

# EARTH



<b>EARTH.....</b>	<b>3</b>
Skills: .....	3
Learning goals: .....	3
<b>Lesson plan .....</b>	<b>3</b>
Class 1: The Earth in space .....	3
What do we need to know?.....	3
What do we need to prepare?.....	6
Class session .....	6
Class 2: Eclipses .....	6
What do we need to know?.....	6
What do we need to prepare?.....	7
Class session .....	8
Class 3: Seasons.....	8
What wo we need to know? .....	8
What do we need to prepare?.....	10
Class session .....	10
Class 4: Layers of the Earth .....	10
What do we need to know?.....	11
What do we need to prepare?.....	11
Class session .....	11
Class 5: Tectonic plates .....	12
What do we need to know?.....	12
What do we need to prepare?.....	13
Class session .....	14
Class 6: Gravity.....	14
What do we need to know?.....	14
What do we need to prepare?.....	15
Class session .....	15
Class 7: Tides .....	16
What do we need to know?.....	16
What do we need to prepare?.....	16
Class session .....	16
Class 8: The Atmosphere.....	17
What do we need to know?.....	17
What do we need to prepare?.....	19
Class session .....	20
Class 9: Human effects on the atmosphere .....	20
What do we need to know?.....	20
What do we need to prepare?.....	22
Class session .....	22
Class 10: The Magnetosphere .....	22
What do we need to know?.....	23
What do we need to prepare?.....	23
Class session .....	24
Showcase .....	24
Exam.....	24
<b>EXTERNAL SOURCES.....</b>	<b>25</b>

# EARTH

The position of Earth in the Universe, how it moves and the different elements and layers that form it

The Earth is a very theoretical and complex topic. It touches a lot of different areas, all focused on the composition of our planet, and for them a deep understanding of the language is needed. The topic is tailored for a group who likes learning and is interested in expanding their knowledge, rather than for groups more into practice and experimenting. It is a perfect follow up project for the one about space, and it is tailored for a similar group of students.

We add experiments to every lesson, but they are focused on understanding and experiencing the theory explained rather than on making the students deduct the theory themselves. This is because the theory is quite complicated and might be out of the reach of their deductive skills.

## **Skills:**

- Searching for information online.
- Taking notes from a lecture.
- Understanding the consequences of our actions in a big scale.
- Using a compass.
- Creating material to showcase information.

## **Learning goals:**

- Rotation and translation movements.
- Solar and lunar eclipses.
- The reason behind the existence of seasons.
- The different layers of the Earth.
- Tectonic plates, continental drift and its relation with earthquakes and volcanoes.
- The effects of Gravity on the Earth.
- The reason behind tides.
- The atmosphere and its layers.
- The magnetosphere and how compasses work.

## **Lesson plan**

### **Class 1: The Earth in space**

Using the previous knowledge that the studies may have, we will talk about the position of the Earth in the universe and how it moves.

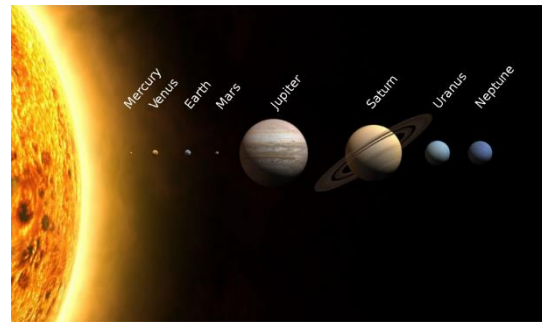
### **What do we need to know?**

The Earth is an almost sphere-shape ball with 6371 kilometres of radius. It is the third closest planet to the Sun in the Solar System, located 146.6 million kilometres away from it. It turns around itself, this is call rotation. One rotation takes 24 hours, that is, one day. It also turns

around the Sun in an elliptical orbit. It takes for the Earth to go around the Sun once 365.25 days. For this, the Earth is constantly moving at a speed of 29.8 kilometres per second.

Note that a year is 365.25 days. This is the reason why leap-years exist. Every four years, we are missing one whole day because we skip the 0.25 day extra from the 365.

These two are not the only movements Earth does, they are just the most important for us, human beings. Our solar system is part of a galaxy; the Milky way. Within the Milky Way, our Sun moves as well. Thus, as we turn around the Sun, we are also moved together with the Sun on its movement around the galaxy. This movement is, however, too slow to make any difference in our lifetime, so we don't pay attention to it.



Picture 1 The solar system

Another important aspect of how Earth moves is our rotation axis. We don't turn being completely straight. The rotation axis is tilted 23.5 degrees. This means that we do not face the Sun with the same angle through the year, and this will be important further in the course when we try to explain seasons.



Picture 2 The Earth is tilted

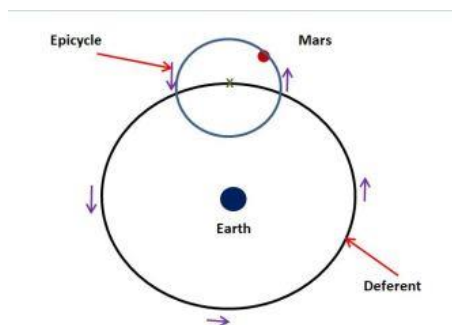
We now all this now, but it hasn't always been so clear. Even though some ancient Greeks already thought of the Sun been in the centre and the Earth and the rest of the planets orbiting around, the preferred idea until the XVII century was that the Earth was the centre of the universe and everything else was turning around us. It was even a crime to say otherwise.

However, as Science and technology was developing, data and facts were appearing that could not be explained if the Earth was the centre of the universe. Some examples are the following:

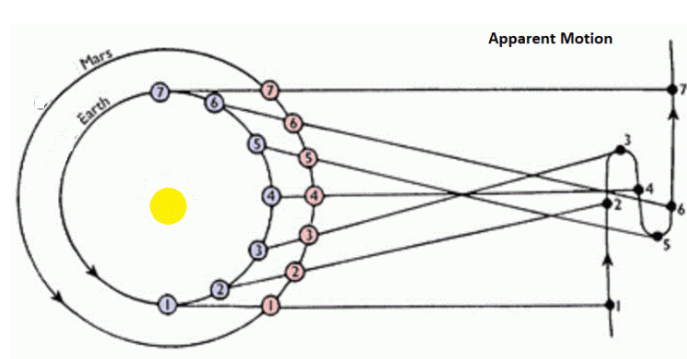
The movement of Mars

Observing Mars in the sky for a long period of time, it can be noticed that it doesn't move at a steady rate. At some point it will stop, start moving backwards, and after some days, it will start moving in the right direction again. This could not be explained by a simple Geocentric model.

To try and explain it and make it fit into the Geocentric model, Ptolomeo, a Greek scientist who developed a very complex model to explain the movements of the celestial bodies, stated that planets such as Mars were not directly turning around the Earth. The idea was that a centre was



Picture 3 Ptolomeo's explanation for Mars' movements



Picture 4 Real explanation for Mars' movements

turning around the Earth, and Mars was turning around that centre. This could explain the movements of Mars, but it is a much more complicated reasoning than reality. What really happens is that Earth travels faster than Mars because we are closer to the Sun. thus, at some point we pass Mars in our translation around the Sun. The moment when we pass Mars, from our point of view it feels like Mars is moving backwards.

