EASY EXPERIMENTS TO UNDERSTAND A COMPLICATED EARTH

THE EARTH AND ITS WAVES

5

Text
Juan Martín Gómez González and Susana A. Alaniz Álvarez
Ilustration
J. Jesús Silva Corona and Elisa López
Translated by
Carlos Mendoza and María de los Angeles Labardini Flores

Universidad Nacional Autónoma de México

Enrique Luis Graue Wiechers
Rector

Leonardo Lomelí Vanegas
General Secretary

Jorge Volpi Escalante
Coordinator of Cultural Diffusion

William Henry Lee Alardín
Coordinator of Scientific Research

Socorro Venegas Pérez
General Director of Publications and Editorial Promotion

Lucia Capra Pedol
Director of Geoscience Center

Susana A. Alaniz Álvarez
Ángel F. Nieto Samaniego
Yadira A. Hadassa Hernández Pérez
Editors

Nicholas Shipman
Technical revision

Elisa López Alaniz
Art Director

Juan Carlos Mesino Hernández
Document Formatting

First edition: September 2019

Centro de Geociencias
Universidad Nacional Autónoma de México
Boulevard Juriquilla núm. 3001, Juriquilla, Querétaro
C.P. 76230, México

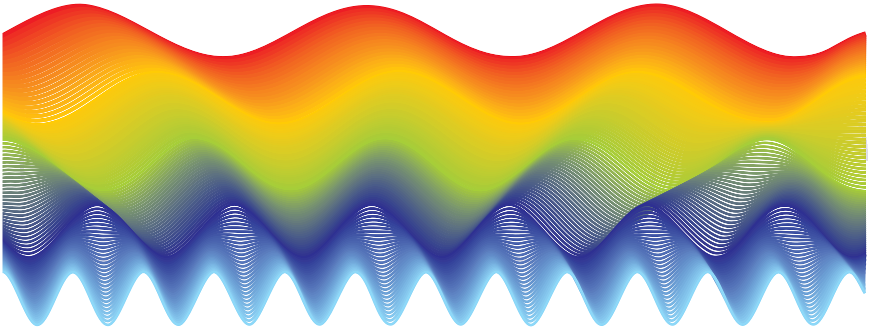
ISBN (General Works): 978-607-02-9176-0
ISBN 978-607-30-2055-8

Printed and Made in Mexico

“EASY EXPERIMENTS TO UNDERSTAND A COMPLICATED EARTH”

THE EARTH AND ITS WAVES

Index



INTRODUCTION

The first men who inhabited the Earth were surprised by, and even afraid of, many natural phenomena. Their explanations were simple, and occasionally, imaginative. As their knowledge of the world improved, their way to explain it also changed.

With time, knowledge improved and the observations of nature were governed by what is now known as the scientific method. Despite the rigour demanded by such a method, it is not nonetheless based around hypotheses experimentation and simple descriptions. This way, once the phenomenon has been understood, the human being tries to reproduce it and, with time, builds more complete and elaborate models. One example is the airplane, whose first concept, the ornithopter, from Leonardo Da Vinci, was a type of airplane that flaps its wings mechanically. No one imagined, at that time, that his idea would evolve so much that it would become the current version of modern airplanes.

In this booklet we talk about wave interference on which the theory of light is based. This concept was crucial in determing whether light behaved as a particle or as a wave. Nowadays it is known that both behaviors are part of light. Thomas Young was the one who demonstrated that light behaves as waves, based on the study of interference phenomenon. This demonstration is part of the ten most beautiful experiments of physics. In this booklet we try to show the similarity between the behavior of the waves that are part of light and the waves of other phenomena that happen on Earth.

WAVES IN DAILY LIFE

In the human environment, many events involvingwhere waves intervene, such as those created when playing a musical instrument or when there is an earthquake. In music, when you make an instrument's strings vibrate, the energy applied when the strings are strummed propagates in the form of waves that travel in different directions. Something similar occurs with ground vibrations caused by earthquakes, which spread through all of the Earth. In daily life waves are also part of the radio, television, telephones and cell phones, microwave ovens, medical instruments, etc. In all of these a source exists that generates waves, which are a type of energy that travels from one place to another and whose effects can vary.

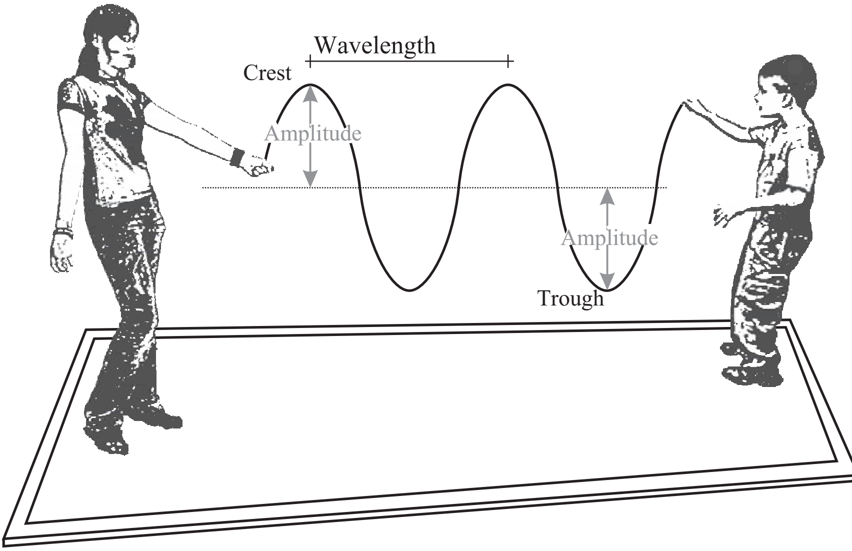
It doesn't matter how the waves were generated, as they all share some similarities in behavior. Such similarities have allowed their understanding; for example, the behavior of light when observing waves in water. As you know, light travels at high speed and this prevents us from easily appreciating its behavior.

