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2. Optique

2.1.1. Introduction (objectif de l'optique)

2.1.2. Nature de la lumière (spectre des ondes électromagnétiques, photons, ondes…)

2.2. Optique géométrique

2.2.1. Principes de l'optique géométriques et propagation de la lumière.

2.2.2. Réfraction (lois de Snell-Descarte, angle limite et réflexion totale)

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2-Optics

2.1.1. Introduction: Optics is the branch of physics that studies the behaviour and properties of light, including its interactions with matter and the construction of instruments that use or detect it. Optics usually describes the behaviour of visible, ultraviolet, and infrared light. Light is a type of electromagnetic radiation, and other forms of electromagnetic radiation such as X-rays, microwaves, and radio waves exhibit similar properties.

Most optical phenomena can be accounted for by using the classical electromagnetic description of light, however complete electromagnetic descriptions of light are often difficult to apply in practice. Practical optics is usually done using simplified models. The most common of these, geometric optics, treats light as a collection of rays that travel in straight lines and bend when they pass through or reflect from surfaces. Physical optics is a more comprehensive model of light, which includes wave effects such as diffraction and interference that cannot be accounted for in geometric optics. Historically, the ray-based model of light was developed first, followed by the wave model of light. Progress in electromagnetic theory in the 19th century led to the discovery that light waves were in fact electromagnetic radiation.

2.1.2 Nature of light

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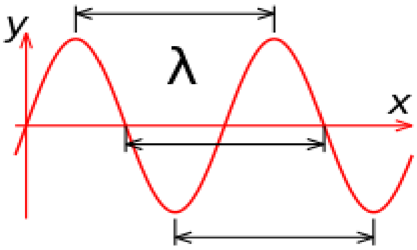
2.1.2.1 Light is electromagnetic radiation that can be detected by the human eye. Electromagnetic radiation occurs over an extremely wide range of wavelengths, from gamma rays with wavelengths less than about 1×10^{-11} meters to radio waves measured in meters.

2.1.2.2 A wavelength is the distance between one point on a wave to the same point on the next wave, such as a crest or trough. Because it is a distance, it is usually reported in units of nm, mm, cm, or m.



The formula to convert wavelength to frequency is given by:

Speed = Frequency x Wavelength

Therefore, Wavelength = (Speed of the wave)/ (Frequency of the wave)

Symbolically, the formula is represented as:

$$C = f \times \lambda$$

Where,

λ is the wavelength of the wave (measured in meters),

C is the speed of the wave in a given medium (measured in m/s),

f, ν is the frequency of the wave (measured in Hertz or 1/s).

2.1.2.3 The photon: Planck’s discoveries paved the way for the discovery of the photon. A photon is the elementary particle, or quantum, of light. Photons can be absorbed or emitted by atoms and molecules. When a photon is absorbed, its energy is transferred to that atom or molecule. Because energy is quantized, the photon’s entire energy is transferred (remember that we cannot transfer fractions of quanta, which are the smallest possible individual “energy packets”). The reverse of this process is also true. When an atom or molecule loses energy, it emits a photon that carries an energy exactly equal to the loss in energy of the atom or molecule.

This change in energy is directly proportional to the frequency of photon emitted or absorbed. This relationship is given by Planck’s famous equation:

$$E = h\nu = \frac{hc}{\lambda}$$

where   is the energy of the photon absorbed or emitted (given in Joules,), is frequency of the photon (given in Hertz,), and   is Planck’s constant,

2.1.2.4 **The Electromagnetic Spectrum**

The **electromagnetic spectrum** is the full range of electromagnetic radiation, organized by frequency or wavelength. The spectrum is divided into separate bands, with different names for the electromagnetic waves within each band. From low to high frequency these are: radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays. The electromagnetic waves in each of these bands have different characteristics, such as how they are produced, how they interact with matter, and their practical applications.

Radio waves, at the low-frequency end of the spectrum, have the lowest photon energy and the longest wavelengths—thousands of kilometers, or more. They can be emitted and received by antennas, and pass through the atmosphere, foliage, and most building materials.

Gamma rays, at the high-frequency end of the spectrum, have the highest photon energies and the shortest wavelengths—much smaller than an atomic nucleus. Gamma rays, X-rays, and extreme ultraviolet rays are called ionizing radiation because their high photon energy is able to ionize atoms, causing chemical reactions.

