# EASY EXPERIMENTS TO UNDERSTAND A COMPLICATED EARTH

## 2 Light and color

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What would the world look like without colors?

What is the rainbow made out of?

Why does it have colors?

Why is the rainbow circular?

# Introduction

Light is one of the most important means we use to interact with the world. We do this through our sense of sight. With it, we can get our meals, socialize with others, go from one place to another, or simply admire nature. Speaking of contemplating nature, who has not been delighted to see the blue sky, the different colors of the rainbow or the auburn tones of a sunset? Throughout history, these events have surprised different cultures due to their spectacular and distinctive characteristics. The rainbow in particular is striking thanks to its arching shape, how it appears to be floating between the Earth and the sky, and its colors.

Have you ever thought what the world would be like without colors? In this booklet, we are going to explore the necessary conditions for the rainbow to form and also the way in which we perceive objects and colors.

Before we continue, let me introduce our two friends: Isaac the hamster and his good friend Carmelo the cat, who at this very moment are talking about some very interesting facts related to light.

# Newton´s Experiments

**Carmelo the cat:** You know Isaac, yesterday I saw a spectacular rainbow and several questions came to my mind that I could not answer.

***Isaac the hamster:*** What questions did you have? I might be able to help you find the answers.

**Carmelo the cat:** It is about the rainbow. What is it made out of? Why is it circular? Why does it have colors?

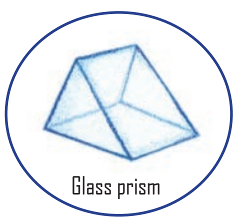
***Isaac the hamster:*** Those are interesting questions. You know Carmelo, one of the first people to answer those questions was my buddy Isaac Newton; he was one of the most outstanding scientists of all times.

**Carmelo the cat:** Really? How did he do it?

***Isaac the hamster:*** *I*n 1666, Isaac Newton carried out the following experiment. On a bright sunny day, he darkened his room and allowed a sunbeam of light to pass through a small hole in the covered windows. He then made this beam go through a piece of glass shaped like a prism. Newton observed a multicolored band of light, with all the colors and distribution of the rainbow coming from the prism. Nowadays, this multicolored band is known as the visible spectrum. Our eyes can can distinguish seven different colors without effort.

Newton noticed that these colors always appeared in the same order from top to bottom: first red, then orange, yellow, green, blue, indigo and finally violet. To make sure that all the colors were contained in the white light and were not generated by the prism, Newton selected one color component by placing a small piece of

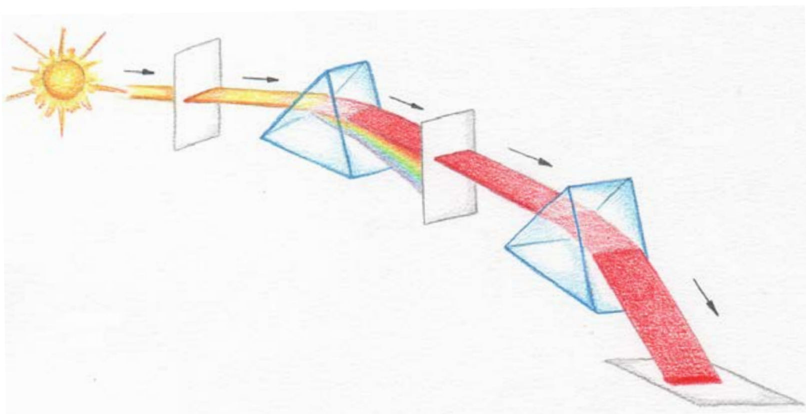
White light is represented as yellow for a better visualization




When a white light or a sun beam goes through a glass prism, the beam decomposes into multiple colors.

cardboard with a small hole where the beam would go through. When making this light component go through a second prism, he observed that it was not separated into colors. Based on this simple experiment, Newton concluded that the white light contained all the colors and that its separation (called the chromatic dispersion of light) was because each color separated or refracted a different amount when the beam went through the prism.

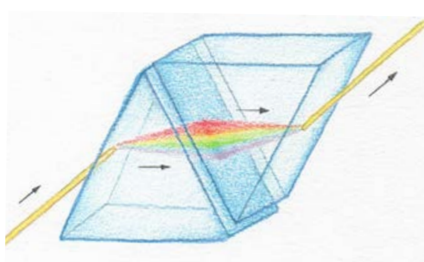
**Carmelo the cat:** Chromatic dispersion? What a strange name!



***Isaac the hamster:*** Also, Newton thought that if all the colors coming out of the prism were contained in the white beam, he could combine them again and produce white light. To prove this, Newton placed an inverted glass prism in front of the multicolored beam. He was right: the colored band, when combined again, produced a white light.

If you are interested in recreating this experiment, you need to get two glass prisms. You can get them at the Optic Research Center (www.cio.mx) and place them as shown in the picture 2 or 3 millimeters apart.

It's easy to do it!



# Refraction of Light

***Isaac the hamster:*** Carmelo, do you know what happens to a light beam when it goes from a transparent environment to a different one; for example from air to glass?