Surely you have seen that waves meet each other and "overlay". This behavior is called interference, which is also related to multicolor effects, such as when light is reflected on films of soap bubbles, on thin films of oil floating on water, or on the surface of a DVD. We will see some of these phenomena here, and we will verify the effect of wave interference with various experiments.

WAVE PROPERTIES

A wave, from the simplest point of view, is a perturbation that moves with the passage of time. A wave implies a movement of energy. The wave can repeat itself several times in the same place during a certain period of time (e.g. the sound of a violin's note), or it can present itself in an unrepeatable way (e.g. the sound of an explosion or the plucking of a string).

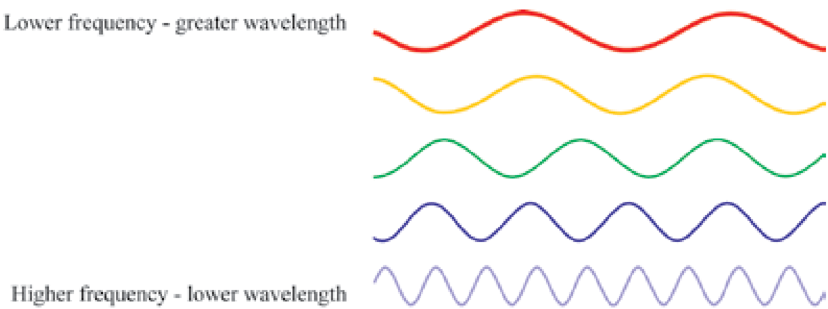
If we shake a rope, we will see it as a line that goes up and down continuously. In the case of light or sound, the size of the waves is several million times smaller than in the rope.



Before starting with the experiments, we will give you the name of the most important parts of waves. The highest point of each wave is called the crest and the lowest one is the trough; the distance from either of these to the "zero" point of the wave (the position before the disturbance) is known as its amplitude. The distance between two crests or between two troughs is known as the wavelength. If you count the crests (or troughs) of a wave that passes in front of you in a second, for example in the water or on an oscilloscope, what you are measuring is its frequency.

The differences in the characteristics of waves can easily be perceived in sound and in light. For example, in music, a high frequency is associated with a high-pitched tone like the one created with a violin; while a low frequency is associated to a low-pitched one, like the one emitted by a double bass. If the amplitude is high, the intensity of sound (volume) will also be high. In the case of light, the frequency, or the wavelength, is associated with color; while its amplitude is associated with its intensity, that is, if it's more or less bright. The relation between frequency and wavelength will be seen later.

The speed of the wave does not change within a given medium, but the speed does change when the medium changes; somewhat similar to what happens when you run from an area of cement to one with sand and then to water, each time your speed will decrease. For example, sound waves travel much faster in liquids and in solids than in the air – up to 5 times faster in water and 10 times faster in steel.



On the other hand, when the wave speed is constant, if the frequency is increased, the wavelength will decrease and vice versa, if the wavelength is increased then the frequency will decrease. Therefore, when an ambulance approaches you, you hear a very high-pitched siren because the sound waves diminish their wavelength, increasing their frequency and making the pitch higher. Whereas if the ambulance moves away, the waves expand and increase their wavelength, decreasing their frequency, and the sound becomes low-pitched.

WAVES THAT TRAVEL IN WATER: ocean waves and tsunamis

You must have noticed that when you throw stones in a pond or lake, circles are formed that grow from the same center (concentric). These are traveling waves. In the next experiment we will learn a bit about how such waves are formed and the form they acquire. Pay attention to the moment when two waves pass through the same place at the same time, this is known as interference.

Experiment 1

Materials

- A container with water
- 2 straws

Procedure

First, we will use a straw: put one of its ends in your mouth and the other end in the water's surface; now blow softly through it. For the exercise to work better, the straw should only touch the water's surface.

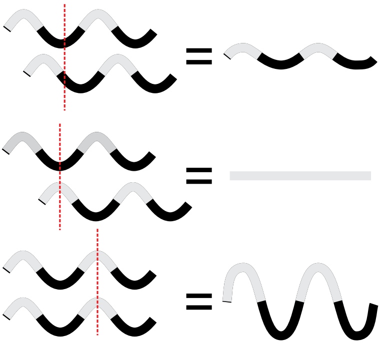
What happened?

When blowing through the straw, waves that travel through the whole container are formed. The blowing force modifies the shape and amplitude of the waves. If you put the straw perpendicular to the surface the circles will be concentric.

Where is the interference?

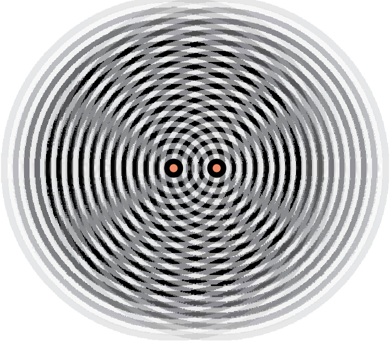
The circular form of the waves in the water is modified when these bounce on the container's edge and return (reflect) to the center of the container. These waves, when meeting the others that continue coming out of the straw's tip, overlay making two waves that pass through the same place at the same time; at this moment interference occurs. When the crests of two waves meet, their amplitudes are added, producing an even bigger wave, this is constructive interference; whereas, if a crest meets a trough, the amplitude of the resulting wave decreases, this is known as destructive interference.

.



a)

b)



a) Interference pattern using two straws. b) Variation in the amplitude caused by constructive and destructive interference. When two crests or valleys coincide, the interference is constructive; you can observe them as brilliant stripes when the crests of the two waves coincide, if the valleys coincide then darker stripes appear. When a valley and a crest coincide, the interference is destructive and you can see it as a zone without a wave (gray lines, perpendicular to the waves in the diagram).

Variant with two straws

To make the interference more obvious we are going to change the experiment a bit. Now we will use two straws.