Visible light and radiation of longer wavelengths are nonionizing; their photons do not have sufficient energy to cause these effects.

Throughout most of the electromagnetic spectrum, spectroscopy can be used to separate waves of different frequencies, so that the intensity of the radiation can be measured as a function of frequency or wavelength. Spectroscopy is used to study the interactions of electromagnetic waves with matter.

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The types of electromagnetic radiation are broadly classified into the following classes (regions, bands or types):

1. Gamma radiation
2. X-ray radiation
3. Ultraviolet radiation
4. Visible light (light that humans can see)
5. Infrared radiation
6. Microwave radiation
7. Radio waves

This classification goes in the increasing order of wavelength, which is characteristic of the type of radiation.

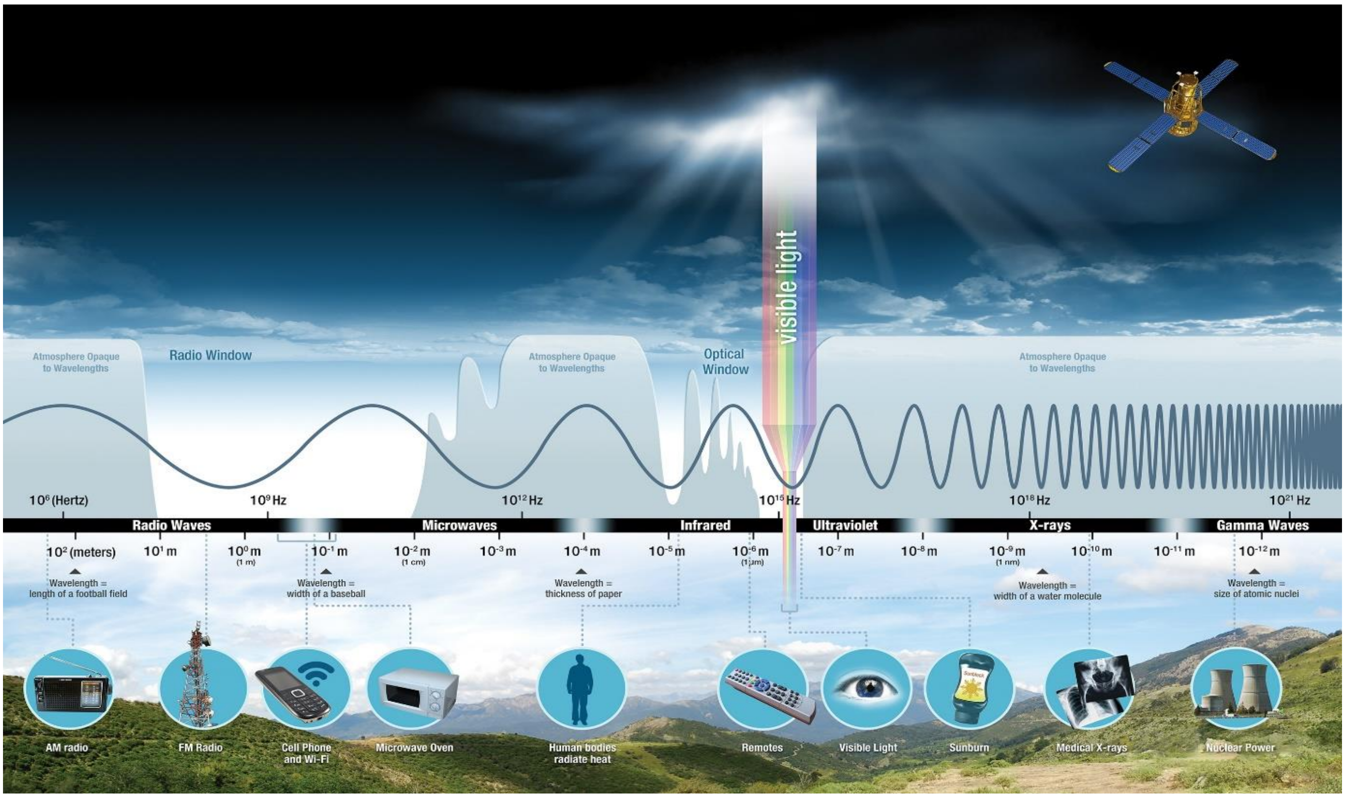

Figure 2.1 : The electromagnetic spectrum

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2.2. Geometric optics:

2.2.1 Geometrical optics, or **ray optics**, is a model of optics that describes light propagation in terms of *rays*. The ray in geometrical optics is an abstraction useful for approximating the paths along which light propagates under certain circumstances.