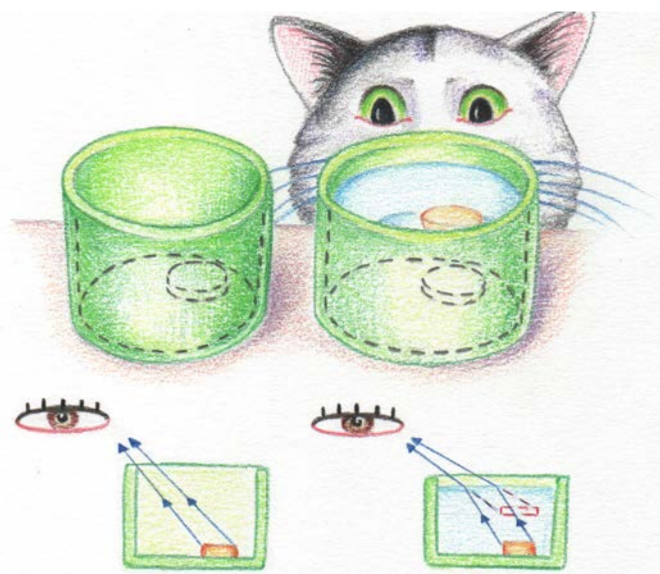
**Carmelo the cat:** No, what happens?

***Isaac the hamster:*** Well, it suffers a deviation in its path. This phenomenon is known as the refraction of light. With the prism you can see that the incoming and the outcoming light both suffer a deviation. At the entry point, the light goes from air to glass and it is refracted, the same occurs at the end point because the light goes from glass to air.

**Carmelo the cat:** I don't understand this very well, can you explain it a little more?

***Isaac the hamster:*** To better understand the refraction of light, let´s invite our friends to do the next experiment. Place a small coin inside a cup so that you can see it from a certain position. Then step away bit by bit until you can only see the edge of the coin. The light coming from the edge of the coin travels directly to your eyes. Now, without moving, ask a friend to slowly pour some water in the cup. What happens? Well, the coin can be seen completely, not just the edge! Do you know why Carmelo?

**Carmelo the cat:** Well, ummm....



Coin Revealing Experiment

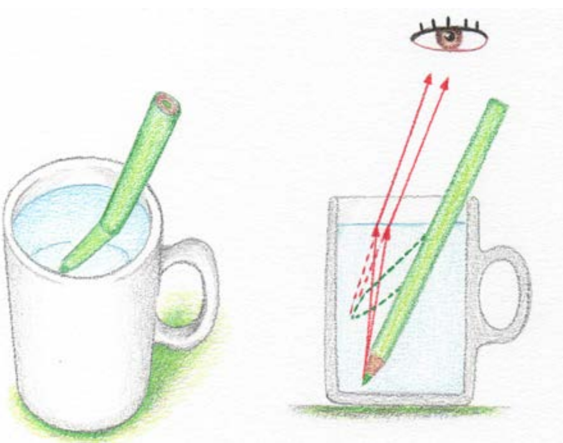
Without water, the light coming from point A, travels in a straight line to Isaac's eye.

With water, the light at each point of the coin, travels in two trajectories towards Isaac's eye.

*Isaac the hamster:* With water, the light that hits the edge of the coin and travels to your eye goes through air and is therefore refracted. This produces the illusion that the light comes from the point where you see it, above from where it actually is. As this happens with all the points on the surface of the coin, you have the impression that the coin is higher than its real position. This same phenomenon explains why objects tend to appear closer in a pool. You know, in ancient times, some aboriginals who used harpoons for fishing knew how to throw them to compensate for the effect of refraction; that is, instead of throwing the harpoon where the saw the fish, they would throw it at an angle that would hit the place where the fish really was. The image we can see inside the glass is known as the virtual image because it does not exist in the position where it appears to be.

**Carmelo the cat:** Meow! How awesome!

*I*



Distortion of an object due to the phenomenon called refraction.

On the right side you can see that the pencil tip seems to be higher when there is water.

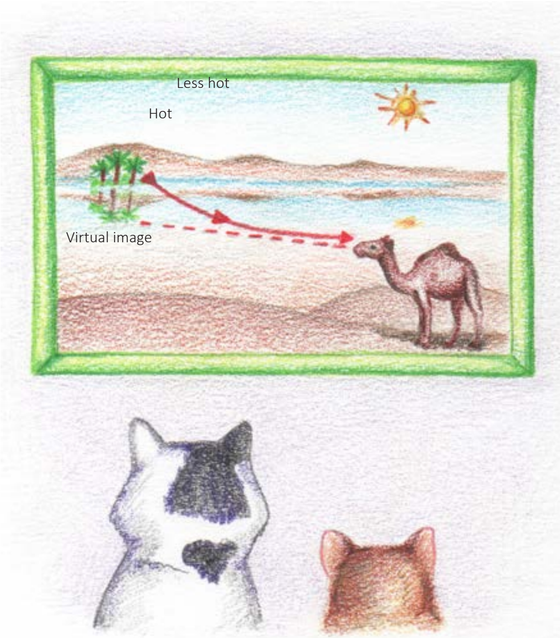
*saac the hamster:* Refraction also explains why the shape of objects changes when they are in the water.

The mirages produced in the desert or when we travel by road are due to the refraction of light. In those circumstances, you can see objects at a distance (generally water) on the floor, but when you reach the place there is nothing. This is another example of a virtual image.

**Carmelo the cat:** I see, but how does this happen?

*Isaac the hamster:* I am going to give you an example using the scene represented in the picture on that wall. There, the camel sees a palm tree that's apparently inside of a lake at a distance. Let´s see what's happening. In broad daylight, the air closer to the floor is warmer than the one at a higher altitude. The difference in temperature makes the light refract differently at various heights; this means that the air's ability to refract light depends on its temperature. Because air has different temperatures at different heights, the light that travels from a distant object (like the palm tree) decomposes into various trajectories before it reaches the observer´s eye. What seems to be a lake is the virtual image of the sky on the floor.

