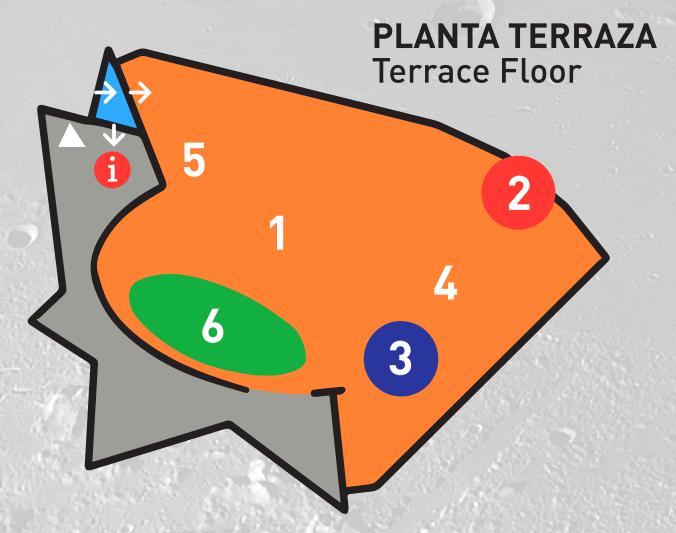




# General guide to the Science and Cosmos Museum

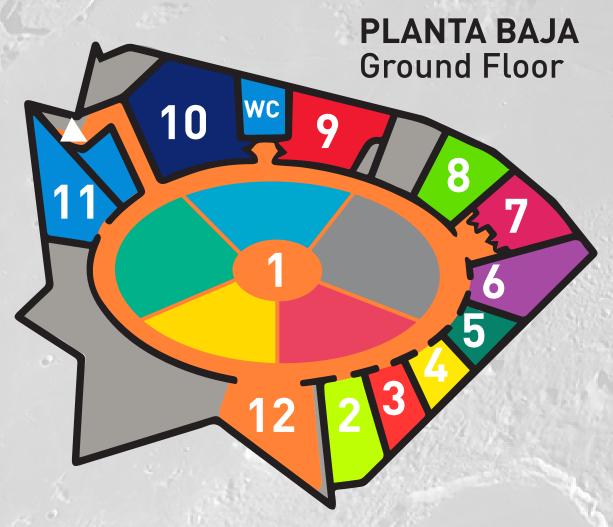






- ▲ ASCENSOR Elevator
- 1 INFORMACIÓN Information
- 1 PLAZA "AGUSTÍN DE BETANCOURT" Agustín de Betancourt Square
- 2 ANTENA DE RADIOASTRONOMÍA Radioastronomy antenna
- 3 TELESCOPIO Telescope

- 4 RELOJ DE SOL ECUATORIAL Analemmatic sundial
- 5 BUSTO PARLANTE
  "AGUSTÍN DE BETANCOURT"
  Agustín de Betancourt
  talking bust
- 6 ZONA WI-FI Wi-Fi zone



- ▲ ASCENSOR Elevator
- 1 EXPOSICIÓN Exhibition
- 2 TALLER DE DIDÁCTICA Didactic Workshop
- 3 EFECTOS ÓPTICOS Optical illusions
- 4 SALA CROMA KEY Chroma Key room
- 5 LABERINTO DE ESPEJOS Mirror Labyrinth
- 6 COSMOS LAB LABORATORIO CREATIVO

- Cosmos Lab Creative Laboratory
- 7 PLANETARIO Planetarium
- 8 SALIDA DE EMERGENCIA Emergency exit
- 9 MICROCOSMOS
- 10 SALÓN DE ACTOS Assembly hall
- 11 EXPOSICIONES TEMPORALES
  Temporary exhibitions
- 12 ZONA DE DESCANSO Rest zone





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The human body







## ¿POR QUÉ PIRÁMIDES? Why pyramids?

Sacred places have often been conceived of as elevated spaces that draw the believer closer to the divinity. For this reason, once architectural techniques became sufficiently refined, mosques or cathedrals raised their vaults, minarets, towers and spires to the sky. However, for thousands of years, the formula favoured by almost every culture was the pyramid. They are found from the Mexico and the Andes to Egypt and China, probably without these civilizations having communicated with each other. Besides resembling a mountain, from an architectural point of view, structural reasons make it the most stable durable shape that can be designed.

#### Statics and Aesthetics

Most constructions built by human beings are built with durability in mind, besides the emotional impact they are meant to cause on the person contemplating them. This is especially important regarding permanent sacred places such as sanctuaries, tombs, temples or churches, intended to reflect the eternal.



#### Hands on!

Cause an artificial earthquake by moving the platform and see how the pyramid is more stable than the other three structures you can build here (a truncated cone, a cylinder and a polyhedron)'





### CON USTEDES EL OZONO

### Introducing you to ozone

Ozone is a highly oxidizing gas with a characteristic acrid odour that irritates the eyes and respiratory system. Its presence in the lower atmosphere is undesirable due to its pollutant effect. However in the upper layers -the stratosphere- it carries out a vital function, forming a layer that acts as a shield filtering out ultraviolet rays from the Sun and protecting us from their harmful effects.

In the 80s, a "hole" in the ozone layer was discovered in Antarctica. It was confirmed that the hole was caused mainly by the destruction of ozone particles via the accumulation of chlorofluorocarbons (CFCs), organic compounds used as refrigerants and propellants in aerosol applications. Since 1987, many international agreements have been signed in order to reduce the production of substances that destroy the ozone layer.

#### Hands on!

Push the button to activate the ozone generator. Move your nose closer to the vent and you will notice its peculiar characteristic odour.









# 3

## IGUALANDO PRESIONES Water finds its own level

#### Communicating vessels

Who has never heard of the famous law of communicating vessels, by which a fluid always reaches the same level when inside two containers linked to each other?

#### The Force of the Atmosphere

This happens because the pressure produced by the atmosphere on the fluid's surface is always the same, regardless of the volume in each vessel and its shape.

#### Hands on!

Using the buttons you can raise or lower one of the vessels, to see how the liquid always maintains its level by flowing from one to the other.







# LA TIERRA TIENE FIEBRE The Earth is warming up

4

The Sun heats the Earth by the solar radiation it emits. Our atmosphere is a thin film that allows in almost all this visible adiation.

However, certain gases from the atmosphere (carbon dioxide, methane, water vapour and others) obstruct the infrared radiation that comes from the heated ground and prevents the Planet from losing the accumulated energy by expelling it into space.

This has a worldwide effect similar to that of a greenhouse, raising global temperature. Under normal conditions it allows the oceans to maintain their liquid form and determines the evolution of life on our Planet. However, the greenhouse effect appears to be out of control on Earth as a consequence of human activity. We are releasing huge amounts of carbon dioxide and methane into the atmosphere, which results in the overheating of both oceans and continents, progressively melting the ice-caps and glaciers. Scientists predict climate changes that will be very harmful to ourselves and many other species if greenhouse gas emissions are not reduced drastically.



#### Hands on!

Read the temperature on the thermometer and notice how the Earth covered by the perspex dome (simulating the atmosphere) heats up more than the other.





# HACE 200 MILLONES DE AÑOS... 200 million years ago...





At the beginning of the Triassic period, the start of the Age of Dinosaurs, every continent on Earth was joined together forming a supercontinent known as Pangaea, surrounded by a single ocean called Panthalassa.

#### Continental Drift

As the scientist Wegener discovered, the continents started to drift during the Triassic period, forming the so-called Sea of Thetis, the ancestor of the Mediterranean. Two large continents were first formed: one to the North, Laurasia, and another to the South, Gondwana. Finally, 65 million years ago, at the end of the Age of Dinosaurs, the drift ended and each piece of the "puzzle" went on to take its present position.

#### Life in the Triassic Period

These fossil organisms (not to scale) represent some of those that lived in the Triassic.

#### **PLANTS**

a. Gymnosperms

#### **ANIMALS**

- b. Amphibians
- c. Laberinthodonts (giant amphibians)

#### **REPTILES**

- d. Chelonians (turtles etc.)
- e. Ichthyosaurs (aquatic reptiles)
- f. Therapsids (mammal-like reptiles)
- g. Saurischian Dinosaurs
- h. Ornithischian Dinosaurs

#### **MAMMALS**

i. Eutherians





# DESDE EL ESPACIO The Earth viewed from space



#### Spying on the clouds

Technological advances in the last few decades allow us to watch the changes in cloud cover from space. In particular, thanks mainly to two types of environmental satellites. From their position 36,000 km above the equator, sensors placed on 'Geostationary Earth Orbiting satellites' cannot "see" the higher latitudes near the poles; so Low Earth Orbiting satellites are used to obtain these images because they cross the poles. The two types thus complement each other and provide an overall picture.

#### Hands on!

Interact with the touchscreen to discover the weather in real-time in any part of the planet.







### VIGILANCIA METEOROLÓGICA Meteorological surveillance

#### A matter of time

The goal of weather observation is to determine the value of different variables and physical parameters that describe the state of the atmosphere at a certain time, to analyse, forecast and warn us about the coming weather. It also allows for long-term climate monitoring.

The current generation of weather stations with the latest sensor technology, such as here on top of the Museum, allow us to obtain data on temperature, humidity, rainfall and wind speed and direction. For example, measuring the impact of raindrops on a surface we can calculate the amount of water that has accumulated; and through the variation in ultrasonic signals, we can obtain the wind speed and direction.

This section has been produced in cooperation with the Izaña Atmospheric Research Centre (IARC) aided by Vaisala (the Museum's weather station) and the Teide Cable Car.

#### Hands on!

Interact with the touchscreen placed on the left and look for real-time meteorological data from the station located on the rooftop of the Museum. On the second screen, you will be able to compare these results with those from different stations that the



Agencia Estatal de Meteorología, AE-MET (National Meteorological Agency) has placed at different altitudes.