The simplifying assumptions of geometrical optics include those light rays:

- propagate in straight-line paths as they travel in a homogeneous medium
- bend, and in particular circumstances may split in two, at the interface between two dissimilar media
- follow curved paths in a medium in which the refractive index changes may be absorbed or reflected.

Geometrical optics does not account for certain optical effects such as diffraction and interference. This simplification is useful in practice; it is an excellent approximation when the wavelength is small compared to the size of structures with which the light interacts. The techniques are particularly useful in describing geometrical aspects of imaging, including optical aberrations.

2.2.2. Principles of Light Propagation:

The principles of light propagation govern and explain the actions of light as it traverses diverse materials. Here are some key principles to keep in mind:

- ✓ **Rectilinear Propagation**: When light moves through a uniform medium, it progresses in a straight line. This principle is known as rectilinear propagation.
- ✓ **Reflection and Refraction**: When light waves encounter a change in medium, they can be reflected back into the first medium, or refracted (i.e., transmitted and bent) into the new medium.
- ✓ **Diffraction and Interference**: Light waves can also spread into the regions of shadow when they pass through a narrow slit (diffraction) or superpose to give bright and dark bands (interference).

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Définition of optical parameters

1. REFRACTION INDEX:

The term "refraction of light" refers to how light bends when it travels perpendicularly through transparent media. The refractive index is a measurement of how much a light beam bends as it passes through various materials. The speed of light in a medium reduces as it moves from a rarer to a denser one.

The refractive Index is dimensionless. For a given material, the refractive index is the ratio between the speed of light in a vacuum (c) and the speed of light in the medium (v). If the refractive index for a medium is represented by n, then it is given by the following formula: $n = c/v$

2. DIOPTRES:

A diopter is a surface separating two different medium indexes. Apart from those with mirrors or diffracting surfaces, usual optical systems (camera objective lenses, projection lenses, glasses, microscopes) are exclusively made of a number of diopters.
Optical systems generally have a revolution axis and diopters used are generally spherical or plane. The system axis is the line goring through the diopters centers of curvature; it is perpendicular to the diopters planes.

3. THE LAW OF REFRACTION:

When light travels from one medium to another, it generally bends, or *refracts*. The law of refraction gives us a way of predicting the amount of bend. This law is more complicated than that for reflection, but an understanding of refraction will be necessary for our future discussion of lenses and their applications. The law of refraction is also known as Snell's Law, named for Willobrord Snell, who discovered the law in 1621.

4. Snell's LAW

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Like with reflection, refraction also involves the angles that the incident ray and the refracted ray make with the normal to the surface at the point of refraction. Unlike reflection, refraction also depends on the media through which the light rays are travelling. This dependence is made explicit in Snell's Law via *refractive indices*, numbers which are constant for given media.

Snell's Law is given in the following diagram.

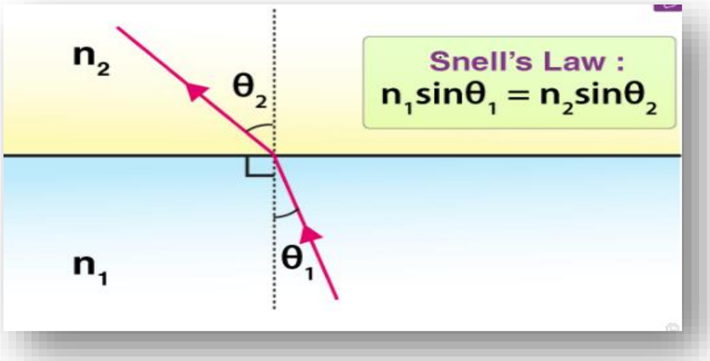


Figure 2.2: Snell's Law.

The normal on the surface is used to gauge the angles that the refracted ray creates at the contact point.