**Carmelo the cat:** Oh! Just like in movies!



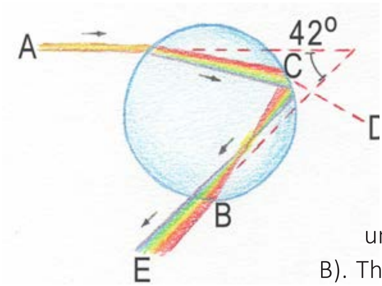

The air closer to a hot surface produces virtual images of objects that are relatively far from the observer. This phenomenon is called a mirage.

***Isaac the hamster:*** So now you know why light is refracted or deviated but you still do not know why each color is deviated at a different angle as in the example of the decomposition of colors in the prism. The modern explanation to this is that a transparent material responds differently to each color due to its atomic structure.

**Carmelo the cat:** Oh!

# The rainbow

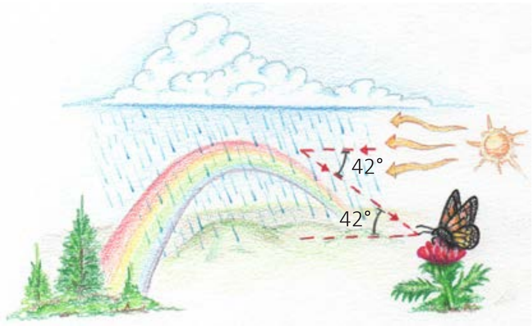
***Isaac the hamster:*** Chromatic dispersion is the decomposition of white light into all its colors because each color is refracted differently when it goes from one medium to another. A spectacular example of this can be seen in a rainbow. Rainbows are formed because the white light from the Sun is chromatically dispersed and reflected in water droplets; let me show you with a picture. First, light is dispersed when going through a water droplet (point A) and when it reaches




the surface on the other side (point C) it is reflected, similar to what happens with a mirror. In this way, a fraction of light coming from point A is reflected to point B and another one to point D, which cannot be seen by an observer at point E. After this reflection, the beams continue spreading until they come out of the water droplet (point B). Therefore, each water droplet causes a small dispersion of the sunlight and all the water droplets that are in an adequate position between the observer and the Sun contribute to a virtual image of the multi colored arch called a rainbow.

This phenomenon is a lot more noticeable at a 42º angle between the observer and the light source. Furthermore, if we consider the spherical symmetry of the water droplets, which means they can be perceived the same from any angle, then all the water droplets that are at that 42º angle form a circular arch.

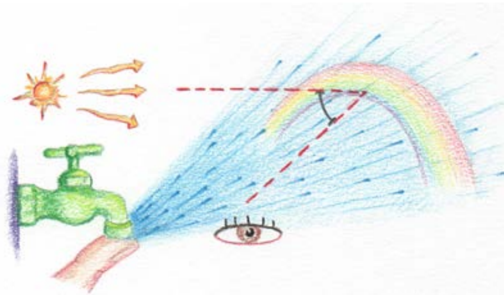
**Carmelo the cat:** Well…!




The rainbow is formed due to the chromatic dispersion and to the reflection of light coming from the Sun inside the water rain drops.

# Create a rainbow

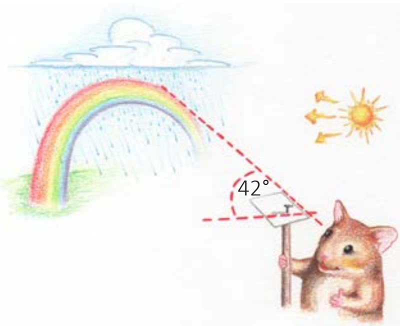
***Isaac the hamster:*** On a sunny day, we can simulate rainfall using the water from a tap, a hose and our finger. Then to observe the rainbow we just need to make sure the angle between the light and the observation point is 42º.



# How to measure the size of a rainbow?

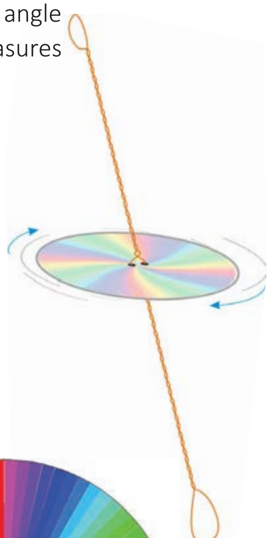
***Isaac the hamster:*** Tell me Carmelo, how do you think you could measure the angular size of a rainbow?

**Carmelo the cat:** With a ruler, right?




***Isaac the hamster:*** Not exactly, but I suggest you try this other experiment. Cut a piece of cardboard in a rectangular shape of about 10 cm by 20cm and place it onto a stick or anything vertical that can support it (like a stick) using a nail or tape. Aim one of the edges of the paper towards the highest point of the rainbow arch. Measure the angle between the shadow of the nail, which will indicate the direction of the sunlight and the edge of the paper. This angle is half the size of the angular size of the rainbow and measures about 42º. This is the size of the rainbow.

**Carmelo the cat:** Meow!



# Newton´s color disc

***Isaac the hamster:*** Carmelo, to recombine the different colors of the light into a white light we can use the two prisms or a disc containing certain colors. When you spin the disc fast enough (using a fan or spinner) your eyes perceive the color of the disc as white.

Newton's color disc, used to obtain white light by combining different colors. You can make it spin with a thread as shown in the picture.