Procedure

Place one end of each straw in your mouth and open it in a "V" form; put the other end of the straws on the water's surface. Now blow softly through them.

What happened?

Two sets of concentric circles form from the tip of each straw. After a few seconds, when the circles start growing they will overlap and begin to interfere with each other. When the set of waves join, they form a pattern known as an "interference pattern" on the surface of the water.

One more variation

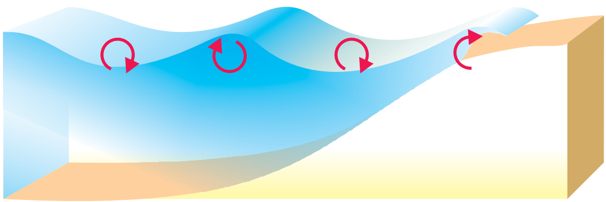
You can choose one of the following options to modify the interference:

1. Change the blowing force.
2. Change the distance between the straw's tips.

In both cases you will see how the interference pattern varies.

Apply it in your life

In the sea, waves whose amplitude and length depend on the force of the wind are generated in a similar way to what happened in the experiment. The wind that makes the water move can make waves grow in an important manner. When reaching a certain height, the waves lose their equilibrium and "break" due to two situations: when their height increases enough that the wave can't maintain its own weight (it has been calculated that the wave breaks when the amplitude is greater than approximately 1/7 of the wavelength); and the second, when the wave crashes into the coast, here the top part will travel faster than the bottom part, just like we observe at the beach.

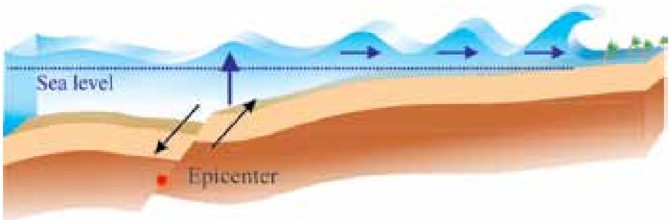


Water particle movement (indicated by the arrows) in the sea near the coast.

At the beach you can see that there are bigger waves than others. When the crests (or valleys) of two waves with similar characteristics meet, their amplitude increases so you should be careful when they get close to you. Other times, you will see that there are waves that seem very big when far, but when they reach the beach they are not so big, in this case a destructive interference has occurred, and the waves eliminated each other.

Examples in nature: Tsunamis

Tsunamis are very big waves that can be generated by an earthquake, a volcano, an avalanche at the bottom of the sea, or by the fall of a meteor. On December 24th of 2004, a tsunami occurred near Sumatra Island. First there was an earthquake 30 km deep that shook the island, with a Mercalli intensity of up to XI and a Richter magnitude of 9.2. This earthquake generated uplift of the ocean floor and formed a tsunami that grew so much that it caused much damage within a few minutes in the northeast part of Sumatra Island and some neighboring countries. The highest waves reached up to 25 meters near the beach and their wavelengths reached more than 100 km in the open sea. The difference between a beach wave and a tsunami, besides its size, is that the first one only moves particles near the surface, whereas in the second, the wave covers all the body of water down to the ocean floor.



Modified Mercalli Scale
(simplified)

I. Only detected with instruments.
II. Felt by people at rest. The suspended objects might oscilate.
III. Felt in interiors. Parked vehicles may move lightly.
IV. Felt in the exterior. The tableware, window glasses and doors vibrate, and the walls creak. Parked vehicles clearly sway.
V. Felt in exteriors. Pieces of tableware and window glasses break, and unstable objects fall.
VI. Felt by everyone, some heavy furniture moves from its place. Light damages.
VII. Minor damage in well designed and well-built buildings and considerable damage in the ones planned badly. People driving vehicles in motion feel it.
VIII. Considerable damage in ordinary buildings with partial collapses; great damage in weakly built structures. Heavy furniture overturns. Loss of control of vehicles in motion.
IX. Great damage in some buildings with partial collapse. Buildings come out of their foundations. The ground cracks noticeably. The underground pipes break.
X. Most of the buildings are destroyed from the foundations; considerable cracking of the ground. Considerable landslides at rivers banks and strong slopes. Rivers break their banks.
XI. Bridges and masonry structures are destroyed. Wide cracks on the land. Sinking and collapses in soft terrain.
XII. Total destruction. Visible waves on the land. Objects are thrown up in the air.

The Mercalli scale is used to establish an earthquake's intensity according to the damage caused, which varies from one place to another. Its difference with the Richter magnitude scale is that the Richter scale measures the energy released at the earthquake focus, as registered on seismographs, and has only one value.

WAVES THAT TRAVEL IN SOLIDS: earthquakes

Wave interference in water and in solids

Have you ever noticed that in places like a pond or a tub, the water's surface is almost never completely flat? If you move closer, you will be able to see that the surface has ripples that constantly change. In the next experiment we will see how these ripples are the result of the interaction between the waves when they expand.

Experiment 2

Materials

- A transparent container (e.g. a plastic or glass container)
- Water
- Midday sunlight

Procedure

Hold the container with both hands under the sun's rays or place the container on top of a table or a transparent glass base. Pour water halfway. The container must be separated at least about 50 cm from the floor. Now hit one of the container's walls.

What happened?

When hitting the container, you will see in the water a wave that travels from one side to another. The waves will be seen as strips in dark and light tones. If you observe more carefully, you will notice that after hitting the container, waves will appear, you will see waves with bigger amplitude and then almost simultaneously others with smaller amplitude. This happens because hitting the container makes waves travel faster in its walls (solid) than in the water (liquid).

When the container vibrated it made all the walls produce waves in the water. This is a way in which we can verify the wave's speed in two media. Besides, as the waves spread faster in the solid part of the container, it makes you see almost simultaneously a wave on the other side with similar amplitude as the first one.