#### Moons of Jupiter

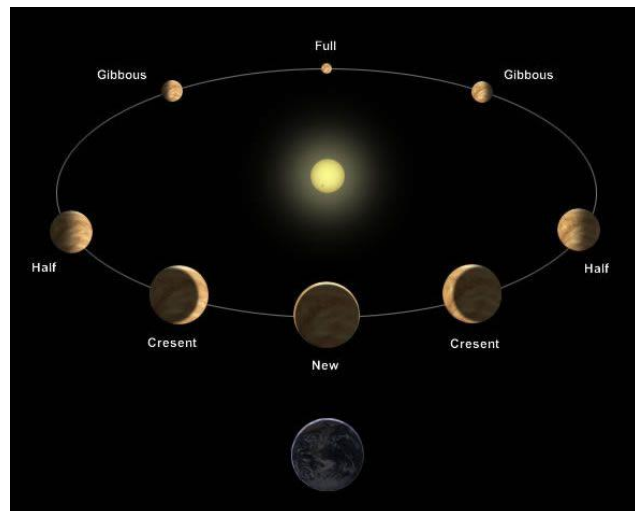
Galileo Galilei, a great astronomer from the XVII century discovered that there were four bodies that were turning around Jupiter. They were the first 4 satellites of a planet ever discovered. The fact that these four bodies were not turning around the Earth was a proof that not everything in universe turned around us. So, how could we assume that we were the centre of everything?



Picture 5 The four moons discovered by Galileo

#### Phases of Venus

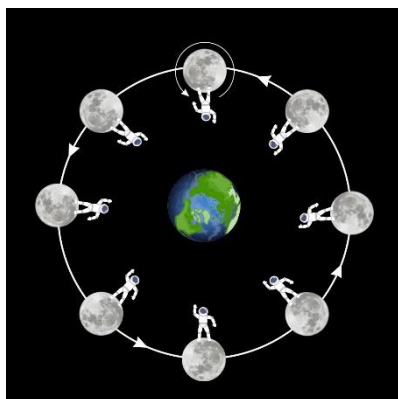
Galileo also observed that the size of Venus changed along the different phases, from being the smallest on its full phase to be in its biggest size during the new phase. This can only be explained if Venus turns around the Sun.



Picture 6 The phases of Venus

Even with proofs it took a long way to move from the Geocentric model and fully accepting the Heliocentric one. This was due to the opposition of religious powerful people, who saw blasphemy on the idea of Earth not been the centre and, thus, most important place on the Universe. The Inquisition even made

Galileo publicly reject his own theory if he didn't want to be sentenced to jail. However, facts eventually became undeniable and the Heliocentric model was finally accepted.



Picture 7 The Moon always shows us the same face

Finally, after talking about the Earth, we have to briefly talk about the moon and its own movements. Just like Earth, it has two main movements: rotation on its axis, and rotation around the Earth. The curious part about the Moon is that both movements take exactly the same time to be done; 28 days. This means that the Moon turns around itself once in the same time than it turns around us. As a consequence, the Moon is always facing the same side to us, what means half of the Moon has never been visible from Earth. This is, the dark side of the Moon.

## What do we need to prepare?

- Three different size balls. One for the Sun, one for the Earth and one for the Moon
- One small ball to represent Earth and one to represent the Moon per pair of students.

## Class session

To begin this session, we will present the topic: Earth. Then, we will ask the students about what things they know and what other things they might want to learn about the planet where we live. Some of the questions we might already have covered in the lessons to come. If some of their interests are not part of the cycle, we could consider adding them or quickly discussing them during this session.

Next we will talk about our position in the universe. If the project about Space has been done, we expect the students to already know this information. Otherwise, we will quickly introduce it. Then the two main movements of Earth will be mentioned. To show how it looks like, we will have brought three balls. We can ask three students to stand up and each take one. Then, they can move as the body they interpret (Sun, Earth and Moon). The Sun will stay put in the middle, the Earth will turn around it while spinning, and the Moon will spin while moving around the Earth, what will mean somehow also turning around the Sun.

Now it will be time to talk about what people used to think before. Maybe it even appears at the beginning of the session, if some of the students think that Sun revolves around the Earth. Otherwise, we will introduce this thought and talk about how different observations, as the phases of Venus, the movement of Mars and the presence of moons in Jupiter, led to a change of paradigm. With this we want the students to understand that Science is in constant evolution, and that new discoveries can make all we know be reconsidered.

To end the class, we will provide a challenge to the students. They know that the Moon takes 28 days to turn around the Earth once. Then, we will also tell them that it always shows the same face to us. Knowing that, we will ask them to try and deduce how long it takes for the Moon to spin once. For this activity we will split the class into pairs and provide two small balls to each pair so they can replicate the movements of the Moon to make their deductions.

## Class 2: Eclipses

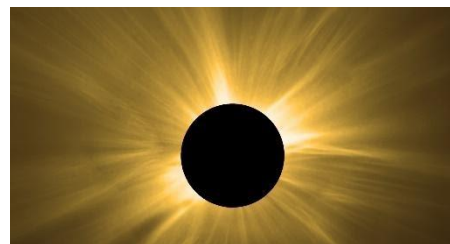
The students will research how eclipses happen, and then they will explain to their peers using balls to represent Earth, Moon and Sun.

## What do we need to know?

An eclipse happens whenever the Earth or the Moon blocks the light of the Sun. From our point of view, this event makes either the Moon or the Sun disappear for some minutes and then reappear again once the blocking body moves away. There are two types of eclipse:

### Solar eclipse

This kind of eclipse happens when the Sun disappears from the sky, covered by the Moon. In this case, the Moon goes in between the Sun and the Earth, casting its shade on us and making the Sun disappear.



Picture 8 Solar eclipse



## Moon eclipse

The second type of eclipse is the Moon one. In this cases it is the Earth that goes in between the Sun and the Moon. Casting our own shade on the Moon it looks like it disappears and appears again once we move away. The circular shade that we see covering the Moon in this eclipses is actually the shade of Earth itself.

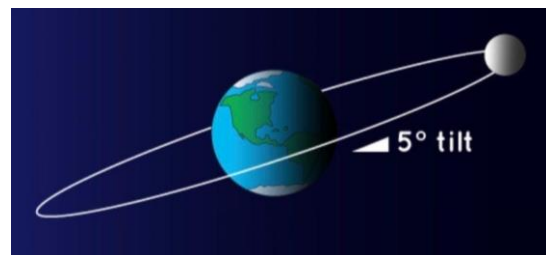


Picture 9 Moon eclipse

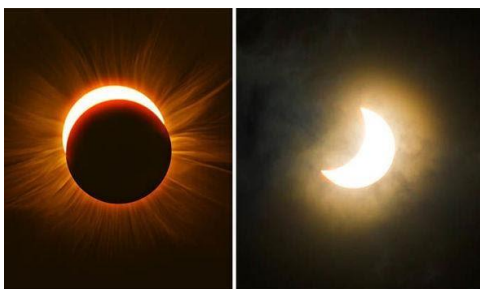


Picture 10 Position of Sun, Moon and Earth in both types of eclipse

Now, we already know that the Moon turns around the Earth every 28 days. This means that every month, the Moon must be located between the Sun and the Earth, and also once a month it must be located in the opposite place; leaving the Earth in the middle. Then, why isn't there a moon and a solar eclipse every month? The answer to this question lays on the fact that the Moon's orbit is not parallel to the Earth's one around the Sun. Thus, eclipses only happen when, at the moment on the month where the Moon is on the right place, it is also at the right "height" within its orbit.



Picture 11 The orbit of the Moon is tilted



Picture 12 Partial eclipses

This also produces that not all eclipses are what we call total eclipse. Sometimes, the Moon is almost in the right position, but not completely. In these cases, we get to see partial eclipses. These times the Sun or the Moon are only partially covered by the shade casted by either the Moon or the Earth. Depending on how close the Moon was to the right position, a partial eclipse can go all the rage from covering almost nothing to be almost a total one.