# Polarization of light

***Isaac the hamster:*** Now you know, Carmelo: to form a rainbow you need sunlight and rain; that is, the sky cannot be completely cloudy. Also, the angle between the sunlight and the observation point must be 42º.

On a sunny and rainy day try to spot the rainbow. Get some polarized lenses and observe the rainbow. What happens? Well, part of the arch disappears! Now turn your head about 90º in any direction without removing your lenses and observe how it changes.

In addition to color, another important characteristic of light is polarization. Polarized lenses, as well as some insects, can detect polarization, but not the human eye by itself. Polarized lenses are designed to block or absorb the light of a specific type of polarization.

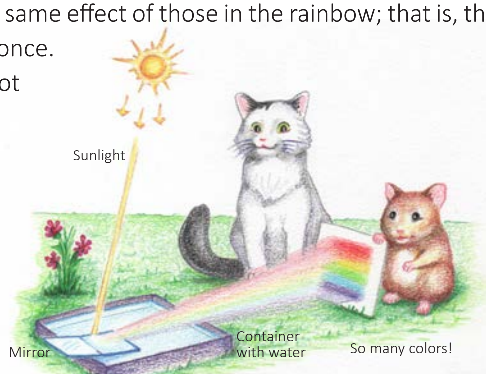
We know that the light reflected inside the water droplets has a different polarization depending on the positions of the droplets in regards to the rainbow. That is why, when we observe the rainbow with polarized lenses, the light coming from specific parts of the arch is completely blocked and others are partially transmitted to our eyes.

**Carmelo the cat:** Polarization! I've never heard of that either.

# Create your own color spectrum

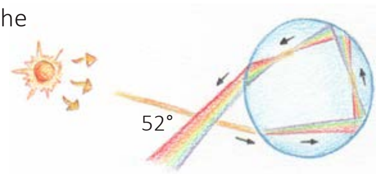
***Isaac the hamster:*** Carmelo, get a mirror and place it in a container with water. Use a white piece of paper to observe the light reflected by the mirror from a few meters away. What you will see on the paper is a beautiful color spectrum. How did it form? Remember that some of the light beams that reach the mirror go into the water, reflect onto that same mirror and are then refracted when they leave the water. These beams suffer the same effect of those in the rainbow; that is, they are refracted twice and reflected once.

Observe that, actually, there are not only seven colors but an infinite number of them. For example, if you carefully observe the spectrum, you can see that there is a great variety of shades of red, green, etc.



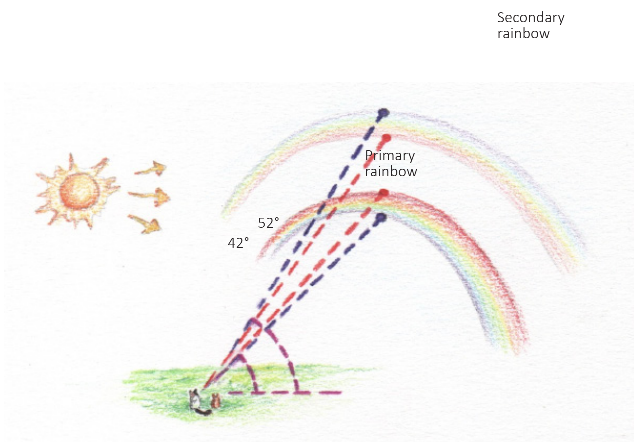
# Secondary Rainbow

***Isaac the hamster:*** Carmelo, if you carefully observe a rainbow, you may be able to see that there is another rainbow, that's not as bright, as the first one. This is known as the secondary rainbow and it is produced by a second reflection in the water droplets. In these types of rainbows, the order of the colors is reversed.




**Carmelo the cat:** Yes! I've seen it before.

Besides the primary rainbow there is another rainbow on top. This is known as the secondary rainbow



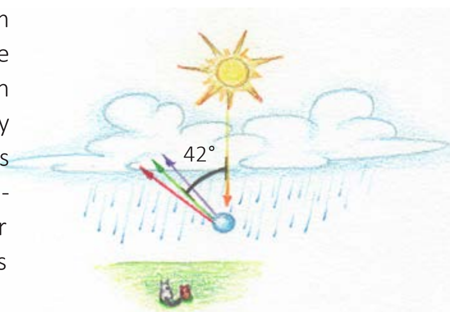

# Interesting facts about the rainbow

**Carmelo the cat:** And can you go through a rainbow?

***Isaac the hamster:*** No. When you stand and observe the rainbow you see all the water drops that are at a 42º angle between the incoming light and the observation point. When you move towards the rainbow, other water droplets different from the previous ones are now at that same angle. Therefore, when you move, the rainbow also moves, although it would seem to stay still. Of course, this only happens if there are other water droplets that can reflect the light to our eyes.

**Carmelo the cat:** I noticed that in the primary rainbow, the red color is above the violet, but according to what happens to light in a single water droplet this should be reversed.


***Isaac the hamster:*** Good point. The 42º angle at which the rainbow can be seen is just an average. For the red component the exact angle is 43º and for the violet is 41º. This makes the angular width of the rainbow 43º - 41° = 2º. When the dispersed red component from a water drop reaches the eye of the observer the violet one cannot be seen. However, the violet component located in a water droplet 2º below the previous one can indeed be seen. In this way, the red comes from the water drops located in the outermost part of the rainbow and the violet one comes from the drops located in the innermost part. The water droplets that contribute to the formation of the rainbow have a diameter approximately between 0.25mm and 4 mm. Bigger droplets tend to flatten on their way to the floor: contrary to what most people think, big water droplets are not "tear" shaped and small ones are spherical.