Explain it

If two or more waves that travel in a medium meet, the result at any point will be the total sum of the individual waves. You will see this projected in the shape of stripes of different shades. The light and dark stripes are in a constructive interference when the crests and the troughs coincide. In the end, this effect is the one that generates the type of luminous web that moves continuously with the water's movement, as observed in pools.

Examples of wave travel in solids: the effects of earthquakes

Earthquakes occur when there is a displacement between two blocks on the Earth's crust, the energy released spreads inside the Earth in the form of seismic waves in all directions.

Sometimes, during wave travel, the waves get trapped near the Earth's surface and bounce among the structures that form the crust. This phenomenon occurred during the Michoacán earthquake on September 19, 1985 (magnitude 8.1 on the Richter scale and with a Mercalli intensity of up to IX). The energy that was released in the earthquake's place of origin reached Mexico City's basin, and the waves were trapped in what was an ancient lake, which was mainly composed of clay, sand and gravel.

This way, the waves started to bounce in the most rigid rock at the base of some hills like Chapultepec and Estrella. These bounces made seismic waves concentrate in certain areas and, by interfering constructively, their amplitude increased just like in the experiment where we hit the container with water. The vibration frequency of the ground coincided with the oscillation of several buildings that entered in resonance, which is another way of referring to "constructive interference". This resonance is what made several buildings collapse.

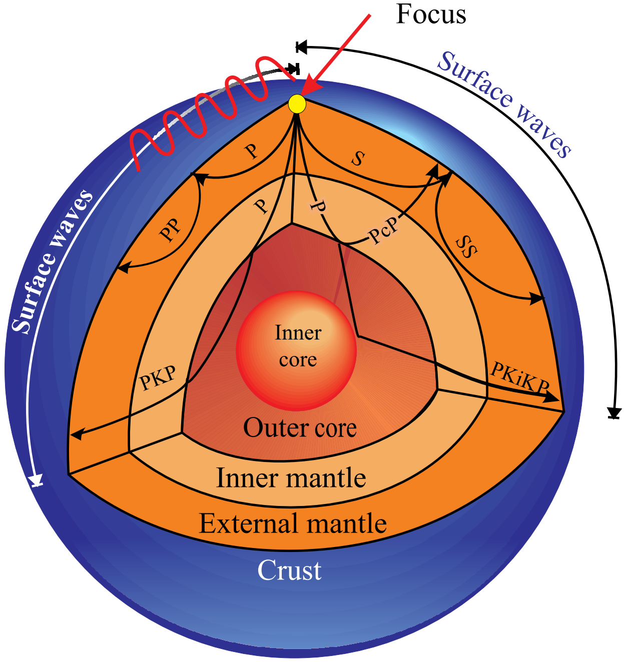
Example of the use of waves to get to know the Earth's interior

An explosion or an earthquake are energy sources that generate seismic waves that travel and are reflected in the different layers of the Earth's interior. These waves may be recorded by a set of detectors located on the planet surface.

When looking for petroleum, water or minerals, seismic exploration is used, which consists of wave detectors called geophones. In the case of energy released by earthquakes, the detectors are called seismographs. The time the seismic waves take to travel from the source to the detectors allows us to calculate the depth of the layers that form the Earth.

When an earthquake occurs, there are two main types of waves that travel through the planet's interior which are generated. The first waves to reach the seismograph are the "P" waves which are transmitted in solids and in liquids. The "S" waves arrive immediately after, but these are only transmitted in solids. Thanks to this difference in wave behavior, it is known that there are "solid" layers inside the planet (crust, lower mantle and inner core), a "plastic" layer like the one in the upper mantle which is known as "asthenosphere", and a "liquid" layer in the outer core. By the way, in this liquid layer a convection effect is generated that produces the Earth's magnetic field.

If the earthquake occurs at a shallow depth, surface waves are generated, which are the ones that create the movement that you feel under your feet.



The identification of the different layers that form the Earth was made possible by the use of seismic waves; understanding their variations, as a function of the medium they travel through, was a fundamental part of this discovery. The P are the direct primary waves , PP show P waves reflected on the Earth´s surface, PcP are P waves reflected on the outer core, the PKP are P waves transmitted in the outer core, PKiKP is a PKP wave reflected on the inner core. S are direct secondary waves, SS is an S wave reflected on the Earth’s surface.

WAVES THAT TRAVEL IN THE AIR: sound

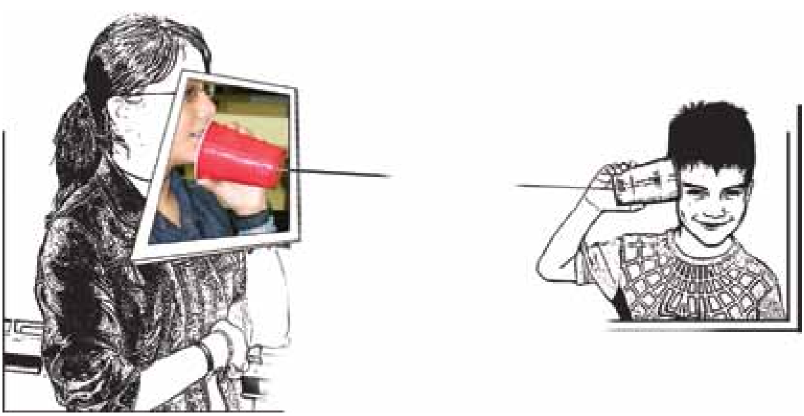
Experiment 3

Materials

- Two plastic cups
- More than 5 meters of string

Procedure

Make a hole at the bottom of the cups and tie the end of the string in each one. Ask a friend to hold one of the cups and separate them so as to have the string as taut as possible. Now whisper some words into the cup. You will notice that even if you said it very quietly, your friend will hear it.