## What do we need to prepare?

- 3 laptops to do research (they can also use their own smartphones)
- Three different-sized balls per team
- Any crafty material they might require

## **Class session**

In this class we will push the students to be the ones talking and explaining. To begin with, we will introduce the topic of the session and we will ask them what they know about eclipses. Once they understand the concept of the class, we will divide the group into three teams.

*We made three teams because there are three main topics to talk about, and we had a class small enough to make three teams of three. If the group is too big, three teams might be too little, since a group of more than 3 or 4 will not have enough workload to share in order for everyone to be involved. In that case several groups can get the same topic and then only one will explain it.*

Each team will receive one topic:

- Solar eclipses
- Moon eclipses
- Partial eclipses

Then, using either a laptop or their phones they will have to do research on what their topic is and how and why they happen. To focus the search, you can ask them to find out where the Earth, the Sun and the Moon are on each case. For the last topic, a helpful question to guide the search can be “why are not all eclipses total?”

Once the teams have finished their research, they will have to come in front of their peers and explain their findings. For this, they will have three balls that they can use to represent physically their type of eclipse. They can also come up with any other kind of way of presenting their findings in an interactive and visual way.

## **Class 3: Seasons**

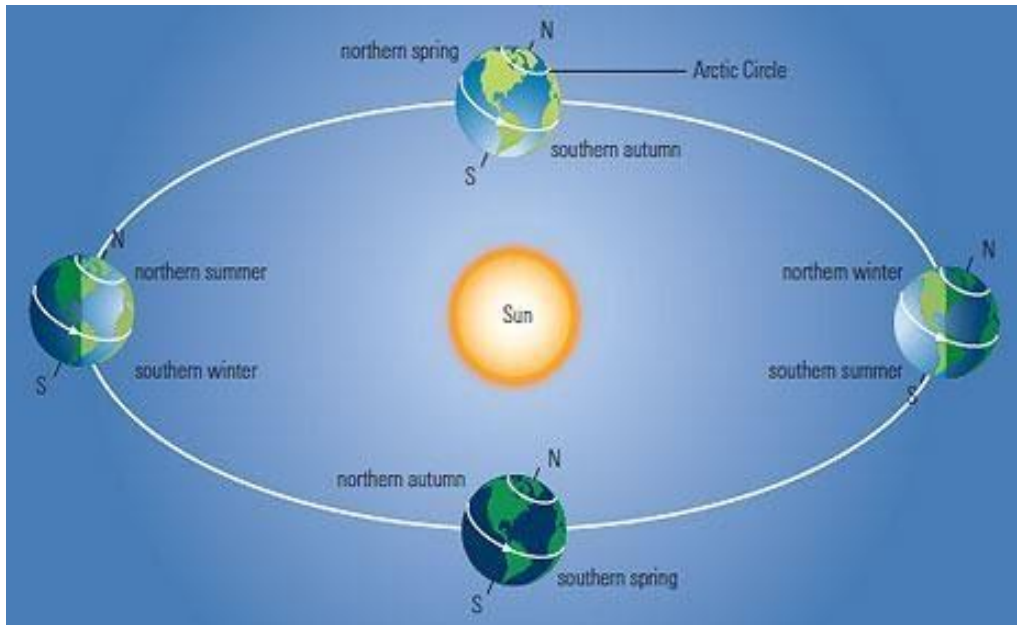
Using a lamp, a basketball and a laser thermometer, students will learn how the seasons work.

### **What do we need to know?**

As the year goes and we turn around the Sun, in some places on Earth the weather changes drastically. We call seasons to this changing of the weather, but why do they exist? A first answer to the question usually is that maybe we are closer to the Sun in summer and further away in winter. It is a good guess, but it is false. First of all, when it is summer in Greece it is winter in Australia. It is impossible for the Earth to be closer to the Sun in Greece and, at the same time, be further from Australia. Thus, this cannot be the explanation. Besides, the moment of the year when we are the closest to the Sun is January, and we are the furthest in July.

The real reason behind seasons is the tilt of our axis. This tilt makes half of the Earth to be pointing towards the Sun during half of the year, and the other half is pointing on the opposite direction. During the time Greece, for example, is pointing towards the Sun, the sunlight gets to Greece in a more direct angle, concentrating the heat in a small space and, consequently, heating this land more than it would if it hit with a shallower angle. This time of the year is summer.

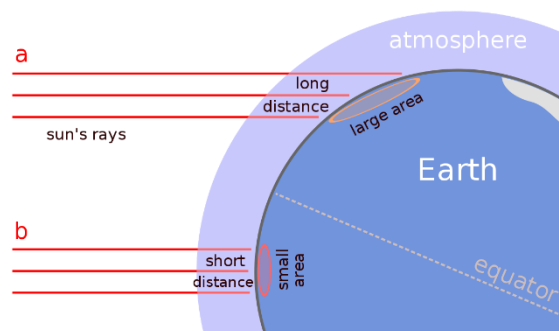




Picture 13 How the Earth look during each season, related to the Sun

Besides, during this time of the year the land is exposed to the sunlight for longer periods because the days are longer. Therefore, the land heats up even more due to a longer exposition to light. During winter exactly the opposite happens. Light hits in a shallow angle, spreading along a big area and, so, heating it up less. Furthermore, there are less hours of sunlight, so the land doesn't get warmed up.

There are several ways we can check that, actually, light heats up material faster when it falls upon a surface on a direct angle. For example, we can use a magnifying lens. If we focus the sunlight with a lenses in a  $90^\circ$  angle we are likely to burn it up, while if we incline it and spread the light in a wider area, the material might not even get warmed up. The same goes for a lamp that produces heat (LED and modern lamps do produce heat, so it should be an old lamp). If we focus its light on a surface and we manage to measure its temperature, we can see that the more direct the angle, the hotter the surface will get.



Picture 14 The shallower the angle, the wider the surface where light is scattered

During spring and autumn neither of the hemispheres of Earth are pointing towards the Sun, so these periods are intermediate in temperature.

Finally, an interesting remark to make is that there are areas in the planet, those close to the equator, where there are no seasons. The temperature is always summer-like. This is due to the fact that those areas of the Earth are always pointing to the Sun. The further away we go from the equator, the more extreme the difference between summer and winter will be, because the position will be more affected by the tilt of the axis

## **What do we need to prepare?**

- Big world ball
- A flashlight per team
- Papers
- Coloured pens
- Balloons with dark colours
- Magnifying glasses
- A lamp that produces heat
- A laser thermometer

## **Class session**

Today we will talk about the seasons, so our first question will be why our students think seasons exist. If no one guesses that it is because our distance to Earth, we will present this possibility, and then we will try, together, to disprove it. Next, we will tell our students the real reason; the tilt of the Earth's axis.

We will hold our Earth globe and one student will shoot light from a flashlight as if it was the Sun. Then we will ask the students if they think the light hits everywhere in the same way. After some discussion, we will let them try to figure it out with a small experiment. In groups of three, they will get a flashlight, some papers and pens. They will shoot light to the paper and mark with a circle where the light hits. Then they can tilt the paper in different angles, not moving the light, and mark the light circle on each case. They will realize that, the more tilted the paper, the wider the surface touched by light.

After this discovery, if weather allows and the Sun is strong enough, we can see the consequences of it by focusing sunlight on a balloon using a magnifying glass. If we tilt the glass, the light will be scattered around a big area and the balloon will not explode, while if we focus it in a point, the balloon will pop.

A similar experiment can be carried out using a laser thermometer and a flat surface. We can measure its temperature before been exposed to any light. Then, we can shoot light either with a lamp that produces heat or even with the magnifying glass itself. We can do it in different angles and for each case measure the temperature. The more direct the light is focused, the higher the temperature should be.