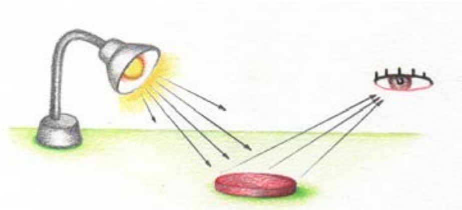
In these figures a single water droplet and its chromatic dispersion in a light beam is represented when it's noon (top figure) and during dawn (bottom figure).

The 42º angle between the light and the observation point is also influenced by the time of day in which the rainbow is observed. When the sun is high in the sky, for example at noon, the light of the arch generally does not reach an observer, which makes it very hard to see a rainbow at this time of day from the Earth. However, in the afternoon or early in the morning, when the sun is almost on the horizon, you can most likely see a rainbow in all its splendor.

# The world of colors

***Isaac the hamster:*** To finish I am going to describe to you the way we perceive the color of the different objects that surround us. We can see most of the objects because they are lit.

There are some objects that have their own light, for example the Sun, a lamp or a firefly. You can think of an object as formed by many dots, and each dot receives light, part of it is absorbed and another is spread out in all directions. If some of these rays reach an observer's eye, then he can see the object. If the object absorbs all the light, then it cannot reach the observer's eye and the object is seen as black. In this way, black is the absence of light and is not a color. Similarly, if you are somewhere where there is light but no object to reflect it towards our eyes, then everything looks black as well. This explains why the color of the sky at night is black, except for the stars and planets. Stars have their own light because they are like our Sun, but the planets and the Moon don´t have a light of their own and they still shine. Why?



**Carmelo the cat:** Because they reflect light?

***Isaac the hamster:*** Very good! Also, if objects do not absorb all the light, then they are perceived as the color that they do reflect. In the case of a red coin, it is seen as red because it absorbs all the white light except the part of the red color. Similarly, if an object illuminated with a white light is perceived as yellow it is because the blue color is absorbed, in other words, it mainly reflects the green and red color. And so, when you shine a blue light on a yellow object, the object will look black because the light it gets completely absorbed: there is no other light to reflect.

We know that when you combine three colors, called primary colors, you can get the rest of the colors, depending on the amount you use of each. One set of primary colors is red, green and blue. Thus if we combine equal parts of red and green we get yellow; if we combine the same amount of green and blue, we get light blue. The combination of the same amount of the three primary colors produces white. Another set of primary colors is light blue, magenta and yellow. These colors when combined in equal parts produce black. In the art world, red, blue and yellow are normally considered to be the primary colors.

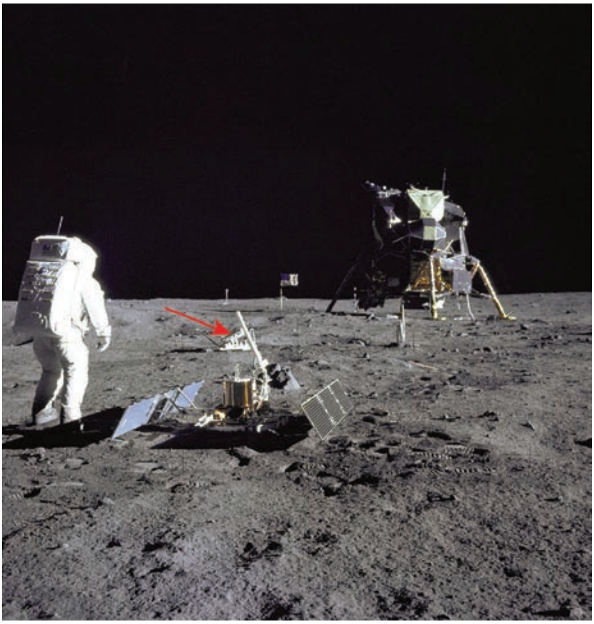
Fun fact: the most common color used in the flags of different countries is red, generally because it attracts attention and is associated to fire and blood.

**Carmelo the cat:** Then, is that why red is also used in traffic lights?

***Isaac the hamster:*** Exactly! But other colors in nature like the blue of the sky or the white of the clouds cannot be explained using only the phenomenon of absorption.

Besides reflection, absorption and refraction; there is another phenomenon called scattering. Here, we consider all objects formed by other smaller ones that absorb and scatter light in all directions.

These smaller objects can be, for example, the different molecules that make up air, the water droplets that make up clouds, the grains of material contained in a chalk, the ice crystals in snow, the particles of milk, and so on.



This photograph was taken on July 2nd, 1969 by the first man who stepped on the Moon, astronaut Neil Armstrong. In the picture you can see Edwin E. Aldrin with a seismic experimentation module. In the back, you can see the Eagle lunar module and in the middle marked with an arrow, a mirror called a retro reflector. With this device we were able to calculate that the Moon is moving 3.8 cms farther away from Earth each year. Picture courtesy of NASA, AS11-40-5948, http://grin.hq.nasa.gov/BROWSE/apollo11_1.html

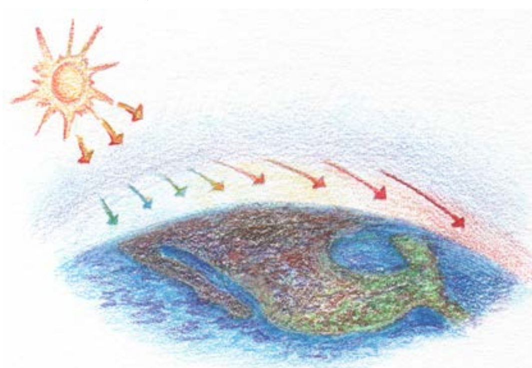
If there were no atmosphere with all its particles, the sky would be black during the day (except for the light of the stars and the planets) since there would not be anything to scatter the sunlight to our eyes. This fact was confirmed with the first pictures taken from the Moon in plain daylight in 1969, where the sky looks like a black background from the moon.This happens because the atmosphere in the Moon is very thin and has almost no material to scatter light.