Explain it

A body emits a sound when it vibrates, which stimulates the sense of hearing. When you speak inside the cup your voice's waves are transmitted through the string, making it vibrate like if you were playing with a slinky (a toy similar to a very long and very flexible spring). The waves travel along the string and when arriving to the cup on the other side of the string, they pass again into the air as acoustic waves. When the waves get to the eardrum, this starts to vibrate and to communicate the vibrations through a set of bones that collide with each other stimulating the auditory nerve.

As you might have noticed, sound is not only transmitted through the air, but also through any other material, be it gas, liquid or solid; the only medium in which it can't spread is vacuum. The average speed of sound in air is 331 m/s, in sea water it is 1435 m/s, while in solids like steel, it is 5000 m/s. This shows that the speed at which sound spreads depends on the material that serves as a means of transport.

Apply it in your life

If you live or go to the countryside you can intuitively verify that the speed of sound is lower than the speed of light.

- To observe the difference in the relative speed between light and sound you can use a lamp and ask a friend to help. Place yourselves apart for several tens of meters and shout at the exact moment when you turn on the light. Your friend will immediately see the light while your scream will arrive a few seconds later. Galileo did a similar experiment trying to determine the speed of light; however, he was only able to conclude that the speed of sound is lower than the speed of light.
- When you go to an event where there are fireworks, observe that a few seconds after a firecracker has been launched you perceive the explosion's light but its sound comes a few seconds later.
- When there is an electric storm and you see lightning in the sky, the thunder is heard several seconds later. You can even calculate the distance that the lightning strikes. Count the seconds between the moment you see the light and the moment you hear the thunder: for every three seconds the distance will be approximately one kilometer since light travels at almost 300 000 kilometers per second (km/s), that is why you can see it almost instantly while the sound travels much slower at 0.331 km/s.

WAVES THAT DON'T NEED A MEDIUM TO SPREAD: electromagnetic waves

In nature there is a certain type of wave that doesn't need a medium to spread. These are known as electromagnetic waves. This type of wave may be the most common in your life, since light belongs to this type of wave.

The light and the double slit Experiment 4

Thomas Young demonstrated that when the light of two sources meet, an interference pattern appears, an unmistakeable sign that light behaves as a wave. In this section, we are going to reproduce part of Young's double slit experiment. He was the first person to discover this phenomenon.

Material

- A piece of metal paper (you can get it from cookies and snack wrappers)
- A box cutter
- A light lamp
- A metal ruler

Procedure

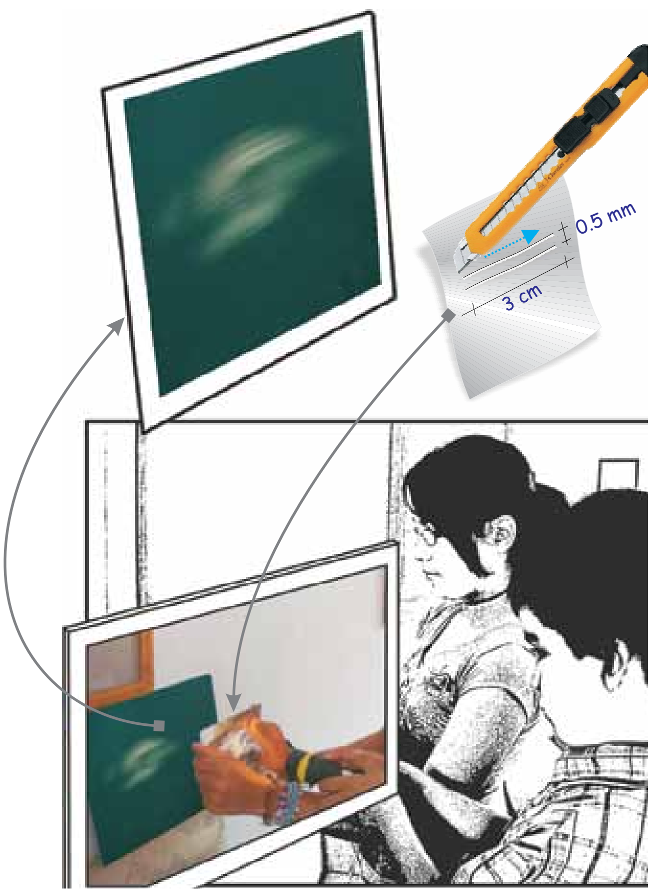
Ask an adult to make the cuts with the box cutter. You have to make a pair of parallel cuts of approximately 3 cm long on the paper. The separation between the cuts has to be as small as possible, approximately half a millimeter (0.5 mm). Ask someone to hold and stretch the paper with both hands, turn on the lamp and direct the beam of light towards the slits in the paper. Project the image on a wall in a room, preferably a dark one, to see the result.

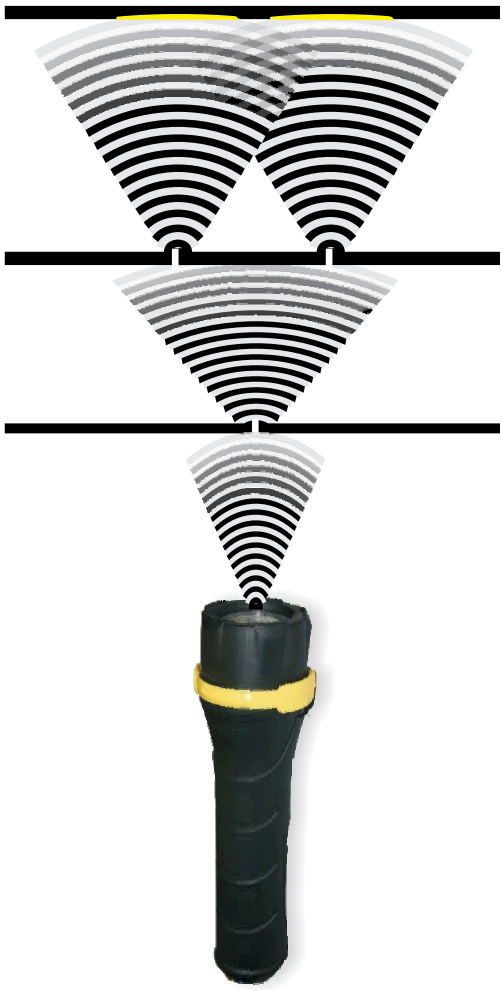
What happened?

