International Day of Light 2022 - Special Project.

Blue sky, red Moon.

Playing with scattering

Light scattering is the phenomenon by which different wavelengths are refracted at different angles as they pass through material media.

We must remember that light has a dual nature, it is a particle (the carrier of electromagnetic energy, the photon) and in turn it is a wave (the mechanism by which radiation propagates)

We could then represent light, according to its wave nature, by means of a wave, which has certain characteristics: wavelength, frequency (number of waves per unit of time), and amplitude (see Figure 1). The amplitude is related to the intensity, while the wavelength or frequency is related to the energy.

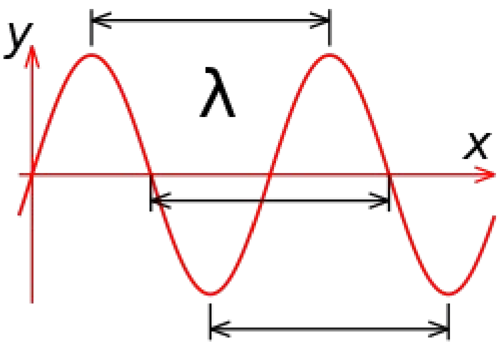

Figure 1. Representation of a wave. The distance between the maxima is called the wavelength, and the number of waves per second is called the frequency.

The wavelength indicates the distance between the maxima of the wave or a complete wave), and is expressed in units of length (m, km or nanometers) and the Greek letter "λ", lambda is used to represent it. On the other hand, the frequency indicates the number of waves per second, and is represented by the unit called Hertz (number of waves/s).

Es sencillo ver qué pasa cuando se multiplican estas dos cantidades entre si, si analizamos las dimensiones, por ejemplo:

$$\lambda \times f = cm/s$$

it turns out a unit of speed!!! what speed are you talking about? of the speed of propagation of the light wave... that is to say "c" (~300.000 km /s)

Since "c" is a constant, when one of the magnitudes is large, the other must be small (long wavelength implies low frequency, for example).

Light interacts with matter and eventually reveals its characteristics producing spectra. Figure 2 has described several characteristics of electromagnetic spectra, the l, energy regions, to highlight that area that the eye can detect between 400 and 700 nanometers, from violet to red

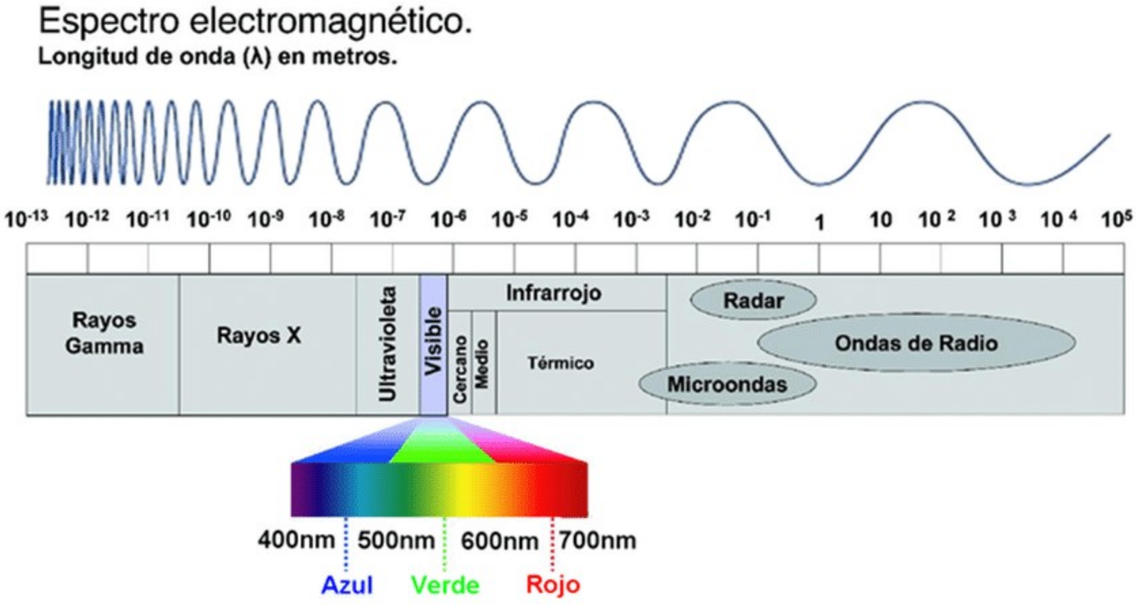

Fig 2.Electromagnetic spectrum, energy regions and different wavelengths. The visible region is highlighted.