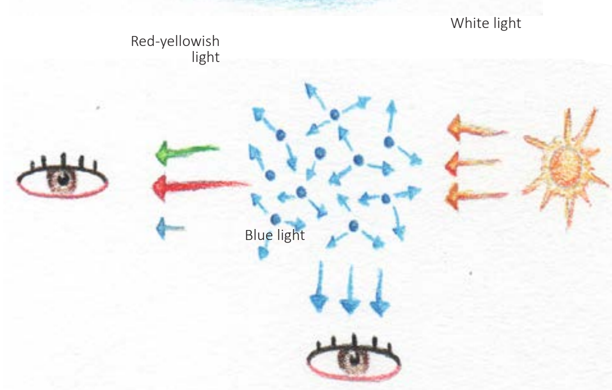
**Carmelo the cat:** How interesting! A black sky in the middle of the day!

***Isaac the hamster:*** When particles have a size smaller than a fiftieth of the thickness of human hair, like for example air particles, how much light is scattered depends on the color it is illuminated with. A molecule of nitrogen (air is around 78% Nitrogen) mainly scatters blue; the other colors are scattered as well, just not as much. **This is one of the main reasons why the sky looks blue in any direction you observe it. This also explains the redness of sunsets: the blue component is very weak by the time it hits our eyes.**

**Carmelo the cat:** But at noon the part of the sky that's closer to the Sun does not look red. Why?

***Isaac the hamster:*** Good observation skills! In this case, the light closer to the Sun looks yellow. The difference between the color perceived at noon and the color during the sunset has to do with the different amount of blue present in the light that reaches an observer. If there were no blue component, the light would have an orange-red color; however, if there was a small amount of blue combined with the rest of the colors, the resulting light would be yellowish. At sunset, less light reaches an observer because during that time of day, the white light coming from the Sun must travel through more air than in any other time of the day and that is why the blue component of light suffers a lot more scattering and does not reach an observer´s eye.



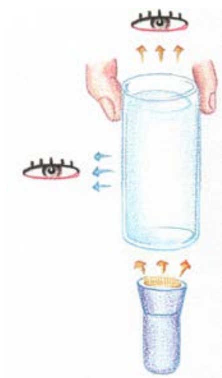


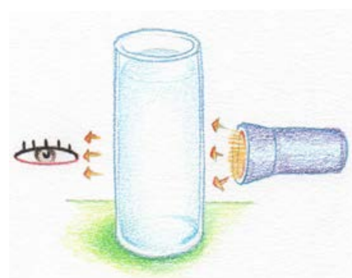

Scattering of white light (which has the same amount of red, green and blue) due to the molecules in the air (blue dots) . The blue arrows represent the scattering of mostly the blue light.

**Carmelo the cat:** I can´t stop being amazed!

To confirm what I just said, let´s invite our friends to do the following experiment. Get a transparent glass and pour water inside (about 350 millimeters). Then, add between 20 to 40 drops of milk (1-2 millimeters) and mix well. In a dark room, ask a friend to shine a flashlight from the top. If you observe it from the side, you will see that the light has a very light blue color. But if you look at it from below, you will see that the light from the flashlight has an orange reddish color. In this experiment, the milk particles (fat and protein molecules) have the same effect on the white light of the flashlight as that of the different air molecules on the white light of the Sun. Finally, if you shine the flashlight on one side of the glass and look through from the opposite side, what do you expect to see? Well, it would again be a light with a reddish tone, but not as red as the previous case because here, the light goes through less ¨milk in water¨ and therefore does not scatter as much blue.

Experiment which shows the scattering of white light caused by dissolved milk in water.
Observe what happens when you look at the scattered light using a pair of polarized lenses from different positions. From each position, turn the lenses around.





***Isaac the hamster:*** Now, if the objects are composed of bigger particles than those described before, then the scattering of light has no preference for a specific color and the small objects scatter all the colors in equal amounts. The ending result is that the observer perceives all the components of colors and therefore identifies the light as white.

This is exactly what happens when the Sun shines over the water droplets contained in a cloud, making them look white. But, why do some clouds look dark?

**Carmelo the cat:** Because they do not get much light…

***Isaac the hamster:*** Exactly! Sometimes the higher parts of the cloud project shadows over the lower parts, and in doing so the lower parts get less light so there is not much to be scattered. Also, if a cloud is relatively thicker, then not much light can get to the edges and this can also produce a dark color.

**Carmelo the cat:** Oh!

***Isaac the hamster:*** The same mechanism that produces the whiteness of clouds, makes salt, sugar, foam, chalk and snow be perceived as white. The small particles that make up these objects are individually transparent to light.