If the beam is divided in two when passing through the slits, how many thin strips do you expect to see projected on the wall? How many do you really see?

Explain it

On the wall you will see a set of very dark and light thin strips produced by the interference of light. Move the lamp away and towards the paper; the strips will modify their width depending on the distance, but they will also become clearer or blurred. In water, the result is different. The dark strips show when there is destructive interference, while the light ones show constructive interference. The fact that there are several strips, instead of two, shows that light behaves like a wave.





In Young's classic experiment known as the "double slit experiment", two sheets are used. The first one with only one slit, the second one with two. In the projected image, it is possible to see light and dark bands produced by the interference of both waves going through the second sheet.

Colored bubbles

Do you think interference has anything to do with soap bubbles? Surely you have noticed different colors on their surface, do you know why? Let's do an experiment to find out.

Experiment 5

Material

- A container
- Water
- Powder and liquid soap
- Wire
- Sugar or glycerin

Procedure

1. Mix two spoonfuls of soap and two of sugar (or glycerin) in a glass of water.
2. With the wire make a simple figure (circle, square or triangle).
3. Put the wire figure inside the container and shake it a bit, checking that the soap adheres to the wire.
4. Take out the figure and slowly move it in front of you, until you see the soap film, in which you can observe several color strips.

What happened?

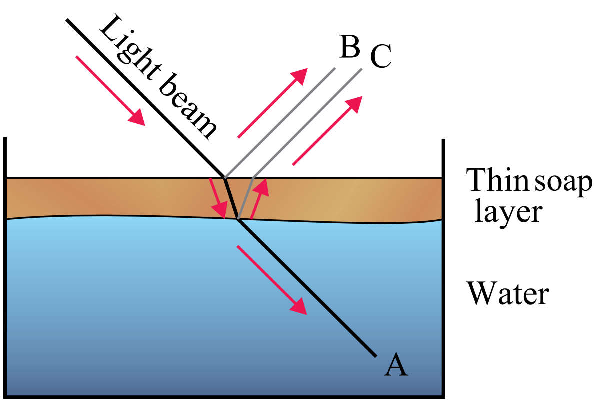
The color strips that you can see over the film of soap appear clearer when you find the adequate reflection angle between the rays of light and the soap film. It will take you some time to find the exact angle where you can see these strips.

Details

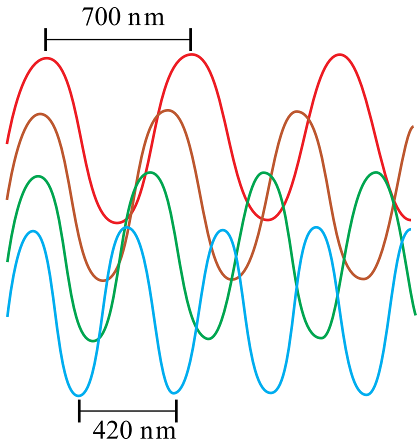
For the experiment to work out well, the water must have enough soap and produce many bubbles. The sugar and glycerin help make the bubbles more resistant. For more efficiency, let the soapy water rest for a few minutes. If the wire figure is not correctly closed, the film won't form.

Explain it

Two phenomena occur when light passes from one medium (the air) to another (the soap's film): a refraction, which means that its direction is deviated a little; and a reflection, which means that light reflects (like in a mirror) in the top and bottom surfaces of the soap film. When the above happens, both reflected waves interfere (B and C in the Figure). The C wave is delayed in relation to B, depending on the soap's film thickness. For certain wavelengths, this delay represents constructive interference, for others destructive.



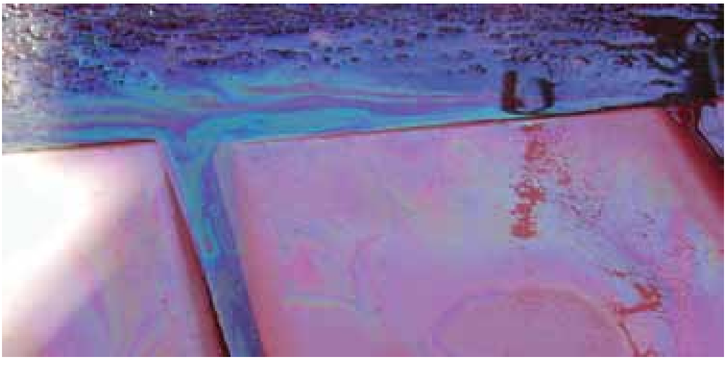
The color that you see corresponds to the wavelength generated from the interference. The red light has a very small wavelength, approximately of 760 nanometers (nm), while the violet light has an even smaller wavelength (of approximately 400 nm).



The color depends on the wavelength

Apply it to your life

Surely you have seen puddles of water on the pavement where you can observe strips of colors on their surface. This happens when there is a film of car oil floating over the water. The same thing that happened to the white light with the soap film occurs with the oil. If you pour oil in a glass of water, you won't be able to appreciate the light's decomposition because the oil film is too thick to generate this phenomenon. Until the thickness of the film thins and becomes of the order of the light's wavelength, the interference will not occur.



Stockings, scarfs and light

Another way to see light interference is through the use of other elements that you can find at home, like scarfs and stockings.