## EL CUARTO ESTADO DE LA MATERIA The Fourth State of Matter

8

#### Plasma: A Very Rare Gas

Plasma, the most common state of matter in the Universe, is a scarce resource here on Earth. Around us, it is only found in neon lights and fluorescent tubes. It takes form when the atoms of a gas are split into their components: their nuclei and electrons. This rupture can take place through heat, as occurs in stars, or by means of electric discharges, as in this sphere.

#### The Living Sphere

This sphere contains a gas at low pressure that becomes plasma by means of electric discharges. When you touch the sphere, the internal current tries to connect to earth through your body, but luckily the insulating glass stops it from doing so.

PLEASE NOTE: If your shoes are not good conductors, your body may be statically charged and you may feel a small, harmless discharge.

Notice how when you touch the sphere, the electric current moves towards your hand creating a spectacular lightning effect.







## MAGNETISMO FÓSIL Fossil Magnetism

9

When a rock, mineral or even material made by human beings - such as an earthenware bowl - is heated up to high temperatures, its magnetic properties change. This is because the metallic particles within it become aligned in a certain direction at that moment, depending on the orientation of the Earth's magnetic field. When the material cools down, the orientation of the particles will remain 'fossilized' or stabilized within it.

Since the Earth's magnetic field changes over time, this effect allows us to date ancient rocks and materials through a technique known as 'Palaeomagnetism' - in the case of rocks and minerals - or 'Archaeomagnetism' when referring to human artefacts.

#### The Curie Effect

Contrary to the previous case, every ferromagnetic material heated up to a certain temperature loses its magnetic properties while it is still hot. This physical phenomenon is called the Curie Effect.

#### Hands on!

See how when you push the button the electric current passes through the resistor and heats it up, turning red. As a consequence, it loses its ferromagnetic properties and separates from the magnet.







## "DADME UN PUNTO DE APOYO UN PUNTO DE APOYO Y MOVERÉ EL MUNDO" - ARQUÍMEDES (S. III A. DE C.)

"Give me a place to stand, and I will move the Earth" - Archimedes (3rd century BC)



King Hiero of Syracuse, not believing him, asked him to move a heavy weight. Maybe not the world, but something really big. Archimedes chose a ship in dry-dock and prepared a pulley system. He pulled the rope and with just one hand launched the ship. This was not magic but Archimedes, one of the greatest scientists of the Greek world.

#### The law of the lever

Pulleys are simple machines that are used to carry out heavy tasks with less effort, and they basically consist of a bar that swings on a pivot called a balancing-point or 'fulcrum'.

An effort (P) applied on the bar makes it swing over the fulcrum, and the load (R) moves a certain distance. The distances between the fulcrum and P or R are called the lever arms.

There are three classes of levers depending on the relative position of the load, the effort and the fulcrum.

#### Legend

Load

Support point or fulcrum

**Effort** 





10

#### First class:

In levers of this first class, the fulcrum is in between the effort and the load. The load is greater than the effort, but its movement is smaller. Pliers belong to this class. The fulcrum (shaft) is in between the effort (applied on the handles) and the load (the object). Weighing scales, hammers and cranes are other examples of this kind of lever.

#### Second class:

In the second class of levers, the load is in between the fulcrum and the effort.

Just as in first class of levers, the load is greater than the effort and the movement is smaller.

The nutcracker multiplies the strength of your fingers so that you can break the nutshell. The load (the nut) is in between the effort (applied to the handles) and the fulcrum (the hinge).

The wheelbarrow and the bottle opener are other examples of this kind of lever.

#### Third class:

In levers of the third class, the effort is in between the fulcrum and the load.

In contrast to the other classes, the effort is greater than the load. As a result, the load moves a longer distance. In pincers, the force is not multiplied but they quicken the movement. The effort (the fingers) is in between the fulcrum (the joint) and the load (a stamp, for example).

The fishing rod is another good example of this third kind of lever.

#### Hands on!

Do you think you could lift a 500kg car with your hands? Try it out using our lever.





### EL TORNADO Tornadoes

# 11

#### A whirlwind with aspirations

A tornado is a body of air that twirls at high speed about its vertical axis. Its lower end comes into contact with the Earth's surface and its top reaches the base of a cloud.

Generally, tornadoes have the shape of a funnel with its narrower end touching the ground and are usually surrounded by a cloud of debris and dust. Most of them produce winds of up to 70 and 180 km/h and travel for several kilometres before disappearing. Exceptional ones can spin at up to 450 km/h or even more, they can be 2 km wide and stay in contact with the ground along more than 100 km of their path.

#### Hands on!

Enter the cylinder and stand on the red mark. You will see how a whir-lwind is being formed. Move closer to the centre, interact with it and see what happens.







### LA VIDA EN ESPIRAL Life in spiral

# 12

#### How to sculpt a whirlpool?

There are two forces responsible for the formation of a whirlpool. A downward vertical force caused by the suction of the drain, and another force perpendicular to the other, produced by the water stream returning to the tank through its upper part.

The whirlpool is funnel-shaped because water pressure increases with depth.

#### Whirlwinds and cyclones

Whirlwinds happen in the Earth's atmosphere due to a combination of forces similar to the whirlpool: an ascending force caused by the sun warming the ground, and another rotational force caused by winds from different directions or by the Earth's rotation. Tornadoes on land, and cyclones at sea, are the most extreme cases of whirlwinds and can have devastating effects.

#### Helices and spirals

These geometrical figures, related to one another, appear in many different aspects of nature, from galaxies to the DNA in our cells, and all the way up to weather phenomena or the structure of some living beings. Even though they lack a common origin, all share the advantage of a great length taking up as little space as possible, whether a spiral staircase or a butterfly's tongue.









## LA ESFERA The Sphere

# 13

#### Worlds with a new perspective

The sphere is the most perfect geometric shape, a body outlined by a curved surface on which all points are at an equal distance from its centre. Our sphere here, about 80 cm in diameter, displays the multiple possibilities of digital projections, making different planet-wide phenomena visible, speeding up time to understand the changes our planet undergoes and reflecting the diversity of planets, stars and moons in our Universe.

#### A real vision of our planet

One of the oldest desires of human beings is to gaze from outer space at the planet they live on. However, the deformations imposed by a flat projection, screen or map on a spherical body lead us to size errors, which grows the more we move away from the central line of the equator. Because of this, Greenland, for example, seems to be the same size as Africa when in reality it is fourteen times smaller.

Only the sphere can truly show reality. This unit allows us to experiment with the diversity and fascination of our planet when gazed at from outer space.



#### Hands on!

Interact with our sphere by means of the control panel to discover all its possibilities.





# MOVIMIENTO EN EL MUNDO MICROSCÓPICO Movement in the microscopic world

# 14

#### **Brownian Motion**

When we look at a drop of water containing small lightweight particles (such as pollen grains) under the microscope, we see how they show incessant chaotic motion. This movement is produced by the collision of water molecules in constant agitation, colliding with the small particles. Known since 1785, this phenomenon called Brownian motion was observed in 1827 by the botanist Robert Brown, and later explained by Albert Einstein in 1905 in one of his articles.

#### Hands on!

Push the button and see how the "pollen grain" and the "bacterium" move when struck by the steel balls simulating water molecules in motion.





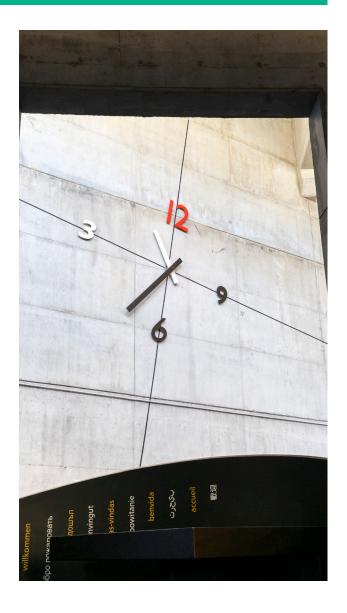


# RELOJ ESPECULAR The Mirrored Clock

Clock: machine providing an uniform motion that allows us to measure time or divide a day into hours, minutes and seconds.

Mirrored: something reflected in a mirror.

Find out for yourself how this clock works.







1

## NUESTRO SISTEMA SOLAR

Our Solar System

Our solar system is made up of only one star (the Sun) and eight planets, of which half are terrestrial planets (Mercury, Venus, the Earth and Mars) while the other half are gas giants (Jupiter, Saturn, Uranus and Neptune). More than 170 satellites spin around them. Orbiting around the Sun there are also five dwarf planets (among them Pluto, considered a planet until recently), about two million asteroids and hundreds of millions of comets, the remnants of the same material that formed the Solar System 4,600 million years ago. In this image (to scale) you can compare the size of our planet with the rest of the large bodies in our Solar System, including our star, the Sun.

#### Hands on!

Stand on the white dot painted on the ground. Looking towards the stairs, you will see the distance of the planets with respect to the Sun. Do you know where Neptune is?







### EL SOL, UNA ESTRELLA DE CINE The Sun, a Movie Star

# 2

#### The Sun's best performances

When humanity did not yet exist, the Sun generated the energy that still reaches the Earth today and keeps us alive. It is the closest star to our planet, and by studying it, we get to know more about the thousands of stars visible in the night sky and of others we are unaware of, forming the billions of galaxies that populate our Universe. Many of these star systems may even support life in a similar way to our Planet. In the images of the Sun we obtain from terrestrial telescopes and artificial satellites, we can discern sunspots and the granulation of its surface (the Photosphere), the impressive protuberances suspended over the lower part of its atmosphere (the Chromosphere) and the spectacular explosions (solar flares) visible in the Sun's Corona. When the solar winds from these titanic expulsions of matter reach Earth, they create the marvellous Northern Lights (aurora borealis) in the atmosphere near the Arctic; if they are really violent, they can affect our satellites and electrical grids.