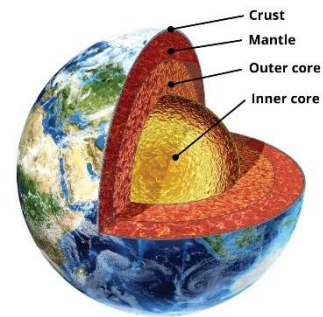
Finally, after the experiments and once all students have understood how seasons work and why the angle in which light falls upon a place affects how much it gets warmed up, we will take the Earth globe again, stand up and project light placing the globe in different position. For each position, we will ask the students what season it would be in a certain part of the planet, so they can prove us that they understood the theory.

## **Class 4: Layers of the Earth**

Each student will be assigned one layer of the Earth to do research about. At the end of the class, they will present their findings.

## What do we need to know?

The Earth is a ball of rock, but it is not made out of the same material from the surface to the core. The interior of the planet is organized in layers, each of them with different materials and in a different state. Even though some of the layers can be divided into sublayers, we will focus on the most important ones for this class. These are four, from the surface to the core; the crust, the mantle, the outer core and the inner core.



*Picture 15 The Earth and its internal layers*

### Crust

The crust is the outer and thinner layer and it is in a solid state. It is the one we step on. It ranges from 5 to 70

kilometres in depth. The thin parts are the oceanic crust, which underline the ocean and is up to 10 kilometres in depth. This part of the crust is denser than the continental crust, and it is made of iron and silicate igneous rocks like basalt. Continental crust is made out of rocks like granite.

### Mantle

The mantle is the second layer from the top, and the thickest one. It goes from the crust to a depth of 2,890 kilometres. It is in a solid state and made out of silicate rocks that are very rich in iron and magnesium. These rocks are extremely hot, so they become very viscous and can flow over very long timescales. This semisolid state of the mantle is responsible for the movement of the tectonic plates, but we will go deeper into this in the next session.

### Outer core

The outer core is a liquid layer. It is made out of melted iron and nickel and it is 2400 kilometres thick, starting right where the mantle finishes, 2890 kilometres in depth from the surface. The fact that it is liquid is the main reason why the Earth has a magnetic field that protects us from solar winds and allows compasses to work, but we will focus on that in further classes.

### Inner core

The last layer is a solid ball of 1220 kilometres radius that is believed to be made out of iron and nickel. Unlike the outer core it is not liquid. This is because the pressure in this layer is much stronger, what makes the melting temperature of the material increase. The temperature at the surface of the inner core is estimated to be the same as the temperature in the surface of the Sun.

## What do we need to prepare?

- 4 laptops to do research (they can also use their own smartphones)
- A model of the earth that can be decomposed into its different layers. We designed one using a 3D printer, but it can be done, for example, cutting different sized balls into halves.

## Class session

In this class we will proceed similarly to session 2. To begin with, we will introduce the topic of the day: how Earth looks like on the inside. Then, we will present the different layers by their name, if possible, showing them in the model.

After presenting the name of the 4 layers, we will distribute them among our students, making four groups. Each team will have to do research on their layer. To guide the searching, they will receive a chart like the following, so they have a clear idea of what information they are looking for;

Name of the layer	
Order (counting from the surface)	
Composition (what is it made of?)	
State (solid, liquid, gas)	
Radius	
Extra interesting facts	

Once every team has finished filling up their chart, one member of each team will come up to explain their discoveries to their peers.

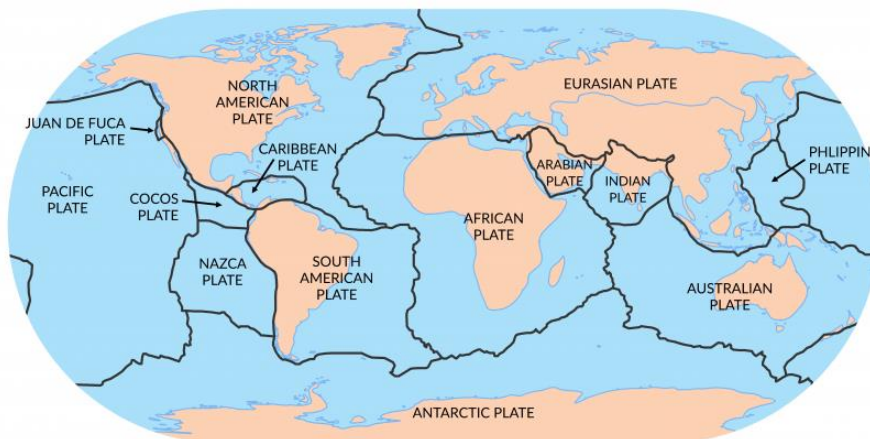
## Class 5: Tectonic plates

Using hot water and chocolate powder the students will see how the crust moves on top of the mantle. Then they will learn about the relation between the tectonic plates and earthquakes and volcanoes.

### What do we need to know?

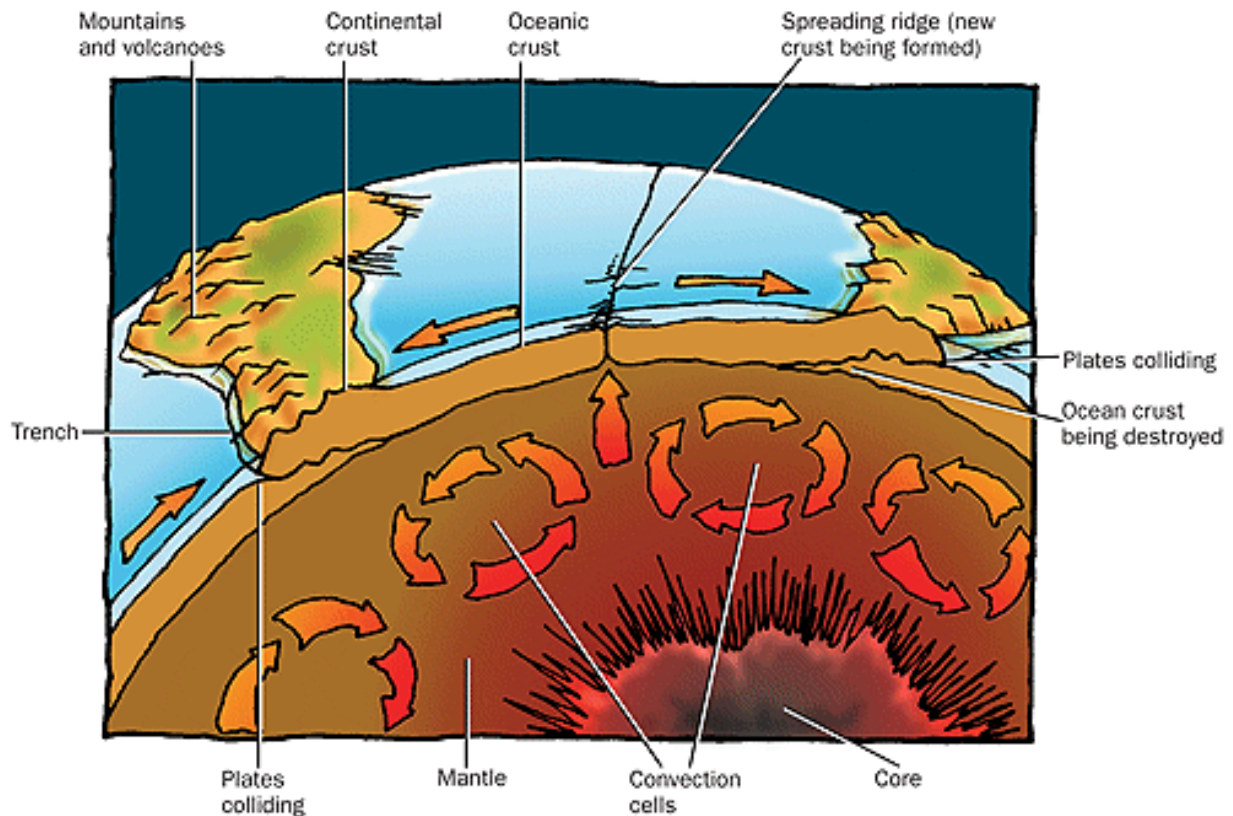
In the previous class we learnt that the mantle is a layer where rocks at very high temperatures are in a solid, yet viscous state. As we go deeper into the planet, the temperature increases. This causes the rocks next to the outer core to be hotter than those above. When a viscous material gets heated, it tends to go higher. Think for example of air. Cold air goes down while hot air goes up, like in hot air balloons.