Experiment 6

Materials

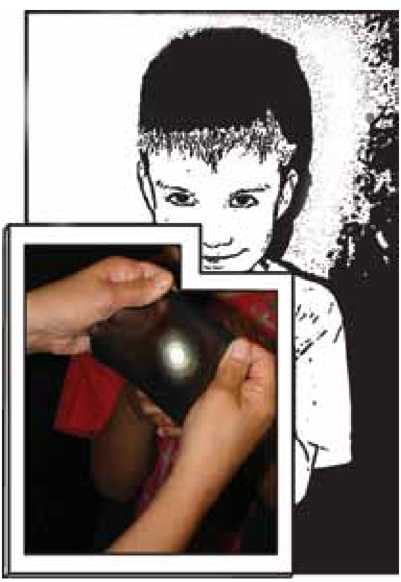
- A woman's stocking (black or brown) or a silk scarf
- A white light lamp

Procedure

Stretch the stocking with your hands close to your face and direct it towards the light source. While looking through the stocking you will be able to appreciate several colored concentric circles.

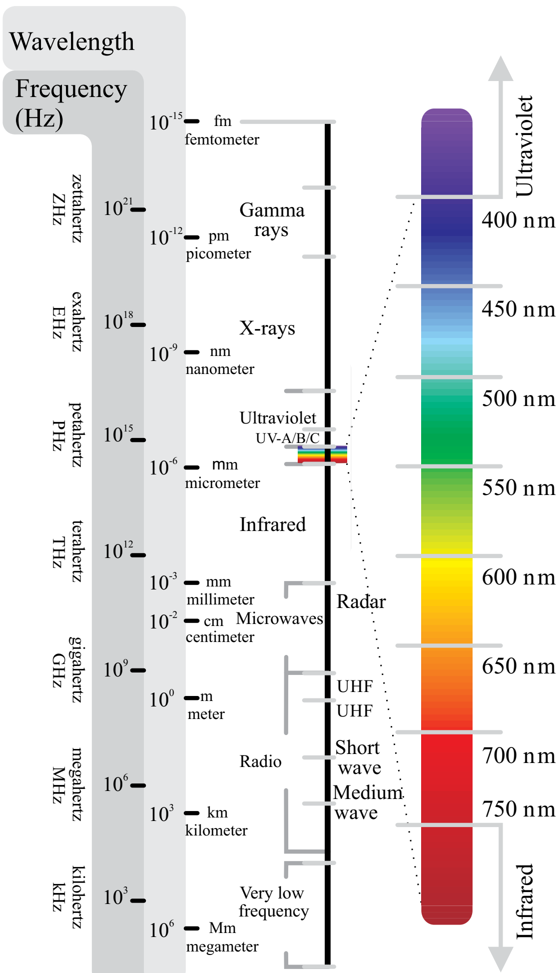
What happened?

The stocking or scarf threads are very thin and the distance between them is so short that it helps light diffract. When a wave circles the end of an obstacle diffraction occurs. When interfering among themselves the rays produce the constructive and destructive interference that causes the colored circles.



Electromagnetic waves in daily life and in nature

Electromagnetic waves are another type of energy in movement but they don't need a medium to propagate. They are invisible and travel at approximately the speed of light. They are very similar to each other but differ in their frequency range (or wavelength). The part of the electromagnetic wave spectrum we commonly find is the one shown in the figure below. The approximate wavelength and frequency intervals are indicated.



Electromagnetic spectrum

The human being only perceives a very small segment of the electromagnetic spectrum. This range is called the visible range of light, and its different wavelengths are perceived by us as colors.

At present, electromagnetic waves are used in telecommunications such as radio, television transmissions and cell phones. Besides, they are very useful in medicine, such as X rays, ultraviolet rays, gamma rays or lasers.

Electromagnetic waves travel in the air at the speed of light. We mentioned before that if frequency increases, the wavelength diminishes; that's why waves with smaller wavelength have a higher frequency. To give you an idea of the relation between them, we will give you some examples: the waves transmitted by AM radio have lengths of hundreds of kilometers with frequencies of hundreds of thousands of cycles per second (from 500 to 1,600 kilohertz). Whereas, FM radio works with waves that have lengths of tens of meters and frequencies of millions of cycles per second (from 88 to 108 MHz, megahertz). A microwave oven, on the other hand, generates waves that are between a few centimeters and millimeters in length, with higher frequencies of hundreds of millions of cycles per second. There are many communication systems that work through satellites, they generally function with frequencies of thousands of millions of cycles per second (GHz, gigahertz), their wavelength is in the range of just a few centimeters to millimeters.

To avoid interference between so many communication systems based on electromagnetic waves, each government, in accordance to international agreements, supervises each radiocommunication service (radio stations, television, radionavigation, radiolocalization, aeronautics radionavigation or cell phone services) to transmit in certain frequency ranges. The fact that each receiving device or station only detects its assigned wave frequency avoids most of the interference.

Three types of waves

This experiment will allow you to visualize the different behavior of elastic waves (which propagate in solids), acoustic waves (which propagate in air) and electromagnetic waves (which do not need a medium to propagate).

Experiment 7

Materials

- Digital alarm clock
- Glass jar

Procedure

1. Put the clock inside the glass jar on top of a table.
2. Program it to ring in one or two minutes. When it rings you can observe the following effects:
    - At all times you will be able to perceive the clock's digits (electromagnetic waves) because the light propagates in air without a problem.
    - When the alarm rings, part of its energy will be transmitted in the form of acoustic waves through the air and will be largely absorbed by the jar's solid, which will make you hear only a soft sound.
    - When the clock vibrates, it will hit the table in which it is set; in this way, another part of its energy will be transmitted like elastic waves.
3. If the jar had no air and the alarm rang, you would still be able to see the clock, but the sound would disappear; although you would still perceive the vibration on the table. If you point to the clock with a laser beam (electromagnetic wave) you will be able to verify how the wave propagates without the need of a medium like air.
4. Finally, if you repeat the case mentioned before, but hanging the clock from the top part of the jar with a string in such a way that it does not touch the table, you will continue to see the clock, but the sound and the vibration on the table will disappear.