#### Inside the Sun

We are familiar with the interior of the Sun thanks to Helioseismology, which studies the propagation of wave oscillations produced at its surface. The technique is similar to the way we get to know the inside of our planet, mea-



suring the seismic waves propagated by earthquakes. At the Sun's core, at 15 million °C, a process called nuclear fusion transforms 564 million tonnes of hydrogen into 560 million tonnes of helium each second, leaving 4 million tonnes spare which is transformed into energy. Think about it, 4 million tonnes each second! That is equivalent to the explosion of about 6 trillion atomic bombs like the one used in Hiroshima.

Nevertheless, the Sun still holds enough fuel to keep us warm for over 5,000 million years

#### Hands on!

Browse through the menu on the screen and enjoy some of the most spectacular images the Sun has offered us over the last years.





# 3

## CUANDO CALIENTA EL SOL When the Sun warms up

#### The Seasons

Every year, on the 4th of January, the Earth is at its closest approach to the Sun. In the Northern hemisphere this is in the middle of winter (and the middle of Summer in the Southern hemisphere), so the seasons clearly cannot be because the Earth is closer to (or further away from) the Sun. The seasons arise due to the inclination of the Earth's rotation axis with respect to the plane in which it orbits around the Sun. Because of this misalignment, the number of hours of daylight varies from one day to the next and between places on the Earth's surface. At the poles, there are months of non-stop daylight or constant darkness. Have you realised that the Earth's rotation axis always points to the same place? Do you know where?



Press the button and watch how the Earth is illuminated differently throughout the year. Identify on the maps the number of hours of daylight as a function of the location of the Earth for where you are.







# GIRA EL MUNDO, GIRA The world keeps turning



#### The Solar System

Our Solar System is made up of planets, satellites, asteroids, comets and interplanetary material, all of which orbit around a small star known as the Sun.

In this model (note: it isn't to scale!), we can see all the planets visible to the naked eye: Mercury, Venus, the Earth (and the Moon), Mars, Jupiter and Saturn. See how they spin and how their orbital velocity changes depending on how far away from the Sun they are (Kepler's Third Law).

A pale blue dot: if the Sun were thesame size as this basketball, the Earth would be a tiny ball only 2.5mm in diameter 32 metres away. Can you find it?

#### Hands on!

Press the button and compare the velocities at which the planets travel around the Sun. Look around the Museum to find the Earth.







### Y SIN EMBARGO SE MUEVEN...

"And yet they move..."

# 5

#### Movement and Temperature

The atoms or molecules of a gas frequently move and clash chaotically among themselves. Temperature is a measure of that movement: the higher the temperature, the faster each particle goes and more violent are those clashes. This module recreates the movement of atoms in the Sun: the atoms at the bottom receive energy, they start moving randomly in any direction and clash with those at the top, passing on a part of their energy and causing all the atoms to move. If the system does not change its parameters, after a while they reach a final state known as 'thermodynamic equilibrium'. Remember: temperature is the measure of the particles' movement, and pressure is the force those particles exert when they hit the surface that holds them.



#### Hands on!

Set the energy wheel at its minimum, all the way to the left. Push the button and see the movement of the balls and how long it takes them to reach equilibrium. Then repeat the experiment with more and more energy each time. See how the balls constantly hit the walls and exert pressure on them.





### EL SOL MAGNÉTICO The Magnetic Sun

# 6

#### Sun Spots

Astronomers in ancient China already knew that our star was not a uniform disc of light. On the Sun's surface, we observe small dark patches, known as sun spots which slowly change size and shape until ultimately disappearing after a few weeks. The number and positions of these sun spots slowly varies reaching a peak every 11 years. How are they formed? Why are they dark?

#### A giant magnet

The motion of electrical charges in the Sun's interior result in intense magnetic fields, just as if it were a giant electromagnet. Our star isn't a rigid sphere, it behaves like a ball of fluid, rotating much faster at the equator than at the poles. This difference in rotation velocity deforms the magnetic field lines, twisting and tangling them. Some of the twisted field lines emerge from the surface of the Sun in the form of an arc, a lot like isolated magnets. In the regions where these "magnetic islands" form, convection is impeded and the temperature begins to drop with respect to the surrounding areas resulting in these dark patches we call sun spots.



#### Hand son!

Play with the magnetic sand on the hemisphere and see the sun spot-like patterns produced by the interaction with the hidden magnets.





## EL SOL EN EBULLICIÓN The Seething Sun

# 7

#### The Sun's skin

Seen through a telescope, the visible surface of the sun reveals an amazing granulated appearance. Each granule, approximately the size of the Iberian Peninsula, is a little cell similar to that of the experiment. Convection: heat in flux The convective cells are formed by the vast difference in temperature between the bottom and the surface of the fluid. In the centre of each cell, a column of hot matter rises, cools on the surface and sinks to the bottom around the sides of the column.



#### Hands on!

Push the button and watch as the convective cells form in the hot liquid. Compare it with the surface of the Sun.





# ¿CÓMO FUNCIONA UNA ESTRELLA? How does a star work?

8

Voilà! Mass disappears and transforms into energy. Einstein was right!

#### Where does energy come from?

Stars are enormous atomic fusion bombs that slowly explode for billions of years. 564 million tonnes of hydrogen are converted inside the Sun every second into 560 million tonnes of helium. But what about the 4 million tonnes that are lost each second? Because E=mc2 it gets converted into energy, into light! Little by little, those particles of light - known as photons - make their way to the Sun's surface until they finally fly free in space. A tiny fraction of that light reaches Earth, where another little fraction of it is absorbed by plants, which they transform into chemical energy that is later consumed by animals. Look at yourself in a mirror: nature really knows how to create interesting things with the atomic energy of the Sun!



Observe the two columns of red liquid: in equilibrium both are at the same level. Push the button now. As you turn on the bulb, the gas in the flask heats up and the molecules' speed increases, also increasing the pressure they exert, finally pushing the column of red liquid up and holding its weight. A star works in the



same way: the enormous pressure of the stellar gas holds the enormous weight of the star.





# 9

### EL SOL, HOY The Sun Today



#### Observing our star from a satellite

The Sun is a gigantic sphere made of plasma - a very hot gas with an electric charge - considered to be the fourth state of matter after solid liquid and gas. Compared to the other stars it is very near us so we can clearly see the structures that appear on its surface. Its activity is not constant, but varies over a period of 11 years.

Nowadays, it is constantly observed 24 hours a day from observatories on Earth and in space, with a level of detail never seen before. Using many different filters allows us to see what happens in the different layers of its atmosphere, all the way up to its surface. Here you can see the latest images, almost in real time, taken from the SDO telescope at the NASA Solar Dynamics Observatory.

#### Hands on!

Using the controls, select a current image of the Sun. You can enlarge it size and discover the secrets the Sun reveals today.





## RELOJ DE SOL ANALEMÁTICO

Analemmatic sundial

10

The sundial consists of two parts:

- 1. The adjustable 'gnomon' (yellow) which has an eight-shaped figure called an 'analemma', marked with the calendar and scales for the declination of the Sun and its position at noon.
- 2. A time-scale (white) that indicates the hours and minutes in both winter and summer time.

#### Hands on!

Turn the yellow board showing the analemma until the eight-shaped illuminated area falls upon the time-scale.

Look for the current date and cover it with your finger. The shadow you cast will mark the hour.







## SOMBRAS CONGELADAS

Frozen Shadows

#### Substances that shine

Almost all materials absorb light energy, converting it into heat. Yet, fluorescent or phosphorescent substances store that energy for a very short time before emitting it again in the form of light. Both the old-style television screens and fluorescent lighting tubes owe their brightness to this kind of substance. When energized by an electric current, mercury atoms radiate ultraviolet light. The fluorescent material lining the old TV tube converts such radiation into white light.

#### Beware! Energized atoms!

The atoms of the phosphorescent material that receives light from the flash become excited by the energy they store. They then stabilize, returning that energy in the form of a greenish light.

#### Hands on!

Push the button. Stand near the wall and wait for the light. Then watch your shadow.









# ESCULTORES DEL COSMOS The Sculptors of the Cosmos

# 2

#### The guides of all cosmic design

The objects of the Cosmos are all moulded by two basic forces: On the one hand, by the force of gravity, which depends on the mass of the object; and on the other, by centrifugal force, which depends on its speed of rotation.

#### Why does the ring flatten?

As the ring spins, each point along it is pulled outwards by centrifugal force. The greater the distance from the axis of rotation the greater this force, as occurs on its equator.

#### Centrifugal force in action

The Solar System was formed by the flattening of a rapidly rotating spherical cloud of gas and dust.

#### Hands on!

The flattening of the spinning sphere, due to the centrifugal force, simulates the formation of galactic discs and planetary systems.







## ACARICIA A UN EXTRATERRESTRE Caress an Alien

# 3

#### Meteorites

This 55 kg rock from outer space is a chondrite – a stony meteorite – of extra-terrestrial origin.

This space "fossil" dating back to the formation of the Solar System is estimated to be 4,500 million years old. It is one of the pieces resulting from an ancient crash between asteroids, and its chemical composition reveals it belonged to one of them.

After roaming in space for millions of years, this stone became white hot and almost burnt up passing through our atmosphere, losing most of its mass; and it finally fell in the Mahbes region of the Sahara desert.

#### How do we know it is authentic?

Every day, dozens of meteorites hit the Earth's atmosphere and get mixed up with our rocks. Nevertheless, careful analysis shows that chondrites are very distinctive: their physical-chemical characteristics reflect a very different origin to that of Earth. Internally, chondrite is specked with little spheres of silicate, which could only be formed in the absence of gravity inside the nebula that gave birth to the Solar System. Furthermore, astronauts have proved that in conditions of microgravity a liquid takes a spherical shape.









## LAS MAREAS The Tides



From the coast, we can see how the tide rises and falls every day. This cycle repeats itself constantly: if there is a high tide now, six hours later there will be a low tide and another six hours later, a high tide again. Over and over again\*.

\*Actually, on average, it happens every six hours and twelve minutes. That is why the high tide comes almost an hour later from one day to another.