When extremely hot semi-fluid rocks go up the mantle, they push the colder ones down. One they are on top, they get cooled down and the rocks that have been pushed down get heated, repeating the cycle. This way, what are called convection cells are formed. This movement of fluid rocks produces on the crust, that is floating on top of the mantle, a movement. This movement can produce breakings on the crust. All the different pieces formed are called tectonic plates.



Picture 16 Tectonic plates on Earth

Depending on how they are moved, plates can collide with other plates, or go away from them. The collisions can build up mountains when a layer goes on top of another, or they can cause earthquakes when they crash. Furthermore, volcanos can also be formed due to leaks of lava between layers.



Picture 17 The process behind the movement of the tectonic plates

To see in real life how this happens we can do a very visual experiment. For it, we will need to set a pot with water then pour on top of it a thick layer of chocolate powder. With this set up, we will set the water to boil. As the water heats up, the chocolate powder will start moving, and eventually we will start to see cracks on the layer. These cracks will become larger; they are the tectonic plates being formed.

In this experiment the water plays the role of the mantle, while the chocolate is the solid crust, that will break into pieces and start moving and colliding against each other.

### What do we need to prepare?

- One world map cut into the different tectonic plates per team
- A pot full of water
- Chocolate powder
- A Gas burner
- Big world map with some earthquakes and volcanoes marked



## Class session

As the class begins, we will turn on the fire and ask a student to be in charge of looking at the pot, so the fire doesn't cause an accident. As soon as something happens in the crust, the student will tell, but it will probably take longer than the introduction of the lesson.

To begin, we will review the previous one. If there are no doubts, then we can move on to the new lesson that lays on the fact that the mantle is viscous and will explain how the crust moves. For this we can make a drawing similar to the one above in the whiteboard. As the students understand how the crust moves, we will divide them into pairs and had each team a set of tectonic plates. They need to try and put them together to form a world map.

While they work on their maps, the water will start boiling and the first cracks will appear in the chocolate powder. As this happens, we can ask the students to gather around the pot to see the process. With the experiment they will get to see how the crust breaks into pieces due to the temperature of the mantle, and we will have to relate those pieces that appear in the powder with the real tectonic plates that exist underneath us.



Picture 18 Chocolate powder breaking into plates

Once the experiment is finished, the students can finish building up their puzzle maps. To finish this session, we will hang up the big map where we will have some earthquakes and volcanoes marked. We will ask them if they see something special in their location. The answer is that all of them lay on the border between two layers.

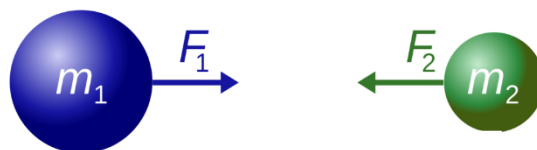
## Class 6: Gravity

With a scaled down version of the model used in the space cycle, the students will learn how gravity works between us and the Earth.

### What do we need to know?

Newton, in the XVII stated that things fall down because there is a force, Gravity, that Earth applies to us, attracting us to its core and, thus, making us fall down if we jump and keeping us tight to the planet. This first definition of gravity explained many phenomena, both on the Earth and in space, but it fell short explaining some cases happening in the Universe.

In the XIX Albert Einstein expanded Newton's theory to create the Relativity theory. Based on this, everything has an effect on everything else. The larger the object, the bigger the influence. planets orbit around stars because they are attracted to their gravity, but planets themselves attract the stars with their own gravity too. However, the force produced by the planets is so small in comparison to the one from the stars that this effect is almost imperceptible.



Picture 19 Any two bodies,  $m_1$  and  $m_2$ , attract each other



In the same way, while the Earth attracts us we also attract the Earth towards us. However, our mass is so tiny in comparison that the Earth is not really affected by our attraction. But still, why do we stand on the planet instead of orbiting around it, as the Moon does? This is because of the atmosphere around the planet. When we fall forward, we can “fly” for some metres, depending on our speed, and we will finally land. The air that surrounds us makes friction against us, reducing our speed and making us fall. If there was no atmosphere, jumping forward with enough speed would set us in orbit.

To see how different objects attract each other we can build a special table to prepare an experiment. Through this experiment we can explain that big masses bend space-time and this is how they attract other bodies. This is what we would explain in the cycle about space, but in this one we do not need to go that far. In any case, a link to the full explanation of the experiment is left in the external resources section.

In our case, we can make a smaller version of the table by clipping some stretchy cloth into an empty frame at least half a metre by half a metre. With this it would be enough for what we need to explain. Using this table, we will put a heavy ball or object in the cloth to represent the Earth. Then we can throw a slightly smaller one, to be the moon, closer to the Earth. It will start rotating around until the friction against the fabric makes it fall (in space there would be no friction). Then, to represent people we can use very tiny balls, or even sand. If we throw some sand it will immediately fall towards the Earth, as we do.

Once both the moon and the sand are standing together with the Earth, we can give a small push to the Moon and we will see how it gets far from the Earth and it might even stay away, falling into the fabric and standing there. However, if we push a piece of sand the same distance it will probably quickly fall back into the Earth.

### **What do we need to prepare?**

- An empty frame
- Some stretchy fabric, like Lycra
- Pegs

### **Class session**

This will be a theoretical, but rather short class. If the cycle about space was already implemented, we can start by reviewing what was studied about Gravity then. Otherwise, we will begin by asking the students what they know about Gravity. Using their input as a guide, we will introduce Gravity as a force of attraction between any two bodies in the universe. Even between the students there is Gravity happening.

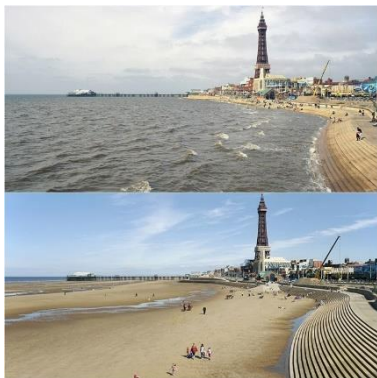
To make it visual, we will take out the small experiment we would have prepared. It can even be done in a big scale, following the instructions from the video in the external resources section if the students are ready for deeper knowledge.

Finally, we will ask the students why we do not orbit around the planet as the Moon or other artificial satellites do. By answering this question, we will set up the introduction to one of the next classes, that will be about the atmosphere that wraps our planet.

## Class 7: Tides

Using a video, we will try to explain the basics of how tides work.