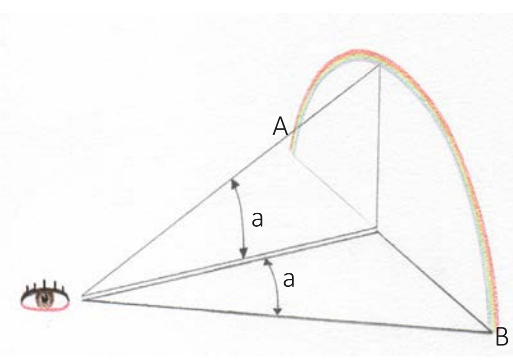
You can confirm this by observing a single grain of salt and then a pinch of salt. In the first case, the grain will look transparent but the pinch of salt will look white. Something similar occurs with bubbles, which are transparent when looked at individually, but look white when they become foam.

**Carmelo the cat:** Of course! I hadn’t realized that!

# Conclusion

***Isaac the hamster:*** Carmelo, now it is possible to answer the questions you had at the beginning about the rainbow: a) what is it made out of? ; b) why is the rainbow circular? and c) why does it have colors?. The answers are as follows: a) it is made of light, b) first, inside a water droplet the phenomenon of dispersion and refraction are more notorious at an established angle between the direction of light and the direction of the observer. Secondly, due to the spherical shape of the droplets, all the ones located at the specified angle reflect light in a similar way. Thirdly, all the water droplets located at a constant angle from the observer generate a cone with an apex in the observer's eyes and the projection of that cone on the wall of rain is the arch of a circle. c) Due to the chromatic dispersion of light produced by the water droplets when there is rain.

In this figure you can see that the projection of a half a cone over a plane is the base of the cone, that is, it is a semi-circle. A cone is a geometrical figure obtained by rotating a straight line around an axe of revolution (middle dotted line) at a constant angle a. This happens with the rainbow, where a = 42º and the direction of light coming from the Sun corresponds to the revolution axis.




In this picture you can only see half the cone, because this is what generally happens with the rainbow, that is, there are no water droplets below the ground that help shape the other half of the cone or the other half of the circle. However, if we observe the rain from an airplane or from a mountain, you are able to see the complete circle. In the figure you can see that the angular size of the rainbow is 2a= 84º, that is, the number of degrees that exist between two completely opposite points over the rainbow, for example between A and B. In this same figure you can also observe two different people produce a different cone because they have different positions and therefore they see slightly different rainbows.

**Carmelo the cat:** Now I get why the word ¨arco¨ is in the Spanish word for rainbow: “arcoíris¨, but I don't understand why the word “iris¨.

***Isaac the hamster:*** The word ¨Iris¨ comes from the Greek goddess who was considered the personification of the multi-colored arch of light. That is why in Spanish, rainbow is called arcoíris. Nowadays, the word ¨iris¨ is associated with some colorful things like the part of our eyes with color. In english, the word “rainbow” comes from its origin in water droplets and arch shape!

Friends, before we say goodbye, Carmelo and I would like to invite you to carry out all the experiments described here. Remember the wise words of Confucius, “I was told and I forgot, I saw it and I understood, I did it and I learned”.

That was an interesting conversation between our friends Isaac and Carmelo. Thanks to them we learned a lot of things. I hope they share their next conversation with us.

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# Isaac Newton (1643-1727)

He is considered the most important scientist in the history of science. He was born on the 4th of January in 1643 in Woolthorpe, Lincolnshire, England. During his school years, he was mainly a self-taught learner. In 1665, he obtained his degree in Arts from Cambridge University. In those times, to get this degree you had to be knowledgeable in History, Latin, Math and religion. Between 1664 and 1689 he was highly productive in a lot of sciences, he contributed in areas like Mathematics and Physics with the description of the nature of light, the invention of calculus, the binomial theorem, and formulating laws of classical mechanics like the cooling laws and universal gravitation. In 1685 he published what is considered to be one of the most important scientific writings of all times: ***Philosophiae Naturalis Principia Mathematica*** (Mathematical Principles of Natural Philosophy). This, like many other science books between the XVII and XVIII century, were written in Latin. Nowadays the language mostly used to share scientific knowledge is English.

It is quite common to associate the notion that the law of gravity was discovered when he observed an apple fall from a tree. It seems that he realized that the apple fell to the floor as the consequence of an invisible influence of the Earth called gravity. He considered that this kind of influence would also exist between any other pair of objects, for example the Earth and the Moon

Using the law of gravity, Newton could explain important physical phenomena such as the movement of the planets and the origin of tides
Using his observations on the chromatic dispersion of light, Newton realized that the telescopes of his time, which were used to see objects at a distance, created different images for each color which made the final images blurry. Newton tried to solve this problem by using different kinds of lenses but because of the low quality of the glass he did not achieve his goal. However, he did solve this problem by using mirrors. Mirrors do not produce chromatic dispersion because light does not go through the material. Nowadays, many of the most powerful telescopes in the world are built using mirrors. Newton built his telescopes with mirrors in 1670.