#### What are tides?

Tides are the result of the periodic rises and falls in sea level caused by the gravitational attraction exerted by the Moon (and to a lesser extent, the Sun) on our rotating planet. Tides are clearly noted in the oceans, since water bodies can be deformed more easily than the Earth's crust. This gravitational effect increases with the mass of the bodies, their size and proximity. Although the Sun's mass is much larger than our satellite, the Moon, it is also much further





4

from our planet, causing it to have a weaker influence over the tides.

## Spring and neap tides

When there is a new moon or full moon, its gravitational influence and that of the Sun are added together, since the Moon and the Sun are then both aligned with our planet. This alignment causes the so-called spring tides, which reach a greater height compared to those of the rest of the month. On the other hand, when the Moon is at first or third quarter, the Sun's influence partially counteracts that of the Moon (since the three bodies are not aligned), causing the so-called neap tides.

#### Tides calculator

#### Hands on!

- 1. Look which phase the Moon is in today.
- 2. Turn the disc until the white ball (the Moon) is opposite today's phase. Now you have the relative Moon-Sun-Earth position for today. Will there be spring or neap tides?
- 3. Turn the sphere representing Earth (using the metal wheel) until the Canary Islands are centred over the time your watch indicates during winter (or one hour less if in summer).

4. Observe the level of the oceans with respect to the Canaries (the blue ellipse) to find the state of the tide. Keep on spinning the sphere, can you tell at what time there will be a high tide?

### Did you know that...

By observing the Moon's position you have a simple rough way of knowing the state of the tide? If the Moon is near the horizon, the tide is low; but if the Moon is high in the sky over the South horizon, the tide is high. Remember: if you know where the Moon is you will how the tide is.

### Did you know that...

The ground we tread on also rises and falls due to this gravitational effect? It can rise up to fifty centimetres during a high tide! You have to bear this in mind while calibrating a GPS or making precise astronomical measurements.





# PAISAJES CELESTES Celestial Landscapes



### The Constellations

Constellations are fictitious groups of stars in the sky, that have denoted certain regions of the night sky since the most ancient times.

They have always been useful, especially in navigation, to find one's way in the dark and keep track of time by night, or to determine the seasons. The oldest representations of our present constellations are found on **kudurrus**, commemorative monoliths related to land grants of the Babylonian kings in the 2<sup>nd</sup> millennium BCE.

## The power of imagination

Different cultures have claimed to see various figures of their mythology in certain star groups. For example, the seven brightest stars of our Ursa Major - also considered to represent a wagon - are seen as a plough by the English, a dipper by the North Americans or a dromedary by the Tuareg. To the Egyptians it was an ox's leg, for the Sumerians a war-chariot, the Native Americans a female bear and the Romans a herd of seven oxen (Septem Triones).

#### Hands on!

On this reproduction of the kudurru erected by king Meli-Šipak of Babylon over 3000 years ago, try to identify the symbols representing the



Moon, the Sun and Venus, as well as our oldest constellations (Capricorn, Hydra, Scorpius...). The solutions are on the computer.

Furthermore, use the computer to overlay the images of various objects, animals or characters on the well-known constellations of Ursa Major and Orion. What other shapes do you see in there? Let us know!





## LA ESCRITURA O LA NECESIDAD DE COMUNICARSE A need to communicate



, thought of community

Writing is one of Humanity's greatest achievements of all time. Its presence marked the cultural transition from prehistory to history.

The first writing systems appeared 5,000 years ago almost simultaneously, in Sumer (Iraq) and Egypt, and others appeared soon later in India and China. Starting from Sumerian pictographs (drawings with meaning), writing evolved into one of its most curious forms, the wedge-shaped Cuneiform script, which was used all over Mesopotamia until the expansion of the alphabets into which it later developed.

## An alphabet for each region

An alphabet consists of a certain number of signs which stand for phonemes (sounds), either just consonant sounds such as p,t,k,b,d,g,l,m,n,as in every early alphabet, or also the vowel sounds only in use in and after the Greek alphabet. Thus, out of Cuneiform script the Ugaritic alphabet developed 3,500 years ago – the most ancient alphabet known. The Egyptian hieroglyphs evolved into Proto-Canaanite to later lead to the Phoenician alphabet about 3,000 years ago.

Every present-day alphabet derives from Phoenician, including the Latin/Roman alphabet in which this text is written; and more directly the alphabet used by the Canarian aborigines. The Ancient Canarian script belongs to the Lybico-Berber family, similar to



that still used by Tuareg peoples in the Sahara desert – known as Tifinagh.

## Hands on!

Admire the beauty of Cuneiform in our model of a kudurru. Find out the origin and evolution of our modern alphabet and that of the Canarian aborigines from the Egyptian hieroglyphs. In our computer, try writing your name in adaptations of the Phoenician alphabet, the hieroglyphs with which Egyptians wrote foreign names and the Ancient Canarian alphabet. Remember none of these used vowels in their writing.





## LA HUELLA DACTILAR DE LOS ÁTOMOS Atomic Fingerprints





What is the Cosmos made of? By analysing the lines of the spectrum we can identify the chemical composition of distant stars and nebulae.

### Hands on!

Observe the coloured lines. They are unique for each gas. Can you identify them in the list. Careful: the lines appear repeated on both sides. Use only those on the right.





## AGUJERO NEGRO Black Hole





#### What is a black hole?

If the Earth were to be compressed into a cubic centimetre, its gravitational attraction would be so intense that light would not be able to escape its surface.

That compressed object, known as a black hole, produces an gargantuan pit in the fabric of space and time.

## How to find a ghost?

A black hole is, by definition, invisible. It can however be detected when we discover a star mysteriously orbiting around an object that we cannot see, and also thanks to the X-ray

flashes emitted as it devours such stars. The best known candidate for a black hole was discovered by the Astrophysics Institute of the Canary Islands. Its name is Cygnus V 404, in the constellation of the Swan.

#### Hands on!

### Feed the black hole

Imagine you are standing in front of a mini black hole. Roll the balls around the funnel-shaped vortex to simulate the path of a star being swallowed by a black hole.





## ¡QUÉ PESADO ERES! Man, you're heavy!

9

Weight and mass are not the same. Mass is the amount of matter in a body, and weight is the force with which a celestial body (including the earth) attracts such a mass. This celestial body can be a planet, a star, a comet... or anything else. The Earth continuously attracts you with a certain force, which is your weight. On the Moon, which is smaller and less massive than our planet, everything weighs about six times less than on Earth. And if you were to stand on the surface of a more massive body such as Jupiter or the Sun, you would be attracted towards it with greater force and would weigh more - even though your mass is always the same. Smaller celestial bodies, such as asteroids and comets, have so little gravity that on the their surface you would weigh the same as one gram of mass on Earth, and with just one jump you would be in outer space! On the other hand, the densest stars we know, white dwarfs and neutron stars have such a high gravity that on them you would weigh as much as 50,000 giant oil-tankers weigh on Earth. How much do you think you would weigh near a black hole?

#### Hands on!

Get on the scale and find out how much you would weigh where gravity is very different.



#### Hands on!

Lift these ½ kg masses and see how much they would weigh on the surface of different celestial bodies.

\*Do not try to lift the dumbbell of the white dwarf: it is bolted to the floor to simulate that it would weigh as much as 400 supertankers on Earth.

\*Weight is a force and must be measured in force units, for example in newtons or kilogram-forces, even though we colloquially simplify it to kilograms.





## SAFARI CÓSMICO Constellations

# 10

## Animals in the sky

The Bird of Paradise, the Eagle, the Ram, the Giraffe, Cancer or the Crab. the Greyhounds or the Hunting Dogs, Canis Major, Canis Minor, Capricorn, Centaurus, the Whale, the Chameleon, the Dove, the Raven, the Swan, the Dolphin, Dorado or the Goldfish, the Dragon, Equuleus or the Pony, the Crane, Hydra or the Water Serpent, Hydrus or the Water Snake, the Lizard, the Lion, the Little Lion, the Hare, the Wolf, the Lynx, the Unicorn, Musca or The Fly, Pavo or the Peacock, Pegasus, Phoenix, Pisces or the Fishes, Piscis Austrinus, Sagittarius or the Archer, Scorpius, the Snake, the Bull, the Toucan, Ursa Major, Ursa Minor, the Flying Fish, Vulpecula or the Fox. A Cosmic Safari

Telescopes are designed to observe really small or dim objects, such as the nebulae we offer you in this Safari of the Stars. You can search for them by moving our telescope from this console. From your own home, you can try to find celestial objects with animal names that are visible with the naked eye and do not require any type of instrument, such as constellations. From the 88 constellations into which the celestial sphere is divided, half of them have animal symbology. Good hunting!







# LOS HEXÁGONOS DE UN GRAN TELESCOPIO The hexagons of a great telescope



The Gran Telescopio Canarias (GTC) has a primary mirror with a surface area equivalent to that of a single circular mirror 10.4 metres in diameter. Segmented into 36 hexagonal pieces, its light-collecting surface measures has an effective area of 73 m², which allows it to "see" further and in greater detail than any other telescope. Its power of vision is equivalent to that of four million human eyes. Each mirror is polished so precisely that its maximum possible deformation is under 15 nano-

metres (millionths of a millimetre). That is, about 5000 times less than the diameter of a human hair. Here you can see a real-size replica of some of the GTC's mirrors.





## LA ESTACIÓN ESPACIAL INTERNACIONAL (ISS) International Space Station (ISS)

# 12

#### The ISS to scale

The scale of this model of the ISS is 1/100 (dimensions) and 1/100,000 (by mass). It lets you appreciate its main parts and the relative size of two astronauts, which makes them difficult to find! This space laboratory was born from merging the stations planned by several countries in the 80s: "Freedom," USA; "Mir-2" (Russia), "Columbus" the European module; and "Kibo" the Japanese experimental laboratory. Thanks to the international collaboration in which five space agencies participated, the ISS became one of the greatest achievements in the field of engineering: the largest research centre built in space. Its first module was placed in orbit in November 1988 and since then it continued growing until 2011, its final completion date. A destination for astronauts from 16 countries, including the first space tourists, human presence has been permanent in space since November 2000, since then there have always been at least 2 people on board.

