF is a **force** which is produced by waves. This is a force that acts upon any charged particle and causes them to move within their field of range.

Damage:

- Optical radiation produce the following damage:
  - **Thermal injury** to the surface layers of the skin.
  - From natural sources, the thermal injury might be called a **sunburn.**
  - UV light has photon energy causing direct effects to protein structure in tissues, also as **carcinogenic** in humans.
- EMF produce following damage:
  - Low-frequency electric and magnetic fields can produce electric fields and currents in the human body also **vertigo, nausea** and **nerve stimulation**.
  - High-frequency electromagnetic fields can heat up biological tissue.
  - Their energy is too low to cause direct damage to genetic material and for being directly involved in the development of cancer.

Therapeutic uses:

- Optical radiation uses:
  - **Imaging microscopic structures** of superficial tissue layers such as the skin or the gut wall (because of its relatively low penetration depth)**.**
  - **lasers** for surgery and ablation and **ultraviolet irradiation** for skin disorders.

- Electromagnetic fields (EMF) with frequencies between 0 and 300 gigahertz can be used in hospitals for diagnostic or therapeutic purposes.
  - Important diagnostic application of EMF is **magnetic resonance imaging (MRI)**,
  - Transcranial magnetic stimulation and diathermy.
  - Magnetic resonance imaging (MRI), **radiofrequency ablation (RFA)** used in cardiology and tumor therapy.

Components of Optical Radiation:

Optical radiation comprises 3 ranges of the wave as mentioned above, here we will describe each in detail.

1. Ultraviolet radiation:

The wavelength of this part of the spectrum ranges from **100 nanometres (nm)** to **400 nm**. It is the *most powerful* type of radiation among Optical radiation on the basis of energy packets(quanta) they contain. UV radiations are **not visible** to a naked eye even not perceived by other senses. As UV radiations are part of sunlight, on their course towards earth they have to filter through the Ozone layer present in the stratosphere and troposphere, which decreases its intensity.

Ultraviolet light is generally divided into:

- ultraviolet C (200 to 280 **nanometers**)
- ultraviolet B (280 to 320 **nanometers**)
- ultraviolet A (320 to 400 **nanometers**)

Properties of UV radiations:

a) UV INDEX:

Measuring the intensity of UV radiation is expressed as UV Index (UVI). it is best described as:

"The ultraviolet index or UV Index is an international standard measurement of the strength of sunburn-producing ultraviolet (UV) radiation at a particular place and time."

The UV Index describes the expected daily peak level of the erythemal UV irradiance at ground level. Higher the UV Index, the faster a sunburn can occur(skin unprotected). The UV Index is a guide to answering the question of what sun protection measures should be taken.

Influencing factors:

- Location with **horizontal surface area**
- Total **ozone concentration** in the atmosphere
- Cloudiness
- **Altitude** of a location

b) BENEFITS / USES:

UV-B-induced synthesis of endogenous **vitamin D** in the body. 7-dehydrocholesterol is present beneath the skin, which is a precursor of vitamin D, therefore when light strikes on skin containing UV-B radiation it initiates the transformation of 7-dehydrocholesterol.

c) DAMAGE:

Damage caused by UV radiation is categorized on the basis of duration as:

- ➔ **Immediate (Acute):** for example, sunburn of the skin or *"welder's flash"* in the cornea of the eye.

➔ **Long-term (chronic):** for example, premature aging of the skin, skin cancer and in the eyes - opacity of the lens (cataract).

d) PROTECTION:

Some of the highlighted measures are mentioned in the below chart:

UV-Index	Exposure category	Protection measures
1 - 2	low	No protection required: You can safely stay outside!
3 - 5	moderate	Protection required: • Seek shade during midday hours! • Slip on a shirt! • Slop on sunscreen with **sufficient sun protection factor** (SPF) • Slap on a hat! • Wear sunglasses!
6 - 7	high	
8 - 10	very high	Extra protection: • Avoid being outside during midday hours! • Make sure you seek shade! • Shirt, sunscreen with **sufficient sun protection factor** (SPF), sunglasses and hat are a must.
11 and higher	extreme	

2. Visible light:

The wavelength of this part of the spectrum ranges from **400 nanometres (nm)** and **780 nm** visually. It is the only region of optical radiation that is **visible** to the human naked eye. It is the only range of wavelengths that stimulates the brightness and color perception in humans.

Properties of visible light:

a) BENEFITS / USES:

Effectiveness of visible light can be classified as Visual and Non-visual effects:

➔ Visual effects:

It helps in perceiving our surrounding environment by the presence of special receptors called **Rods** and **Cones** in the neural layer “retina” of the eye. Both receptors have

slightly different tasks, Rods are more *light-sensitive* allowing us to see at night while Cones better perform the task of *color perception.*

➔ Non-visual (melanopic) effects:

Visible light also regulates our **Sleep Cycle** [*biological clock*] by releasing endogenous messenger substances and sets the "body clock". There is a layer of photosensitive (light-sensitive) *retinal ganglion cells* in the retina, these cells primarily respond to blue light of visual spectrum and mediate suppression of the secretion of the "sleep hormone"**. Melatonin** from the pineal gland, this keeps us awake in daylight. Even during night, light can inhibit sleep, especially if it has a high proportion of blue light.

b) DAMAGE:

Damage is categorized as Chemical and Thermal:

➔ Chemical effects:

Visible lights seem totally harmless but even it causes harm if it is beyond its normal limits. In the eye this light energy is converted into chemical energy and one of the products of the chemical reaction is reactive oxygen species (ROS). If visible light exceeds its limits, the excess formation of these ROS attacks cellular structures and even DNA, leads photochemical damage to the retina of the eye (photoretinitis).

➔ Thermal effects:

Thermal effects mainly exist in long-wavelength region of visible spectrum i.e. Red region. The damage essentially results from heating, although this is only possible at higher irradiances.

Glare: Exposure of the eye to excess luminous intensity leads to overwhelming adaptation ability. As a result, the person is dazzled.

If the eye is exposed to excess luminous intensity, its ability to adapt is overwhelmed. The person is dazzled. The extent and duration of dazzling depend on several factors, including:

- the luminance and size of the light source
- the point of projection on the retina
- the ambient brightness
- the eye’s state of adaptation
- individual factors such as the age of the affected individual.

Glare limits a person’s ability to see for a certain period of time. Even though this effect is temporary and does not constitute damage to the eyes, it can significantly increase the risk of accidents.

3. Infrared Radiations:

Infrared radiation (IR radiation) - also referred to as thermal radiation - is part of the electromagnetic spectrum. It follows the visible radiation in the direction of longer wavelengths ranging from **780 nanometres** to **1 millimeter.** The most important natural source of IR radiation is the sun.

IR radiation is divided into:

- IR-A radiation (short wavelength) with a wavelength range from **780 to 1400 nanometres.**
- IR-B radiation with a wavelength range from **1400 to 3000 nanometres.**
- IR-C radiation (long wavelength) with a wavelength range from **3000 nanometres to 1 millimeter.**

Properties of Infrared Radiations:

DAMAGE:

High heat loads can interfere with the temperature balance of the body, can cause tissue damage or accelerate **skin aging**. Chronic exposure to heat can contribute to lens opacities (e.g. **glass blowers cataract**).