### What do we need to know?



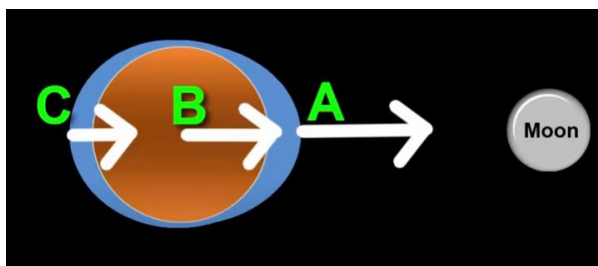
Picture 20 Same location with high tide (above) and low tide (below)

Tides are the movement that big bodies of water do during the day, rising or reducing the level of the sea. The moment it happens varies from one day to the next, and how visible and extreme they are depends on the place on Earth where you observe them.

The reasons behind tides are so complex that they are not fully understood yet. However, it is clear that it has to do with the Moon. In fact, it has to do with the force of Gravity that both the Moon and the Sun have over the Earth.

Now, depending on how deep we want to know in the theory, we leave two different videos in the external resources section of the chapter. The first one gives an easy to understand and

simplified explanation; The Moon attracts everything on the Earth, but the closer something is to the Moon, the stronger is the attraction. Thus, the water facing the Moon is attracted the most, then the Earth itself is also attracted, but less, and finally the least attracted part is the water on the opposite side of the planet. This explanation is over simplified but it is easy to grasp.



Picture 21 Diagram of how the attraction of the Moon causes two tides a day

The second video shows, through simulations, how different parts of the Earth are attracted to the Moon and how the combination of all these strengths causes the water to move in a certain way that produces the tides. Besides, this second video explicitly explains that the gravity of the Moon does not directly lift the water, but causes a force that, given the correct circumstances, can push the water. This is the reason why tides are only present in certain bodies of water. Lakes, for example, do not present tides, and those in small seas, like in the Mediterranean, are not as visible as those in big oceans.

### What do we need to prepare?

- A laptop and a projector to show the video

### Class session

As the previous one, this will be a rather short, theoretical session. We will start reviewing the previous lesson and recapping about gravity. Then, we will explain what the topic of today is; tides. The students might know about tides, depending on where they live, so we will let them explain what they know or think.

Since it is a very complex topic, we will tell our students that not everything is known yet, but there are strong theories and we will study them simplified. Then, we can project the video. Choose the one you prefer according to the level of your students

Once the video is finished, we can discuss with the students what they understood about it and we can explain the theory again in the whiteboard. Once everything is clear we will dismiss the class.

## **Class 8: The Atmosphere**

The students will be given a painting of the Atmosphere with its different layers, and by listening to the class they will need to fill in some information in it.

### **What do we need to know?**

The atmosphere is a layer of gas that covers the Earth. It is made mainly out of Nitrogen (78%), Oxygen (21%), Argon (9%) and other gases in traces amounts. These gases scatter blue wavelength more than other colours, this is why when illuminated by the sunlight, the sky looks blue. The existence of the atmosphere is vital for ours for several reasons. To begin with, the most obvious; it allows us to breath. But it goes beyond:

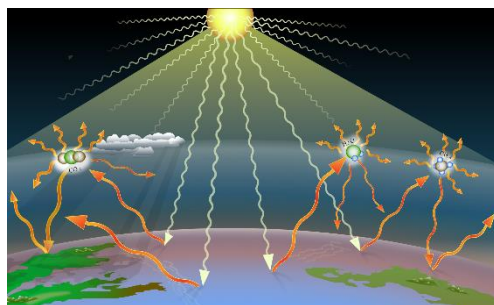
- It allows us to talk: our voice is a wave that travels in the air. Without an atmosphere it would be impossible for our voice to travel around; we would all be mute.
- It protects us from the damaging rays of the sun, working as a filter.
- It keeps the temperature of the planet, keeping the right amount of heat from the Sun.
- It produces the water cycle.
- It is a shield against asteroids that could crash against the planet.

It is organized in different layers, each of them with different characteristics, composition and temperature. Let's have a look to each one of them.

#### **Troposphere**

The first layer is the troposphere, that goes from the surface of the Earth to a height of 18 kilometres. This is where passenger planes and hot air balloons fly. It is the densest layer, and it contains 80% of the mass of the whole atmosphere. The temperature in this layer increases as height does. This is because the main heating source for this layer is the energy radiated from the surface. Thus, the further away from the surface, the colder the air gets. Temperature in the Troposphere can go as low as -55°C.

Weather happens in this layer, and so does the water cycle. Actually, all water vapour of the atmosphere is found in this layer. The high temperatures at the bottom allows water to evaporate. Hot air goes up, so as the water vapour ascends it cools down and condensate, creating clouds. How active the water cycle is in a specific area of the planet will depend on its geographical position; its latitude and longitude, distance to water bodies, the coverage from mountains, the temperatures... Winds also happen because of differences in temperature. Hot masses of air go



*Picture 22 Diagram of the greenhouse effect*

up and move to colder places, while cold masses go down and move to hotter places. This movement, when happening fast, are winds.

Finally, another important aspect of this layer is that it is responsible for the greenhouse effect. The  $\text{CO}_2$  present in this layer prevents part of the heat radiated from the surface to leave, and reflects it back, keeping the Earth at a temperature that allows us to live.

#### Stratosphere

The second layer goes from the top of the troposphere, a place called tropopause, to 55km high from the surface of the Earth. This means that the layer is around 37km wide. This layer can be accessed by meteor balloons, and also by jet-powered aircrafts. The main difference between this and the previous layer is that now, temperature increases as height does.

The reason behind this is that in this layer, oxygen ( $\text{O}_2$ ) is transformed into Ozone ( $\text{O}_3$ ) with the energy provided by the Sun. This transformation releases heat. Most of the reactions happen on the top of the layer, the lower we go, the less oxygen is available to transform, so the less heat is provided by chemical reaction and the lower is the temperature. At the bottom of the layer temperature is around  $-55^\circ\text{C}$ , and on the top, it is around  $0^\circ\text{C}$ .

Within this layer lies the Ozone layer, an area where the Ozone created accumulates. This area is vital for our survival since it acts as a filter, capturing the UV radiations from the Sun and preventing them from damaging us.

#### Mesosphere

The third layer goes from the Stratopause, at 55km, to the Mesopause, at 85km above the sea level. This is, the layer is 30km wide. Here the increasing of temperature gets inverted again. Like in the troposphere, temperature drops with increasing altitude. This is due to the low density of the air in this layer, so it absorbs less and less radiation as altitude increases. Besides, the presence of  $\text{CO}_2$  in this layer produces it to cool down, because these molecules absorb heat and reflect it in every direction; thus, part of the heat is reflected back towards space. The top part of the Mesosphere can reach  $-100^\circ\text{C}$ , being the colder area of the atmosphere.

This region is also where most asteroids are destroyed by the friction against the molecules of the air. Funny enough, it is too high for aircrafts or balloons, but too low for satellites to orbit. It is only accessible by sounding rockets that can only stay for a few minutes per mission in the layer. Thus, it is the less understood layer of the atmosphere, commonly known as the "ignorosphere".