The ISS in numbers: Weighing about 420 tons it orbits around the Earth every 92 minutes, at an altitude of about 380 km over the Earth's surface. Because of the continuous slight friction of the atmosphere, the ISS reduces in altitude so on every visit of the Soyuz spaceships or US space-shuttles it is necessary to propel it up again, since it does not have its own engines. The measure-



ments of the ISS are 108 x 74 metres, as big as a football field. It spins around our planet about 16 times daily at a speed of 28,000 km/h, so it would only take it a minute to travel between the extreme ends of the Canary Islands, from El Hierro to La Graciosa. It has more than 4000 m2 of solar panels, producing 110 kilowatts to fuel its 52 computers that control the ship's systems, as well as its heating and lighting systems. Even though it is equipped to host a crew of 6 for 6 months, sometimes there have been up to 13 astronauts at a time. Notable visitors include Pedro Duque and Michael López Alegría, the two Spanish astronauts, and the Russian Sergei Krikalev, who inaugurated our museum in 1993 and holds the record for being in space for the longest time, clocking up 747 days in six different missions.





## EL GRAN TELESCOPIO DE CANARIAS

## The Great Canarian Telescope

The Gran Telescopio CANARIAS (GTC) is situated at Roque de los Muchachos Observatory (La Palma), which belongs to the Canarian Astrophysics Institute (Instituto de Astrofísica de Canarias, IAC).

Considered the largest and most advanced infrared optical telescope to date, this is an enormous structure weighing more than 400 tonnes, that moves with incomparable precision following the apparent movement of the stars. The engineering at its base is so advanced it can be moved by just one person.

The entire structure of the telescope is protected by an immense steel dome 34 m in diameter, as high as an eight-storey building.

Some questions the GTC could answer: Do planets like our Earth exist around other stars?

How did galaxies come into being?

What is the mass of a black hole?

How are stars born?

Are there many "brown dwarf" stars?

What is "dark matter" made of?

Is the expansion of the universe accelerating?

## How does a telescope work?

Telescopes are optical instruments or systems that provide a closer image of a distant object. Similar to larger telescopes, this model on



exhibition has a system of two concave mirrors that form a minuscule image at the focus of that distant object. The observer then utilizes an ordinary ocular telescope to see that image of the object.





## LA PESADILLA DEL ASTRÓNOMO The Astronomer's Nightmare





## The Canaries: An Astronomical Paradise

A good astronomical observatory must have not only clear skies but also a stable dry atmosphere, free of turbulence. Above the sea of clouds on the highest of the Canary Islands, Tenerife and La Palma, these ideal atmospheric conditions are usual most of the year.

## Why do stars twinkle?

When you push the button, the heat of the resistance provokes turbulence in the air, causing a vibration

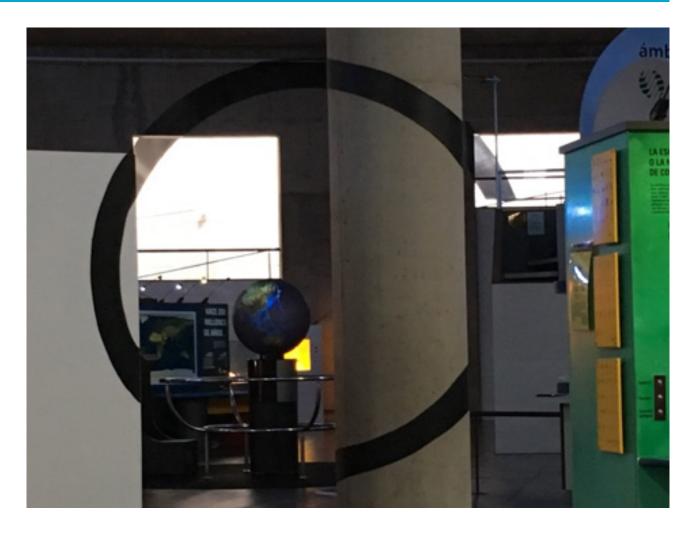
in the laser beam. The image of a vehicle is also deformed and rippled when we are looking through the hot air close to the pavement. Likewise, the turbulent air of the atmosphere causes the light of real stars to flicker or shimmer, which we often call "twinkling".





## EL CÍRCULO ESCONDIDO The Hidden Circle

# 15



It's just what it seems!

This patch on the wall is part of something bigger. In science, the solution is found through tiny fragments that we have to join together like a puzzle. Can you find the rest of the pieces and decipher the mystery?

Perspective plays an important role in our everyday life, particularly in judging distances. Without it we would not be able to drive a car or serve a cup of coffee to our guests. However, perspective may also cause optical illusions.





## FÁBRICA DE COLORES The Colour Factory

# 1

## EL COLOR DE LA PANTALLA DE TE-LEVISIÓN

### The colour of a TV screen

In every dot of the screen there is a group of three really thin phosphorus bars, each of them representing the colours red, green and blue. The combination of these three colours allows the reproduction of any other hue. The signal the TV receives informs it of the brightness each of the little bars must emit in order to reproduce the colours of every dot on the device. Every one of the thousands of dots that form the screen receives new instructions around every 75 times per second (depending on the device).

#### Hands on!

With the help of the magnifying glass, look for the thin bars (red, green and blue) that are used in the TV screen to synthesize the different colours.

## SOMBRAS DE COLORES Colourful shadows

You must have realized by now how the colour white is the result of a mixture of the light of three colours. Now you will see what happens when you remove one of these colours from white light. The one that is left (the colour of the shadow) is the result of combining the other two.



### Hands on!

With the lever placed in the 'combining colours' position, place yourself between the spotlights and the illuminated wall. You will see how shadows aren't always black..

## SUMA DE COLORES Combining colours

Mixing the three complementary colours (red, blue and green) allows us to reproduce the rest of the spectrum. All you have to do is to adjust the brightness of each of these three ingredients.

#### Hands on!

With the lever again in the position of 'combining colours,' turn the knobs to change the intensity of the three light bulbs. Watch closely the colour projected in the central zone, where the three beams of light are superimposed.





## EL PUENTE ROMANO

## The Roman Bridge





In Roman bridges, arches were not necessarily built with mortar or cement. In order to understand this, try to build here your own bridge. With the help of supporting pieces, place the numbered 'stones' in their position. Then remove the supporting pieces and test how stable the bridge is by sitting on it. Its curvature allows it to bear your weight, as it redistributes the tractive forces that would otherwise break it





## DISEÑA TU PROPIO CIRCUITO ELÉCTRICO

Design your own electric circuit





#### Electrical divider

This circuit allows you to divide I=V/R. The value that results from dividing the voltage by the resistance can be read in the current meter or ammeter. The result is illustrated in amperes. In physics, this division formula is known as Ohm's law.

## Some notions on electricity

Batteries have an excess of electrons at their negative terminal and a shortage of them at the positive end. This separation in charge - the force which creates the electrical current that traverses the circuit - is called voltage or tension. To reduce the current we can increase

the resistance, which decreases the flow of electrons.

#### **Electrical units**

The voltage or tension is measured in volts (V). The intensity of the current is estimated in amperes or amps (A). The resistance is measured in ohms  $(\Omega)$ .

#### Hands on!

Choose a voltage and a resistance by turning the corresponding circles, and read the value indicated by the ammeter. Observe how the bulb's brightness is proportional to the current passing through the circuit.





## ¿CÓMO FUNCIONA UNA REFINERÍA? How does a refinery work?



Petroleum is a gift left to us by the living beings that inhabited the primitive Earth, whose extinction resulted in the concentration of solar energy into organic molecules. Industrialized societies have been burning fuel derived from oil on a massive scale - in order to propel cars, ships and planes, generate electricity and heat cities - for a little over a century, from about when coal began to decline in use. Oil reserves are coming to an end, and that is why we need to substitute the burning of fossil fuels for renewable sources of energy. We need to save the oil that's left for other equally important uses, such as the production of lubricants for machinery and vehicles, plastics, synthetic fibres, detergents, and even medicines and food preservatives.

This unit shows the functioning of an industrial installation called a refinery. Here you can find information about the processes of fractional distillation or oil refining, through which its different components are separated.







## RÓMPETE EL CEREBRO Rack Your Brains

### Lox in Box

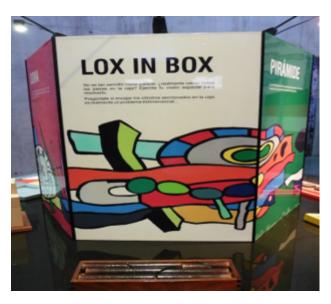
It is not as easy as it seems: do all the pieces fit within the box? Exercise your spatial vision to solve it.

Ask yourself if fitting the selected cylinders within the box is in fact a three-dimensional problem...



## **Tamgram**

Do you have spatial vision in three dimensions? Test yours by solving this three-dimensional puzzle. Try to build a cube with these pieces.



#### Soma

Do you have spatial vision in three dimensions? Test yours by solving this three-dimensional puzzle. Try to build a cube with these pieces.







## RÓMPETE EL CEREBRO Rack Your Brains



## RANAS Y SAPOS Frogs and Toads

A single-player strategy game with simple rules. Rules :

The game starts with the initial configuration of the pieces of the same colour occupying consecutive squares at each end of the board, with a single square empty in the middle. The objective is to exchange the position of the pieces so that they end up grouped together again but at the opposite end. There are two permitted actions:

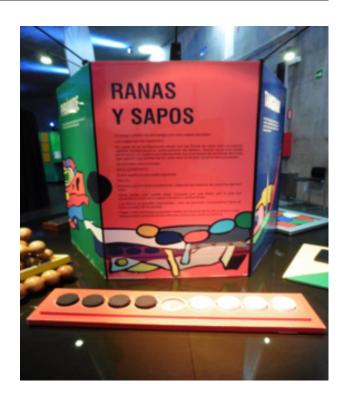
### **GLIDING:**

To move one piece to the next square.