5. COMPLEX Snell's LAW DIAGRAM:

A complex diagram of Snell's Law displays something that is not directly obvious. A ray of light passes through the glass and standing behind it the viewer experiences refraction through three media. The situation is represented in the following diagram :

$$\begin{aligned}\theta_2 &= \sin^{-1}\left(\frac{n_1}{n_2}\sin\theta_1\right)\\ \theta_3 &= \sin^{-1}\left(\frac{n_2}{n_1}\sin\theta_2\right)\\ &= \sin^{-1}\left(\frac{n_2}{n_1}\sin\left(\sin^{-1}\left(\frac{n_1}{n_2}\sin\theta_1\right)\right)\right)\\ &= \sin^{-1}(\sin\theta_1)\\ &= \theta_1\end{aligned}$$

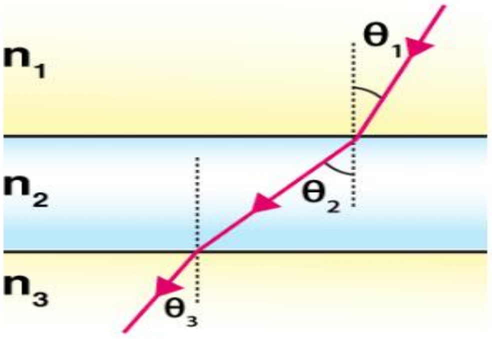
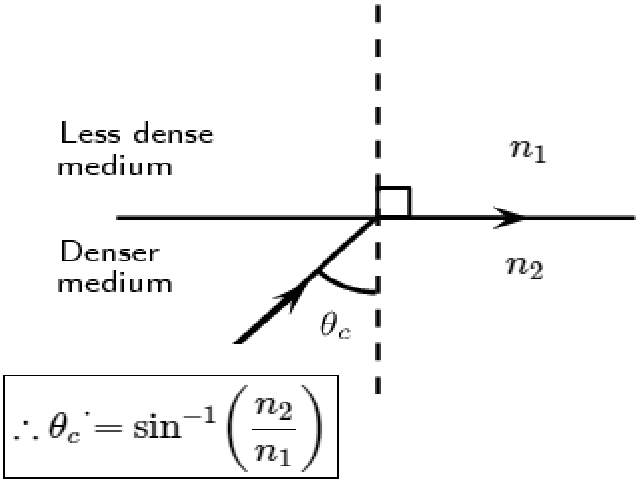


Figure 2.3: A complex diagram of Snell’s Law.

6. CRITICAL ANGLE:

The critical angle is the angle of incidence where the angle of refraction is 90 degrees. Light must travel from an optically more denser medium to an optically less dense medium.



$$\therefore \theta_c = \sin^{-1}\left(\frac{n_2}{n_1}\right)$$

Figure 2.4: When the angle of incidence is equal to the critical angle, the angle of refraction is equal to**90**°.

If the angle of incidence is bigger than this critical angle, the refracted ray will not emerge from the medium, but will be reflected back into the medium. This is called **total internal reflection**.

The conditions for total internal reflection are:

1. Light is travelling from an optically denser medium (higher refractive index) to an optically less dense medium (lower refractive index).
2. The angle of incidence is greater than the critical angle.

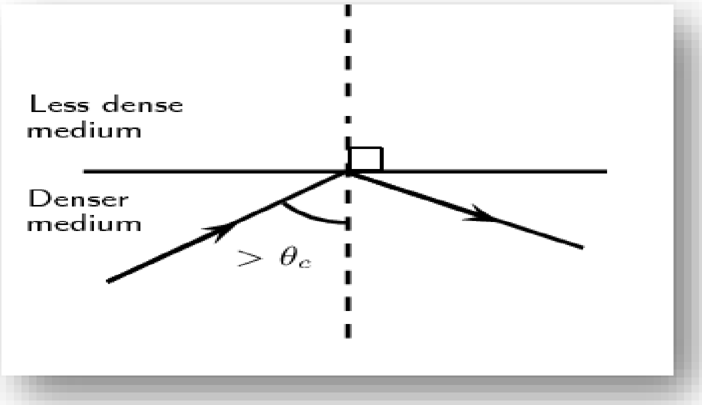


Figure 2.5: When the angle of incidence is greater than the critical angle, the light ray is reflected at the boundary of the two media and total internal reflection occurs.