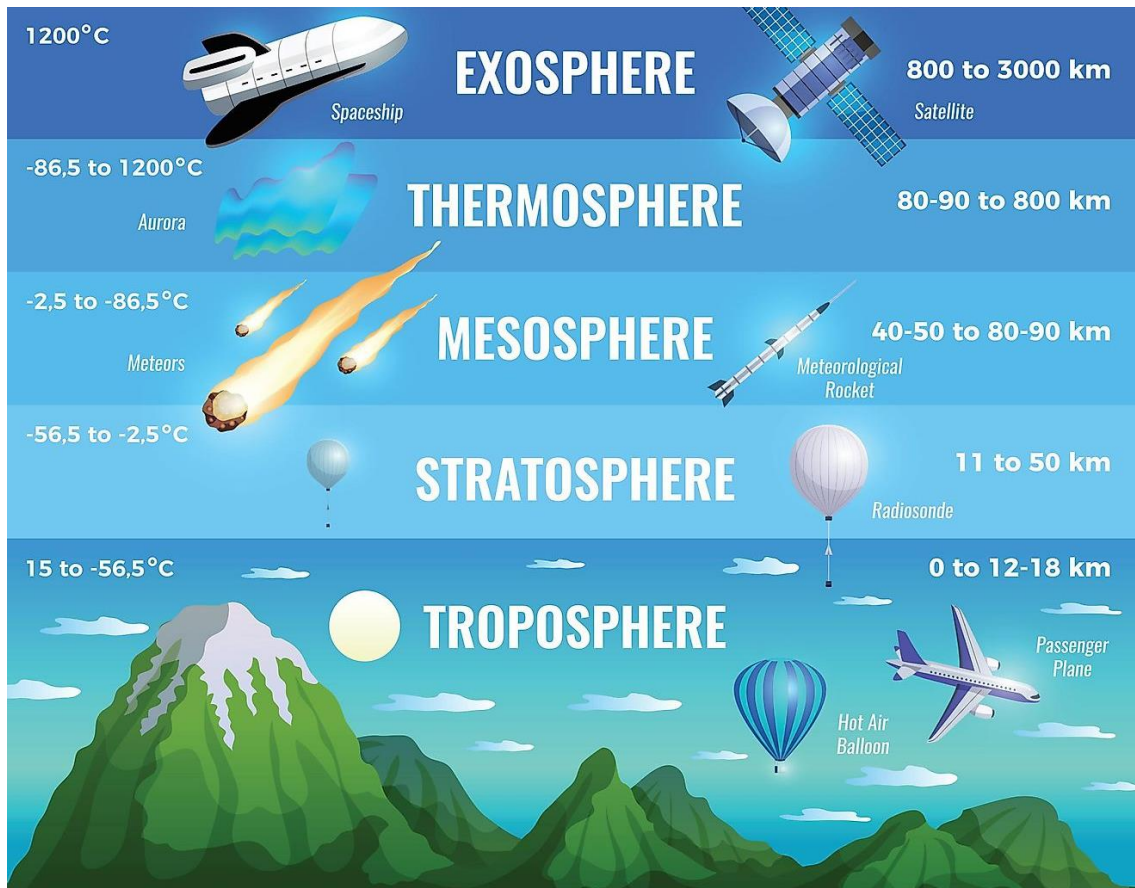
#### Thermosphere

This is the second wider layer of the atmosphere, going from 85 to 500-1000 kilometres above sea level, depending on the solar activity. This layer contains most of the ionosphere, a region of the atmosphere that is ionized due to the solar radiation. This allows, among other things, the transmission of radio waves. This is also the layer where northern or southern lights happen.

Again, temperature increases as altitude does. This is simply because the higher we go, the closer we are to the direct radiation of the Sun. Molecules here can go up to  $1500^\circ\text{C}$ . However, if a human being would be in this layer it would not feel it hot, because the density of the air is so low that it would not conduct enough energy from or to the human skin. In fact, for a molecule of any component in this layer, it would take around one kilometre of movement before crashing against another molecule.

## Exosphere

This last layer extends from the top of the thermosphere to around 10.000km above sea level, where it merges with the solar winds. It contains mainly extremely low concentrations of hydrogen and helium. The density is so low that it does not behave as a gas anymore, and particles constantly scape into space. It can take hundreds of kilometres for two molecules to collide within the exosphere. Most of the artificial satellites that we send to space orbit the planet in this layer.



Picture 23 Different layers of the atmosphere, its altitude and temperatures

Now that we know about the atmosphere and its layers, we are going to explain a little experiment to understand how our voices travel through the air. For this we will need a plastic bowl, plastic wrapping and some rice.

We will place a layer of well stretched plastic on top of the bowl, and then we will put some rice or sand on top. Now we just need to shout, or even play music from our phone next to it, and we will see how the plastic shakes, moving the rice. This is because the sound waves we are producing by talking are shaking the air, that moves the plastic.

## What do we need to prepare?

- A glass bowl
- A plastic wrap roll
- Some rice or sand
- One Layers of the Atmosphere sheet per student. They can be found together with this document



## Class session

To begin with the class, we will ask the students what they know about the atmosphere, and why they think it is important for us. They will probably reason that we need it for breathing, but we will try to make them deduce other reasons why it is vital for our life. Once this has been discussed and understood, we can focus for a couple of minutes in the importance of air to be able to talk, by doing the bowl experiment.

Once this first part of the session is finished, we will have each student a sheet with a picture of the different layers of the earth to be filled with the following information: the names, the altitude and the average temperature. Besides, below the picture there will be some drawings of different things that can be found on each layer. They will also have to match each thing with the correct layer.

In order to fill in the sheet, we will give a small class about the layers explaining the main characteristics of each of them. The students will have to pay attention and spot the pieces of information that are important for them to fill in their papers. This way we try to train their skills to take notes in class and pay attention to lectures.

## Class 9: Human effects on the atmosphere

We will discuss with the students how our actions have harmful consequences for the Atmosphere, and together we will find ways to reduce our impact.

### What do we need to know?

For this class we will focus on the two most known effects that human actions have in the Atmosphere; the greenhouse effect and the destruction of the Ozone layer

#### Greenhouse effect

The Earth receives energy from the Sun, and some of that energy is absorbed by the oceans and continents, heating the planet up. Then, the surface of the planet sends out this heat. Carbon dioxide or CO<sub>2</sub>, together with other gases, called greenhouse gases, react with this heat reflecting it in every direction. So, when the heat tries to escape from Earth back to space, some of it encounter greenhouse gases and is reflected in every direction. The heat that is reflected towards space escapes anyway, but the some of the heat is directed back to Earth, preventing the planet from losing all the heat.

The amount of these gases in the atmosphere is perfectly balanced for the right amount of heat to stay and the right amount to escape, keeping the temperature of the Earth in the perfect range for life to exist. If we add more and more molecules of these gases, then more heat will encounter greenhouse gas molecules, rebounded back and keeping more and more heat in the Earth. This causes the temperature of the planet to rise, what is dangerous for our own survival.



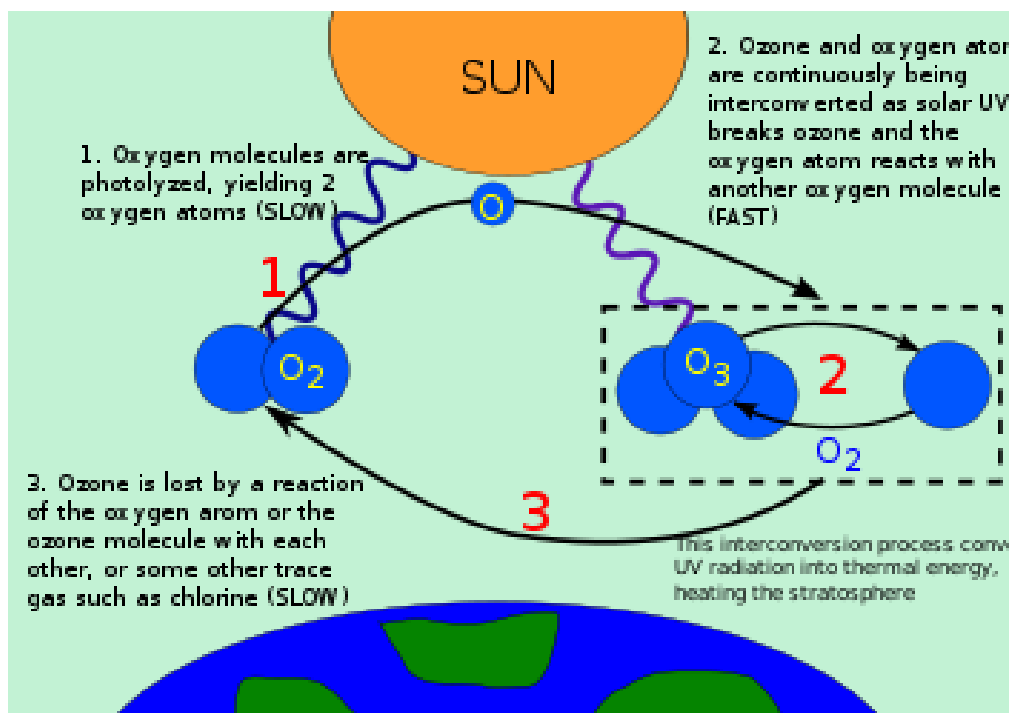
*Picture 24 When the temperature of the sea increase, corals lose their colour and die*