### JUMPING:

To move one piece two squares, jump over a piece of the opposite colour. Each square can only be occupied by one piece, so movements must always be to an empty square.

Pieces cannot go back, they can only move towards the opposite end of the board. As the pieces cannot jump over those of the same colour, they always finish up in the same relative position.







## RÓMPETE EL CEREBRO Rack Your Brains



## PIRÁMIDE Pyramid

With these 6 sets of balls that you have here, try to build a tetrahedron – a pyramid with four equal faces.





## CUARTOS MENGUANTES Waning quarters of the Moon

Do the nine pieces fit within the big square? There are five solutions, but only one of them is symmetrical in some way. Use your wits to look for it. The kind of games in which you have to fit geometrical shapes into the smallest amount of space possible are the hardest ones in mathematics. They are also known as "close-packing of equal spheres", and some can only be solved with the aid of supercomputers. But don't be discouraged, this simpler game is not one of those.





## TOCA LA BOMBILLA Touch the bulb





You are now watching the image of a real bulb reflected in a large curved concave mirror. The real bulb is inverted and out of your reach, at the middle of the mirror's curvature. As the image of the bulb is reflected, it produces the image you now see.

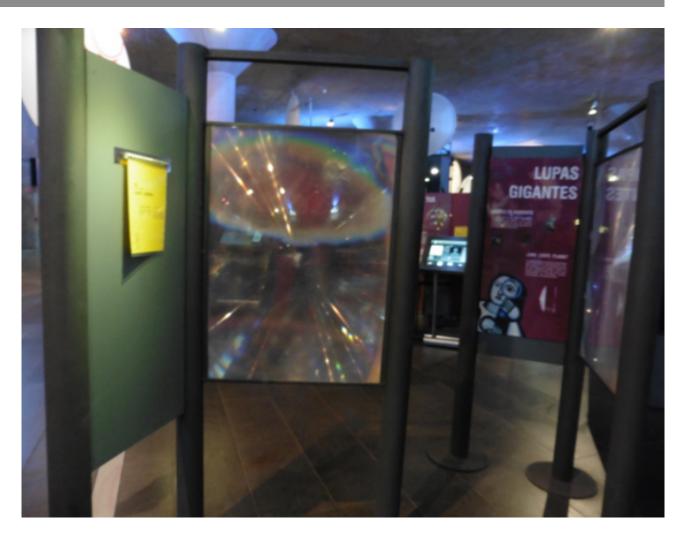
### Hands on!

Grab the light bulb... If you can.





## LUPAS GIGANTES Giant Lenses



## Magnifying glasses

The lens refracts the rays of light projected from an object and converges them into the eye. The brain deduces that the rays have come from a larger object than in reality.

## A flat lens

Could a flat sheet of glass act as a lens? Definitely not. Yet in this case the sheets are not really flat. They

have the same curvature as a lens, but compressed into extremely fine concentric rings. Can you see them?

### Hands on!

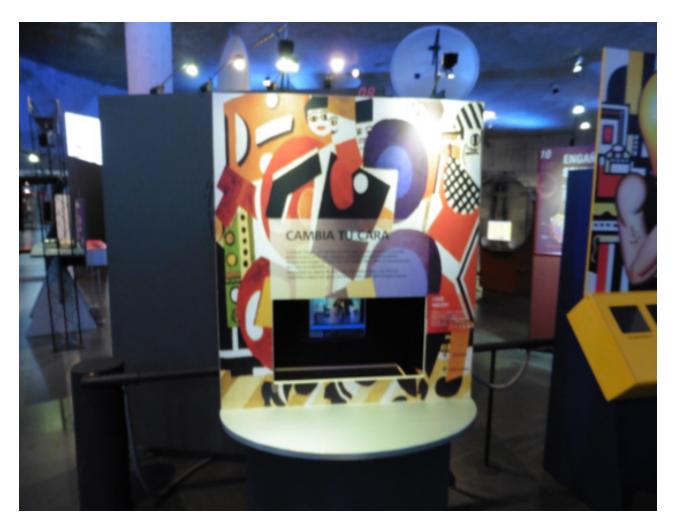
Watch a friend from behind this strange lens.





# 8

## CAMBIA TU CARA Change your face



Any image, for example your face, can be subjected to different deformations underlying which there are many complex mathematical operations. Even though this image contains 307,200 pixels (640 x 480 resolution), such an operation is really easy for a computer.

Here you will see some of those deformations: for each of them, a mathematical formula assigns a new position for each point of the original image.





# 9

# ¿SE APAGARÁ LA BOMBILLA? Will the bulb ever run out of light?



The incandescent light bulb as we know it today is becoming a thing of the past, as it is being substituted by other more efficient eco-friendly bulbs. About 80% of the energy consumed by a conventional bulb is lost as heat and emissions other than visible light.

### Hands on!

Push the button and see the consumption in watts in real time, the total number of hours it has been turned on and the total cost in Euros for each kind of light bulb. You can find even more information in our interactive software.





## ¡CHOCA ESOS CINCO! Let's Shake Hands!



## Spherical mirrors

There are two very important points in the geometry of a spherical mirror:

- 1. The centre of curvature, which coincides with the centre of the sphere;
- 2. The focal point, where all rays parallel to the axis converge. It is situated half-way between the centre and the mirror.

## The changing image

After shaking hands with yourself, you now have the opportunity to explore the magic of a spherical mirror.

The type of image reflected in it depends on the distance between the object and the mirror, which does not apply to a flat mirror.

## Hands on!

Put your hand near the centre of the circle

Can you "catch" the reflected image with it?





## EL ANILLO SALTARÍN The Jumping Ring

# 11

## Why does the ring jump?

The ring jumps as a result of a sudden magnetic repulsion between the coil and the ring itself. How can this be, as there are no magnets in this experiment? It is because of the electric currents flowing through the ring and the wire wound into a coil, producing a magnetic field.

#### Press the button

- 1. An electric current starts flowing through the coil.
- 2. This sudden increase in electric current produces an intense magnetic field in the central iron bar. It is now an electromagnet.
- 3. When the ring 'notices' the sudden appearance of the magnetic field in its centre, an electric current is induced along the ring.
- 4. This induced current also produces a magnetic field in the opposite direction to the other.

This repulsive force between these two magnetic fields is what makes the ring jump.

## History

The Canarian physicist Blas Cabrera carried out intense research into the magnetic properties of matter, although not particularly the effect here shown. This was discovered in 1887 by the American engineer Elihu



Thompson.

Beware! Very strong magnetic fields! Approaching may interfere with pacemakers. Do not wear watches nearby.





# DE QUÉ ESTÁ HECHO TU MÓVIL What is your phone made of?

12

In the production of a mobile phone, a great variety of materials are used, such as lithium and cobalt in the battery, copper in the wires and printed circuit boards, tin for soldering, plastic in the case and even gold and silver in the chip contacts.

#### Hands on!

Touch the screen and discover what your phone is made of with our interactive software and our robotized board.

#### The Dark Side of the Phone

Do you know how many mobile phones there are in the world, and how many of them end up recycled? According to a report by 'Eurosource', about 80 million are replaced every year in the European Union, and at the same time about another 85 million are never used by their owners. There is an important potential in recycling mobiles, both economic and environmental, but only about 5% are finally recycled!

The great demand for the minerals used in electronics, such as Coltan – the ore from which we obtain Tantalum – has increased their costs in recent years. Many of these minerals are obtained by hand, and almost always in developing countries.



Their high value has also caused armed warfare between local factions, sometimes supported by foreign countries. Because of all this, we should always consider recycling our old phone, instead of throwing it away.





## LA RENDIJA HIPERBÓLICA The Hyperbolic Slit

13

When the rod turns around the shaft, a three-dimensional geometrical figure known as a hyperboloid is 'drawn' in this space. A line drawn from top to bottom across this 3D curve provides the hyperbola of the slit. That is why the rod fits so well in the slit, since both of them belong to the same hyperboloid.

### Hands on!

Turn the rod to find out how it goes smoothly through the curved slit.







## AL OTRO LADO DEL ESPEJO On the other side of the mirror

14

Our eye-brain system is designed to learn from past experiences. With this learning, the brain succeeds in controlling the movement of our hands with precision. But in this case, even though the brain knows it is looking at a mirror image, the movements are clumsy and it is very hard to control the hand. This reminds us of the problems we faced in our childhood when learning to draw and coordinate hand movements.



#### Hands on!

Try to follow the silhouette of the star with your finger just by looking at the image reflected in the mirror.





## IDA Y VUELTA Change of Direction

15

The combination of perpendicular mirrors gives rise to an interesting optical effect. If you place yourself facing the angle formed by the two mirrors, you will see your reflection. However you won't see your reflection as if looking in a single mirror, but in the way other people see you. If you look at the corner formed by the three mirrors, you will see your inverted reflection. Being a reflection in the three dimensions of space, the inversion of the image is complete: up is down and right is left. An interesting property of this configuration is that any beam of light that falls upon it lengthwise or parallel to the imaginary axis (which starts in the corner at equal angles to each face) is reflected exactly in the same direction it comes from. The same happens on the inside surface of a sphere.

This principle is used in the reflective paint employed in highways, which contains thousands of tiny balls. Each of them reflects the light in the same direction that it comes from.

### Hands on!

Look at yourself in the triple mirror and see what happens to your reflection in: (a) the corner at which two mirrors join; and (b) the vertex at which three mirrors converge.







## CALIDOSCOPIO AJUSTABLE

## Adjustable kaleidoscope

16

A kaleidoscope usually has three fixed mirrors forming an equilateral triangle. Here, we have removed one of them so you can discover what happens when you vary the angle between the two other mirrors.

See how if the angle is "A" you get 360/A-1 reflections of the original image. That is, if  $A=60^{\circ}$ , you will see (360/60-1) = 5 reflected images.



Place the mirrors at any angle and see how the red dot or the shadow of your hand are multiplied on the base.