Beyond the visible, of course there is more radiation than our eyes can detect. It is interesting to mention that the energy of the radiation can be estimated using a mathematical expression, Planck's Law:

$$E = h .f$$

where "h" is a constant and "f" is the frequency of radiation and that tells us that the energy is greater the greater the frequency; we can use instead of f, λ ($f = c/ \lambda$) and so the expression shows us that for long wavelengths, the energy is low and for short wavelengths, it is high: blue is related to high energies while red is related to the lowest energies in the visible.

Light scattering

Returning to dispersion, the rainbow is perhaps the best known example of this characteristic of light that occurs naturally in nature. But so is the color of the sky, light blue in general, and the color of the sky at sunrise or sunset, reddish.

Rayleigh scattering (named after Lord Rayleigh, who first explained the phenomenon in 1871) is the scattering of electromagnetic radiation by particles whose size is much smaller than the wavelength of the scattered photons11. It occurs when light travels through transparent solids and fluids, but is most often seen in gases. Rayleigh scattering of sunlight in the atmosphere is the main reason why the sky appears blue.

If the size of the particles is greater than the wavelength, the light does not separate, it does not disperse in all the wavelengths that compose it (or in its constituent colors), as when interacting with a cloud it is seen white.

The degree of Rayleigh scattering that a ray of light undergoes depends on the size of the particles and the wavelength of the light and is inversely proportional to the fourth power of the wavelength. ($\sim\lambda^{-4}$), relationship known as Rayleigh's law.

With this wavelength dependence of scattering, in the atmosphere blue and violet light of shorter wavelength will be scattered more than longer wavelengths (yellow light and especially red light) and therefore For this reason we see the bluish sky in all directions (which is actually a mixture of all the scattered colors, mainly blue and green) and we only see it reddened when the Sun is close to the horizon, because the light passes through much more thickness of atmosphere closest to the earth's surface, and the rays reaching us are greatly depleted of photons of shorter-wavelength (blue) and medium-wavelength (green) light, previously scattered from the direct path of the observer.

Light, atmosphere, lunar eclipse

Let us now imagine the situation of a lunar eclipse, with the Sun, the Earth and our satellite aligned and the Moon crossing the shadow cone projected by the Earth. (Figure 3)