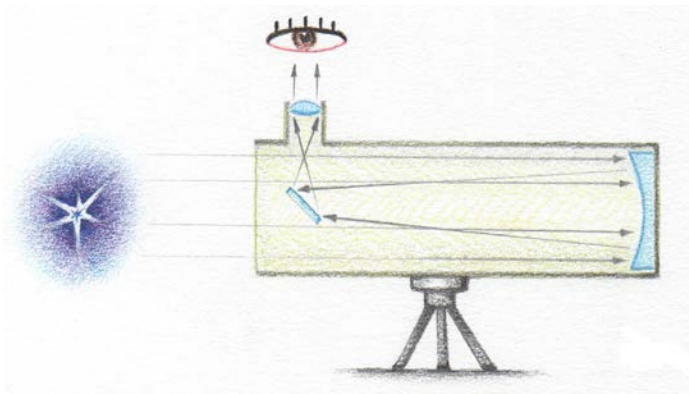
# About the author

**Bernardino Barrientos García** graduated as an electromechanic engineer from the Technological Institute in León in 1993. He obtained his Masters and Phd in Sciences specializing in Optics from the Research Optics Center A.C. (CIO) between 1994 and 1999. Nowadays, he works as a researcher at CIO. His area of expertise is the application of optics in Mechanics.

# About translators

**Ma. Elena Delgado** holds an MA in TESOL ( teaching of English to Speakers of other languages) from the Univ. of Las Americas. She is currently teaching at high school 1 Gabino Barreda from the UNAM. She has taught English courses from A1 to C1 preparing students for Cambridge certifications. Her main interests are related to the use of ICT to enhance the learner´s learning experience. She is also involved in teacher training courses and distance education at the UNAM. In the last three years, she has incorporated the Content-language Integrated learning in her classes with Science topics.

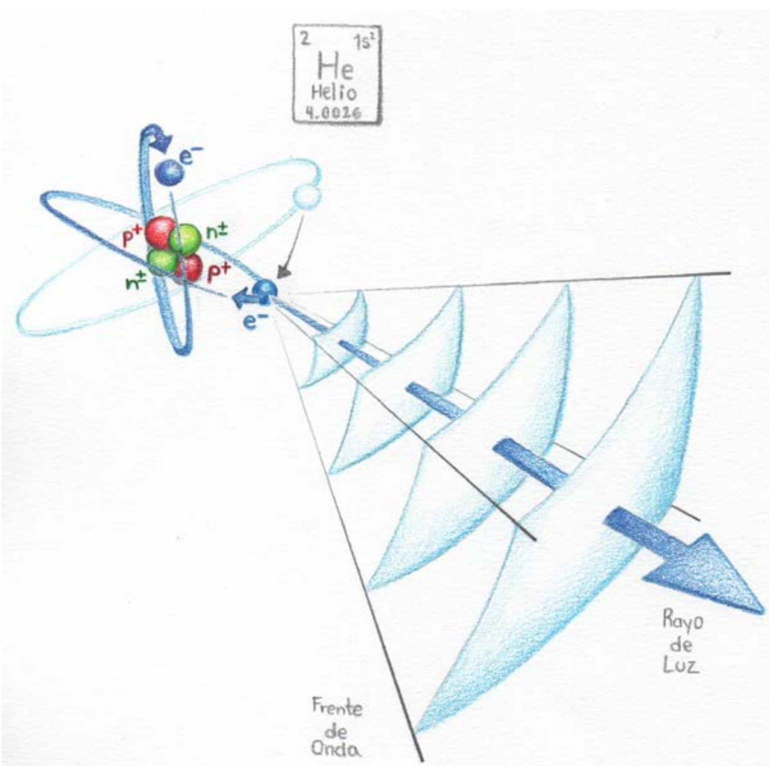
**Federico Cruz** has been studying English since elementary school, having lived in Cincinnati, Ohio for more than 6 years, and has not stopped since. He frequently collaborates with University researchers, revising English work for journal publications and has written popular science articles for online publications. He studied Mathematics at the UNAM, with a focus on Agent Based Modelling. He currently lives and works in Mexico City.



Scheme of light coming from an object far away such as the light of a star. The light falls on a mirror situated in the back of a telescope and is reflected onto a smaller mirror. Then the light passes through a set of lenses called the ocular, to form the image of the object in the observer's eye.

Newtonian Telescope built at the Optics Research Center in León, Guanajuato.

Light is a type of energy (the ability to produce change) that can be depicted by rays (lines). Rays move at a speed of 300,000 Kilometeres per second, km/s (at this speed, you could do 7.5 laps around the world in just 1 second!). Rays do not divert if the medium they travel through is always the same. If the medium changes, for example when a ray goes from air to water, then the rays change direction, like in the refraction and reflection phenomena. Light can also be depicted as a flow of energy particles called photons. Surprisingly, light can also be represented as a wave, where the wave represents not only an electrical component, but a magnetic part as well.



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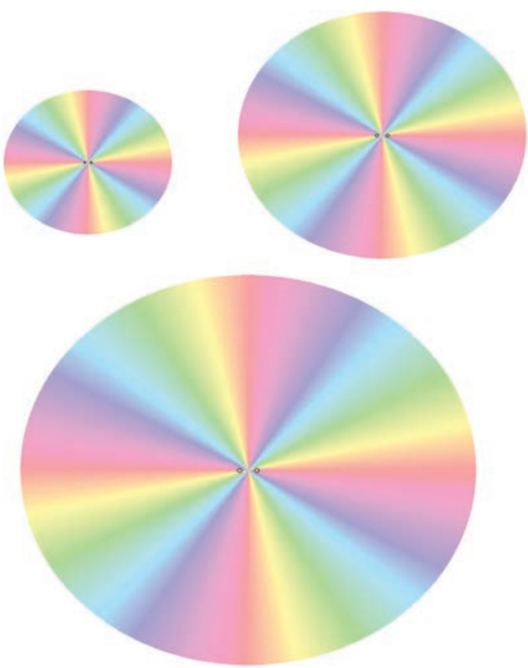

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