# **17**

## JINETES Y CABALLOS

Horses and riders

Sometimes a problem seems too difficult, or even impossible, until you find a new way of looking at it. As horses do not usually exchange their heads and legs, few people find out that the solution to this problem is to place panel B in horizontal position.

## Hands on!

Can you find the way to place panel B above panel A so that the riders are sitting correctly on their horses?



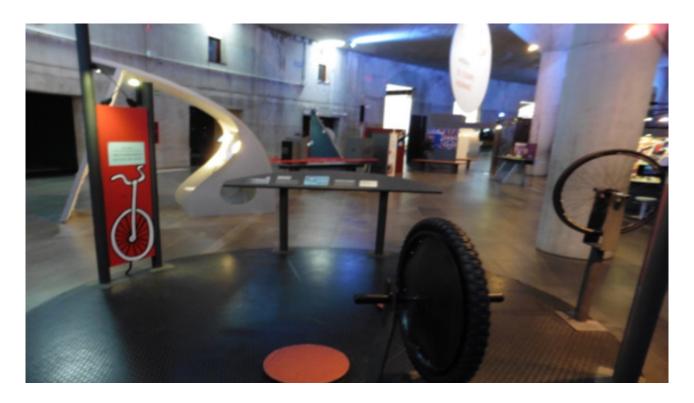




## EL SORPRENDENTE GIROSCOPIO:

The amazing gyroscope





### The artificial horizon

This instrument, essential for air navigation, allows a pilot to know the aircraft's angle in relation to the horizontal, even in zero visibility. Within the plane, a gyroscope keeps its axis parallel to the horizon regardless of the inclination or tilt of the aircraft.

## Staying on course

A rotating object is forced to maintain constant the direction of its rotational axis. Try to change this direction and you will be surprised how the force of nature will oppose you.

### Hands on!

- 1. Spin the wheel as fast as you can.
- 2.. Grab the handles with both hands and get on the revolving (red) platform (the red one.)
- 3. While the wheel is still spinning, try to lean it towards both sides.

.





## MÁSCARAS DIGITALES: Digital Masks

# 19

## Facial recognition

Our brain is capable of identifying - through characteristic physiological traits - our family, friends or acquaintances. Facial recognition is a technology that allows us to identify people and one that has multiple applications: security work, user identification, tickets and unlocking doors, customizing advertising, social networks...

One of the main options of this unit allows you to transform yourself into a celebrity. The faces displayed on the screen adapt to your face, resulting in the illusion that you are those people.

It also allows you to add accessories: 3D objects such as hats, glasses, space suits and many others that become incorporated into your image and follow your movements.







## LABERINTO DE ESPEJOS The Labyrinth of Mirrors

20



## Tricks of light

Have you ever looked closely at your image reflected in the mirror? It looks like you, but your reflection moves its left arm when you move your right. If the mirror inverts an image from left to right, why does it not show you upside down? A single mirror poses many questions. A series of mirrors pose just one: how do you get out of the labyrinth?

## Inside the labyrinth

Don't miss the following before leaving our mirror-maze!

- The light-organ, with light-beam keys.
- The kaleidoscope, where you are the eye and the figure that repeats itself.
- The window to infinity, with an illusion that creates an endless tunnel of light.





## SALA CHROMA KEY How to Produce Your Own Film

21

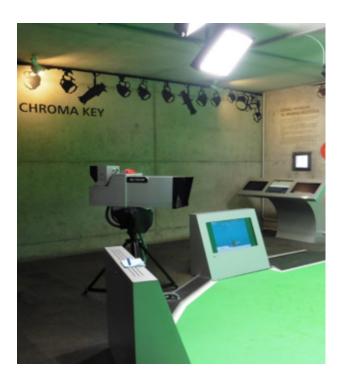
GThe chroma key is an audiovisual technique extensively used in cinema, television and photography. This technique involves substituting the particular colour of an image for another different image with the aid of specialized equipment or a computer.

This technique is often used to change the background when it is too expensive or impractical to shoot the character in the desired scenery (for example, in science fiction movies), while it has been widely used in television for transmitting the weather forecast. Typically, green and blue are used as background colours. The colour red is the most abundant in human skin, therefore it would provide worse results if used.

If something that does not contain the colour green (your skin, for example) enters the visual range of the main camera, the resulting image creates an illusion where you appear to be in other setting. No other element of the scene should be of the same colour as the background so as not to disappear, unless - of course - that's exactly the desired effect (as for example, an 'invisibility cape'.)

### Hands on!

Interact with the screen to discover the different backgrounds stored in



the production table. The screen on the left shows you what the camera is filming, while the screen on the right displays the combination of the camera and the digital background. Stand in our green set and monitor the image through the screens.





## TRUCOS DEL 0J0

Tricks of the eye





Cinema makes use of the persistence of vision, a strange property of our eyesight. What we see lingers on the retina of the eye for up to a tenth of a second after the image has gone. Since films are projected at 24 images per second, our eyes perceive each image before the previous image has disappeared.

## The magic wand

If you wave the wand in front of the projector, narrow strips of the image are reflected. If this is done fast enough, the wand will reflect all the

strips of the image in such a short time that the full image remains reflected on the retina. Thanks to this very principle, television images are seen as moving naturally without flickering.

### Hands on!

After switching the light on, wave the wand in front of the light to build a floating image





### HABLAR ES COMPLICADO

Talking is complicated





#### **Producing vowels**

The plastic models simulate the shape of the 'vocal tract' when pronouncing different vowels.

Without being aware of it, when we talk we modify the shape of our vocal tract in order to select the right tone for every letter within the vocal cords' sound range.

Knowing this, we realize how hard it is for a baby to talk.

#### Wind instruments

The sound is produced by the vibration of the air contained inside them.

The different sound qualities they produce, such as pitch and timbre, are determined by the instrument's variable shape and size.

#### Hands on!

Place the cylinder in each artificial tract and push the button. Then you will be able to hear the sound of the different vowels.





### LA BATERIA HUMANA The Human Battery

## 3

#### The ideal suit

A suit that warms you up when you are cold and cools you off when you are hot; one that keeps you dry under the rain, that keeps the microbes away and cushions your falls. A suit that also repairs itself... It's your own skin!

#### Measure your electric powers

The sweat on your palms works in the same way as the acid of a battery, they chemically react with a metal plate. On aluminium, the reaction produces an excess of electrons, whereas there is a deficit if they are placed on copper.

Your body closes the circuit and establishes an electric current that tends to equalize the plates' charge. The intensity of the current depends on the quantity and acidity of the perspiration on your hands.

#### Hands on!

Try different combinations.







## **ENGAÑA A TUS SENTIDOS**

#### The Illusion of Touch



#### The sensory model

Each part of our body is connected to a specific area of the cerebral cortex in our brain. The more sensitive the part of our body, the larger the area devoted to it in the brain. The sensory model represents the parts of the body in proportion to the size of their sensory area occupied in the brain.

#### Cold or hot?

The skin of our hands is thought to have two types of temperature sensor, as follows:

Type 1 respond only to extreme temperatures;

Type 2 respond to moderate heat and cold (around 37 °C).

If you touch the middle of the plate, type-1 sensors warn the brain about an extreme temperature (cold areas at 10 °C) while type-2 sensors inform us about heat (hot areas at 39 °C). The brain interprets both messages simultaneously and concludes that the object is very hot.

#### Hands on!

Touch the centre. How do you feel this mixture of cold and hot sensations? Is the centre of the plate very hot?







## ILUSIONES TÁCTILES

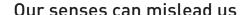
#### Tactile Illusions

## 5

#### Adaptation

A typical feature of our receptors is their adaptation to a sustained stimulus. For example, when we enter the sea and the sensation of coldness soon disappears; or that when we enter a dim room we see nothing at first, but after a few moments accommodation we can see normally.

However, this is not the case with the sensation of pain, since these receptors are the only ones that do not adapt, continuing to relay information to the brain while the stimulus persists.



A vast amount of information about the world around us is received through our senses. This information, which we call stimuli, is detected by specialized receptors and relayed to the brain to be processed into sensations, whether visual, tactile, or olfactory, etc.

#### Hands on!

To see for yourself if this is true, rub your hands against the sandpaper-like plate surfaces (A and C) for 15 seconds. Then rub both hands on the central surface (B). Do you feel the same sensation of roughness in both hands?







### SUMA DE CARAS Merging faces

# 6

#### Freaky mirrors

Usually, mirrors reflect almost all the light that reaches them. This mirror only reflects half the amount of light and lets the rest past to the other side. Turning the wheel increases the brightness on one side and decreases it on the other. At a particular instant, the more illuminated face is the most visible. So, what happens if you equalize the lighting? You will see how a third person makes an appearance - with mixed features from both of you.

#### Did you know ..?

When we were children we had almost 350 different bones, whereas when we stop growing we are left with 206. Why? During development, some of the smallest bones are joined together to form bigger ones. For example, the vertebral column starts with 33 vertebrae, but an adult has only 24 because the rest have joined to form the sacrum and coccyx.







## EL JARDÍN DE LOS OLORES

The Garden of Smells

Our sense of smell works by detecting the molecules scattered in the air we breathe.

#### Your chemical detector

Here you have six different molecules, grouped into three pairs according to their similarity. Test out the quality of the chemical detectors in your nose. Can your sense of smell distinguish between the different molecules in each pair of bottles?

#### The Case of the Carvones

The right-hand pair of molecules are called carvones. We include them here because curiously they smell different even though their chemical composition is the same. This is because their molecular geometry mirrors each other. They look almost identical, just like our hands. The chemical receptors in your nose work like identifying keys or gloves, each molecule fits only in the right "glove".

#### Hands on!

Squeeze the bottles and smell them closely through each hole. Try to guess which of the three options you are smelling, then lift the rubber covers to see the answers.







#### EL ESPEJO ANTIGRAVEDAD

Anti-gravity mirror





#### Levitation?

In the three-dimensional world we live in, here are examples of the three different kinds of symmetry:

- 1. Spherical: a sea urchin around a single point at its centre..
- 2. Rotational: a starfish (a predator of sea urchins, by the way) around an axis that passes through its centre, perpendicular to the plane of its arms.
- 3. Bilateral: the human being about a plane where each half is a mirror image of the other. (We are also a major predator of starfish!).