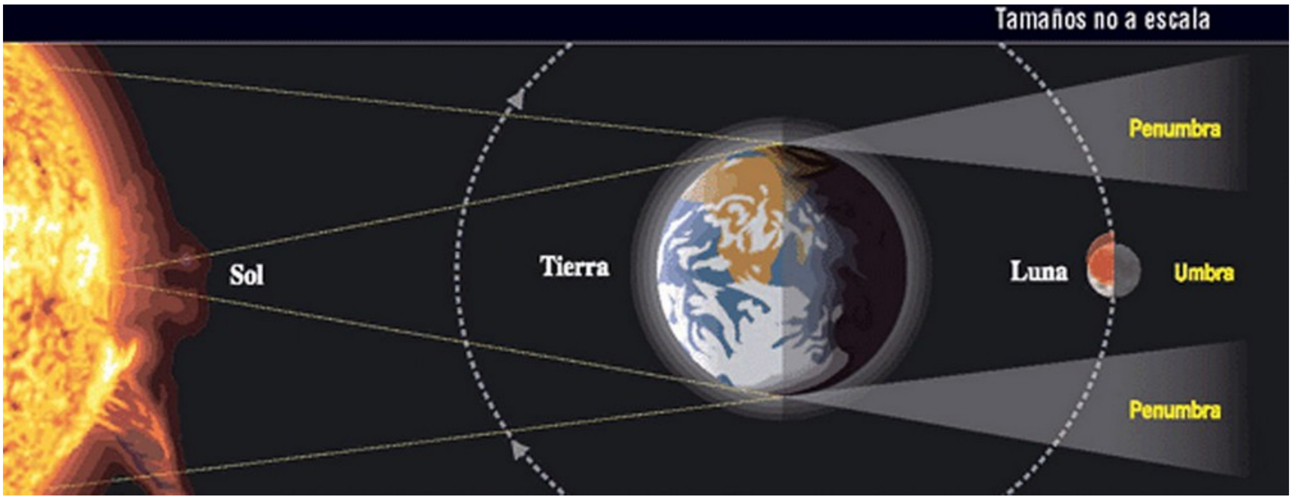

Figura 3. Diagram of a total lunar eclipse (Credit: ESO, Germany)

The light from the Sun reaches our planet and along the edge of the Earth it continues its way towards the Cosmos, but... the short wavelengths (blue, green) scatter a lot while the red passes almost without deviating and manages to illuminate the face of the eclipsed Moon.

That's why in total lunar eclipses, we talk about the red Moon... which is rather orange, a phenomenon that very few people could explain without knowing how light interacts with matter!

Let's do it

Can you imagine how you can demonstrate that light interacting with different materials produces these very interesting phenomena? Do you believe us that scattering makes the sky blue and the sun red at sunset? We invite you to prove it yourself

You should have the following ingredients on hand (simplified list):

1. a glass full of water
2. some drops of milk
3. a cell-phone

if you have another cell phone (from your mom or your sister... you can record the experiment step by step or film it)

The real recipe requires elements that are more difficult to collect in a classroom... but they can be replaced by the ingredients that we detail in the simplified list, an equivalent of "what is really needed" and "what we can use to demonstrate the phenomenon in the laboratory (or the kitchen at home)”:

* You need a Sun (but you are going to replace it with the light of your cell phone, which is produced by a white LED)

*You need an atmosphere, but putting it inside the glass is difficult, so we replace it with water. Water alone does not allow you to see the phenomenon too much… right? (Figure 4)

Figure 4. Glass of water over the cell phone flashlight (left); the same glass seen from the top (right,)

* You need oxygen and nitrogen...this...is also difficult...so we will replace them with a few drops of milk

You must add the milk little by little (you can do it with a syringe without a needle), to notice the difference in the color of the light of your sunshine. (Figure 6)

Figure 6. Adding milk to the full glass

As you add the milk, the light that reaches your eye in the center of the glass (Figure 5) becomes more and more orange, while the light that is on the periphery...outwards, is bluer. There you have... your Sun at sunset... and a complete blue sky! (Figure 7)

Figure 7. Reddened fictitious sun (left): blue sky in the periphery (right)

You can also experiment with a piece of silicone (the kind used for crafts) o any other translucent material and the cell phone light.

To learn more about how to perform the experiment, we recommend you watch these silent videos (Credit: NASE):
silicon https://youtu.be/wWI5hnWJvF0
milk https://youtu.be/J498SCdfNWI

Red Moon

On the day of the lunar eclipse, May 15-16, 2022, the Moon will turn reddish, it is time to take photos, observe (without being dazzled by the light that our satellite reflects) the mountains, mountain ranges and craters in its surface and tell your friends what you learned.

The eclipse will last 5 hours: in Argentina it will start at 22:32 (19:32 UTC) on May 15, it will have its maximum (Moon completely covered) at 1:11 on May 16 (22:11 UTC, May 15) and will end at 03:50 (00:50 UTC)

We await your records of the experiment and observations of the total lunar eclipse (images, movies, audios) ; We are going to make a collaborative video with your contributions that will be uploaded to the page of the Argentine Committee for the International Day of Light!! The contact is:

itedamendoza@gmail.com

We hope you join this challenge!