Some contributions made by Thomas Young (1773-1829)

Thomas Young was a scientist considered to be a polymath due to the many contributions he made in different areas of knowledge. His interests in investigation covered very different fields like Physics, Medical Physiology and Egyptology. Young was born on June 13th, 1773 in England. He studied medicine at the universities of London, Edinburgh, Göttingen and Cambridge. He studied the functioning of the human eye and established three types of receptors, each of them sensensitive to one of the primary colors. He also discovered how the curvature of the eye's lens changes to focus objects at different distances. In 1801, he discovered the cause of astigmatism and began to take an interest in optics.

In 1803, Young carried out one of his most famous experiments, which bears his name. In 1807, Young presented the color vision theory known as the Young-Helmholtz theory. He revived Huygens wave theory of light, and through various experiments demonstrated the dispersion and refraction phenomena. In other Physics studies, he studied the surface tension of liquids and the elasticity of solids. From this last study he calculated the elasticity coefficient for diverse materials, which was later named Young's modulus.

In 1820, Thomas Young established the wavelength of light's components. He was the first to prove that light changes speed when passing through denser media. Besides his interest in Physics, Young had other passions like Egyptology, where he was one of the first to decipher and interpret hieroglyphs of several papyruses.

Acknowledgements

The authors want to thank the following people whose observations substantially improved the text: PhDs Bernardino Barrientos, Manuel Lozano Leyva, Rafael Alberto Méndez Sánchez, Gil Bor, Carlos Mendoza and Ángel F. Nieto Samaniego who checked that the theoretical concepts of the text were correct. Juan José Martínez, Ofelia Teja, Matías Santiago, Karina and Daniel Gómez verified that the experiments were able to be easily reproduced.

About the authors

Juan Martín Gómez González

He is a researcher at the Centro de Geociencias at the Universidad Nacional Autónoma de México (UNAM) in Juriquilla, Querétaro. He holds a PhD in Seismology from Paris University in France. He is a graduate of the Engineering Faculty at UNAM. He is currently a professor in the graduate program of Earth Sciences at UNAM and a member of the National Researchers System. He has published various articles about seismic wave modeling and also the generation and evolution of seismic sources. He also conducts seismic monitoring in la Mesa and Central highland to locate and understand the origin of seismicity in those regions of the country.

Susana A. Alaniz Álvarez

She is a senior researcher at the Centro de Geociencias at the Universidad Nacional Autónoma de México (UNAM). She obtained her PhD in Earth Sciences in 1996. She is a member of the Mexican Science Academy and is also an Academic member of the Engineering Academy. She carries out research on crustal deformation and its relation with volcanism. She holds a level III in the National Researchers System. She gives the Structural Geology course in the Earth Sciences postdoctorate program at UNAM and was editor-in-chief of the Revista Mexicana de Ciencias Geológicas. In 2004, she received the Juana de Asbaje prize awarded by UNAM.

About the translators

María de los Ángeles Labardini Flores

She has been working as an English teacher for 12 years and is currently teaching at high school 5 “José Vasconcelos” from the Universidad Nacional Autónoma de México (UNAM). She has been collaborating as a tutor for 8 years. She was part of the PAPIME Project PE400216 “Foreign languages and science dissemination” from September 2015 to May 2017, where she presented academic lectures in the Fair “4 Views to Science”. She participated in the process of implementing academic resources for English in UNAM’s website Red Universitaria de Aprendizaje. She is part of the team that is collaborating in the translation to English of the series “Simple experiments to understand a complicated Earth”. For the last four years she has been the coordinator of PICIA, an Institutional Programfor students to obtain Cambridge certification, levels FCE and CAE.

Carlos Mendoza

He is a researcher at the Centro de Geociencias at the Universidad Nacional Autónoma de México (UNAM) in Juriquilla, Querétaro. He holds a PhD in Seismology from the Colorado School of Mines in the United States and is currently a professor in the graduate program of Earth Sciences at UNAM. He is a member of the National Researchers System and has published numerous articles on the generation of large earthquake sources based on the computational modeling of seismic waves

This issue benefits from the support granted by DGAPA-UNAM to the projects: PE106919, for which Dr. Susana A. Alaniz Álvarez is responsible, and PE400216 ‘Foreign languages in the dissemination of the biological and health sciences’, for which Dr. Yadira Alma Hadassa Hernández Pérez is responsible.

“EASY EXPERIMENTS TO UNDERSTAND A COMPLICATED EARTH”, **THE EARTH AND ITS WAVES**”, editado por el Centro de Geociencias de la Universidad Nacional Autónoma de México, se terminó de imprimir el 23 de agosto del 2019 en los talleres de Diseño e Impresos de Querétaro, S A. de C.V., Av. Universidad No. 166 Ote., Centro, Querétaro, 76000, México. El tiraje consta de 500 ejemplares. Se realizó mediante offset en papel couche de 100 g/cm^2. Las fuentes utilizadas fueron Book Antiqua en el cuerpo del texto, y Carlisle en la portada. El cuidado de la edición estuvo a cargo de Juan Carlos Mesino Hernández

This booklet was printed thanks to the economic support of the
Scientific Research Coordination of UNAM
and project
PAPIME Pe106919

Unión Geofísica Mexicana A.C.

planetatierra
Ciencias de la Tierra para la Sociedad

The serie “Simple experiments to understand a complicated Earth”, is based on the list of the most beautiful experiments in history, published by the Physics World magazine in September 2002. The experiments were selected due to their simplicity, elegance and the transformation they created in the scientific thinking of their time.
Each booklet in this series is dedicated to one of those experiments. Our goal is to help you understand, through experimentation, everyday phenomena that occur in our daily life and in our planet.

This booklet is dedicated to the experiment called
Double slit experiment by Thomas Young.

Books in this serie
1. Atmospheric pressure and the Falling of bodies
2. Light and colors
3. Eureka! The continents and oceans float!
5. The Earth and its waves

You can download the complete series at
http://www.geociencias.unam.mx
https://sites.google.com/site/recursos4miradas/8

Prepared for the National Preparatory School UNAM

9786073020336