#### Hands on!

Taking advantage of this bilateral symmetry of the human body and the reflecting property of mirrors, we can trick someone watching us in the mirror into thinking that we are floating in the air, by just lifting one leg!





### PONTE EN SU LUGAR A Different Point of View

9

## How would you see if you had astigmatism?

Astigmatism is when some parts of the eye are not spherical, usually the cornea. Because of this, there are parts of the image that are focused while others are not.

The eye can for example focus on horizontal lines better than vertical, or vice versa.

#### Take a look!

If you look through this lens, you will be able to see the world as would a person with an astigmatism of 5 dioptres.

## How would you see if you were short-sighted?

In a short-sighted (myopic) eye, the rays of light do not converge on the retina, but somewhat in front of it. Distance vision is out of focus and appears blurred.

If a short-sighted person puts an object a few centimetres away from their eyes, the beams of light converge on the retina and they are able to see it even more clearly than a normal person.

#### Hands on!

If you look through this lens, you'll see the world how a person with a myopia of 10 dioptres does.



## How would you see if you were long-sighted?

In a long-sighted eye (hyperopic, hypermetropic, or presbyopic if due to aging), the rays of light converge behind the retina. People with hyperopia have more difficulty in seeing close objects because the crystalline lens has to make extra 'effort' to focus. Almost everybody loses the ability to see up close after reaching 45 years old, since the lens loses its elasticity, and so its ability to focus (presbyopia).

#### Hands on!

If you look through this lens, you will be able to see the world as does a person with hyperopia of 10 dioptres.





## CÉLULAS A SIMPLE VISTA Cells at Plain Sight

# 10

#### White Blood Cells

Those shiny points moving over the blue background are white blood cells that travel through the capillaries in front of the light-sensitive cells found in your retina. Blue light cannot penetrate the hemoglobin in red blood cells, but it can pass through white blood cells. Because of this, this latter kind of cells can act as little windows in movement through which light can reach the retina.

#### There are better eyes- an evolutionary "design fault"

The human eye is not the best there is. The retina in cephalopods – octopuses, squids, etc. – is better "designed" than ours.

In our retina, photosensitive cells are oriented in the wrong direction: against the direction the light comes from. A light beam has to pass through a tangle of nerves, blood vessels and other cells before they are captured in our retina. In contrast, the first thing a light beam encounters in the retina of cephalopods are the sensitive cells.

#### Take a look!

Watch the shiny points moving in the image. These are the white blood cells inside your eye. Feel your pulse. Do they move with your heartbeat?







### LA PUPILA The Pupil

## 11

#### The size of your pupil

In intense light, the pupil contracts to avoid damage to the delicate retina. In contrast, if the light is dim, the pupil will dilate so as to let in as much light as possible. The pupil also reacts to emotional stimuli that we find intriguing, such as images, objects or people.

#### The colour of your eyes

The iris is a thin muscular tissue responsible for the colour of the eye blue, grey, green or brown - depending on how much pigmentation it contains. The pupil is the circular hole in the centre through which the light passes to the inside of the eye. The iris has radiating and circular fibres that involuntarily modify the size of the pupil.

#### Take a look!

Observe your pupil's reaction if you vary ...







## LA AVENTURA DE NACER

The adventure of birth





## Do you remember when you had a tail?

There are amazing similarities between the first stages of embryonic development among different animals. And yet, the unique genetic information contained in their cells makes them evolve in very different ways.

#### Oh, such happy months!

The sounds you hear in this booth have been recorded from within the womb of a pregnant woman. They recreate the acoustic environment

we have all experienced inside that warm, maternal belly: the pulse of the heart, the murmur of circulating blood, intestinal noises and distant sounds of the world outside.

#### Use your ears!

Listen to the background noise, it is a record of how the foetus hears its mother: the pulse of her heart and blood circulation.





## LA HABITACIÓN INSÓLITA The Unusual Room

# 13

#### Cerebral Dilemma

If you look through the hole, two people in the corners at the back of the room seem to be of a very different height. Why? Our eye-brain system is faced with the following dilemma:

- The room is not rectangular and one person is further away than the other.
- The room is rectangular, and one person is taller than the other.

Normally our brain makes a mistake and chooses the second option. Maybe the idea of rectangular rooms is so established in our culture that our brain is not willing to reject it.

#### A Minor Distortion

When looking through this external hole, the room seems to be perfectly normal, with equal windows and a square-tiled floor. Nothing is going to make you suspect it is distorted, because it was built according to the rules of perspective.

#### Hands on!

Get two people to stand in the corners at the back of the room and look through the hole with one eye. Open the window if you want to take a picture.







### **DEFECTOS DEL 0J0**

Defects of the eye





The principal optical effects are myopia (short-sightedness) and hyperopia (long-sightedness). These three spheres simulate the eyeball: two of them have anomalies and the other one is normal, and the light converges toward the retina forming a cone of light. In the normal eye, the focal point coincides with the retina, which results in a well-focused image. In the short-sighted eye, the focal point or apex of the cone is in front of the retina.

In the long-sighted eye, the focal point is behind the retina and cannot be seen because it is outside the sphere.

#### Hands on!

Use the glasses located behind each sphere and you will see how eye defects are corrected. Pay close attention to the retinas in each.





## LA VISTA ENGAÑA Your Sight Tricks You



#### First trick

Our visual system has a mechanism that highlights sudden changes in brightness and colour, but is incapable of perceiving gradual changes. If you remove the strings, the border between the shades of grey appears perfectly defined and so the eye can clearly appreciate the difference between them. When the strings hide the border, the eye overlooks the gradual change of colour.

#### Second trick

Although one half seems darker than

the other, both of them are identical. The trick lies in the shades of grey not being uniform, but gradually becoming darker.

#### Hands on!

Are these rectangles uniform or not? Find out for yourself!





## LA ESPIRAL The Spiral

## 16

#### Visual sophistication

Our visual system is sensitive to movements of objects coming closer and getting further away. It has processors that are activated when something in our field of vision moves away from the centre. This is interpreted as an approach to the observer, and something comparable happens with increasing distance, when objects move towards the centre of vision.

#### When we look at the disc spinning...

The disc with the spiral simulates movement away from us. After observing it for some seconds, the appropriate receptors begin to adapt. If we immediately look at a 'static' wall (not moving), the other detectors that have been resting (approach receptors) will briefly prevail. The brain thinks the wall is moving closer!

## When we look at something that is not moving...

The detectors for approaching and moving away receive equal signals, consequently the brain concludes that the object is static.

#### Hands on!

1. Look closely how the disc spins for 15 seconds.



2. Immediately after, look at a wall, your hand, a person... What happens?





## DEL NEGRO AL AMARILLO From Black to Yellow:

#### Colour fatigue

In the retina, we have three different types of cells, sensitive to the colours blue, red and green. When we look at a white surface, all these sensors send an equivalent signal to our brain. When we look at a coloured surface for a long time - a blue surface, for example - the corresponding sensors become over-saturated or fatigued. If immediately after we look at a white surface, the fatigue of the blue sensors allows us to receive only green and red light, in other words: we see the colour yellow.

#### The circle spins

This effect is complicated to explain, and is not completely understood. It is thought to be due to the peculiar way the eye-brain system 'invents' the colours we see.

#### Hands on!

Observe the changes in colour as the circle spins.







## 4

## COLORES FICTICIOS Fictitious Colours

#### Colour detectors

Why does our eye-brain system sometimes see colour where there is really only black and white? It seems like our detectors for red, green and blue do not respond in the same way. For example, those for blue take more time to respond, but their response is the most persistent as it fades away more slowly.

#### But when the circle spins...

Sporadic flashes of white light reach our eye from different points on the disc. Their duration varies depending on their distance from the centre of the circle. When we receive a light impulse, the responses of the different colour detectors come into play and one or more colours will prevail over the others, depending on the length of time each flash lasts.

#### When the circle has stopped

The stimulus is long-lasting and the response of the cells sensitive to the colour blue is the same as those for green and red. In this case, the brain interprets this stimulus as white.

#### Hands on!

Push the button and look at the colours that appear on the disc. Investigate what happens if you move closer or farther away.







### LA ILUSIÓN DE MARIOTTE Mariotte's Illusion

# 19

#### The Blind Spot

There is a small specific area in the retina of the eye through which blood vessels and the optic nerve gain access to it, and which lacks light-sensitive cells, so it is indeed blind. The blind spot is an evolutionary imperfection of the human eye. The octopus has a much better eye in that sense, since the blood vessels and nerves that carry the signal from the eye to the brain are connected to the retina from behind. In our retina these connections enter from the front surface that faces the incoming light and even the rods and cones that sense the light are 'the wrong way round'. Apart from impairing transparency, to some extent impeding the light from reaching the retinal cells directly, this layout means a gap is needed for the optic nerve and vessels to exit the eyeball. This gap is precisely the blind spot.

#### Historical note

The blind spot was discovered by Edme Mariotte (France, 1620-1684) in 1668, which caused quite an impact on the knowledge of optics and vision at that time. Little by little, the current explanation has been accepted, incorporating not only the eyes' anatomy but the functioning of our even more incredible brain. Fortunately it tricks us, hiding the blind spot from us in our daily life.



#### Eyes on!

Close your left eye. Position yourself at a distance of about thirty centimetres (12 inches), with your right eye aligned with the centre of the X. What happened is that you detected the blind spot of your right eye. When you use both eyes, the blind spot of one eye is covered by the vision of the other one, but if you close one of them you will be able to perceive the other's blind spot. If so, then why aren't we aware of it when we close one eye on a daily basis?

Now do the same as with the previous panel. What happens when the yellow spot disappears?

The brain, instead of leaving the blind spot's area 'in darkness', fills the space up with what the brain detects is around it: in this case, the brain fills in the grid and makes you think that you are seeing a totally different one.