### Destruction of the Ozone layer

The Ozone layer is an area of the stratosphere with a high concentration of Ozone,  $O_3$ . The creation and destruction of Ozone involves the absorption of UV rays coming from the Sun, that are damaging for most living creatures. The process goes as follows.

- UV rays split  $O_2$  molecules into free oxygen atoms.
- The oxygen atoms quickly react with  $O_2$  molecules and form Ozone
- Damaging UV rays react with the Ozone, breaking it into one  $O_2$  and one free oxygen
- The free oxygen will try to combine quickly with another  $O_2$ , and the cycle repeats
- When a free oxygen meets an ozone, they react creating two molecules of  $O_2$ . Then this molecule of Ozone is out of the cycle, and the two molecules of  $O_2$  will be back in the first stage, waiting for UV to split them into free oxygen.

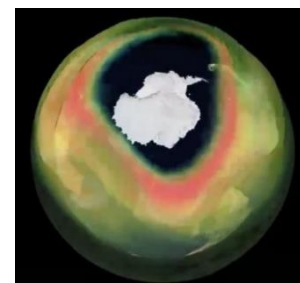


Picture 25 The process of creation and destruction of Ozone

Ozone can also react with other substances. Examples of those are Chlorine or Bromine. One molecule of Chlorine can destroy 100.000 molecules of Ozone before it is removed from the stratosphere. By adding these elements to the atmosphere, the destruction rate of Ozone increases, while the creation of free Oxygen atoms stays at the same rate. Thus, the creation of new Ozone slows down and so does the concentration of this gas in the Atmosphere. This decrease makes the layer become thinner, and it creates the so-called hole in the Ozone layer.

As a consequence, damaging UV rays can pass through the atmosphere and reach the surface of the planet, with negative consequences for all living creatures. These rays can affect and modify the DNA of cells, making it not work properly and not make the right proteins. In human beings, it can cause skin cancer.

One of the most famous human products that used to affect the Ozone layer were the CFCs that were used in sprays, hairspray, insecticides, fire extinguishers or fridges. Nowadays, however,



Picture 26 Ozone layer hole over Antarctica in September 2020

its use has been banned and other substances are used in sprays that is not harmful for the Ozone.

Finally, we are going to carry out one easy experiment to see the effect of CO<sub>2</sub> in keeping heat. For it we will need two glass jars, plastic wrap, a rubber band, baking soda, vinegar and a laser thermometer.

For the experiment we will simply place the two jars, closed with the plastic and the rubber band, in the Sun. In one of them we will not add anything else, while in the second one, we will add vinegar and a teaspoon of baking soda before quickly sealing it. The vinegar and the soda will react releasing CO<sub>2</sub> that will stay inside the jar.

After some minutes, using the thermometer we can measure the temperature of both jars. The one with CO<sub>2</sub> will be noticeable warmer since the gas will keep the heat inside. To make the experiment more serious, more jars can be prepared, with only vinegar and only soda to check that each element individually doesn't have effect on the temperature, and, thus, it is due to the produced CO<sub>2</sub>.

### **What do we need to prepare?**

- At least two glass jars
- Plastic wrap
- One rubber band per jar
- Vinegar
- Baking soda
- A laser thermometer

### **Class session**

We will begin the class reviewing what our students remember about the atmosphere. Then we will introduce the topic of today's class; how some human actions affect the atmosphere and how this can cause negative consequences in our lives. To begin with, we will recap how CO<sub>2</sub> keeps warmth, as we already explained the previous day. If we didn't, or if it was not completely clear, we will explain it again.

Once the students know the role of CO<sub>2</sub> we will explain the experiment we will carry out, and then we will ask our students what they think will happen in the jar with CO<sub>2</sub>. Will it be colder? Will it be hotter? Why? After each of the students write down their own hypothesis we can do the experiment. If we have enough material, we can also divide the class in small groups and let them do the experiment and check their predictions.

After this first part of the session, and after the students have checked that an increase of greenhouse effect gases can increase the temperature of the Earth, and thus it is necessary for us to reduce the emissions, we will explain the Ozone cycle to our students, so they get to know another example of negative human effects in the atmosphere.

### **Class 10: The Magnetosphere**

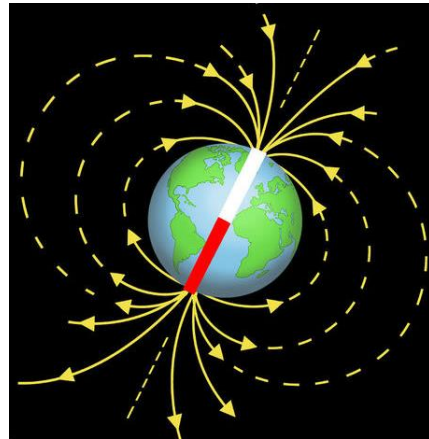
We will briefly introduce the concept of the magnetosphere and its importance. Then, the students will learn how to make and use a home-made compass.

## What do we need to know?

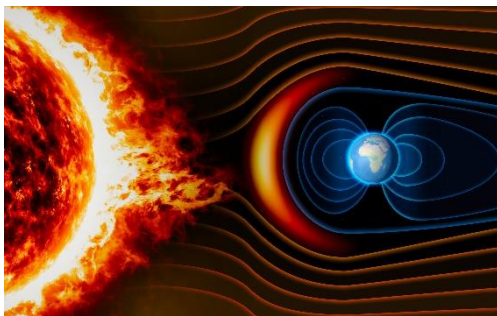
The reasons behind the existence of a magnetosphere, and how it works are far beyond the level that we want to reach with our students. The main objective of this session will be to create a compass, but to know how it works it is needed to have a basic knowledge of the Earth's magnetic field. Therefore, we will simply introduce the concept of the magnetosphere and we will mention briefly how it is created.

Going back to the lesson about the layers of the Earth, we studied that the outer core is the only layer that is in a liquid state. It is made out of Iron and Nickel, two metals that are very strong electricity conductors. As it turns, the outer core becomes a dynamo, acting like a magnet bar with a pole facing north and another one facing south.

Except from Venus and Mars, the resto of the planets, just like the Earth, have a magnetic field that is strong enough to create a Magnetosphere.



*Picture 27 Eath behaves like a magnet, creating a magnetic field*



*Picture 28 The magnetosphere protects us from solar winds*

This magnetosphere protects us for the solar winds. These are particles like electrons and protons released from the Sun, that are harmful for us and that could even whip out atmosphere. Some of the particles from the solar winds enter the atmosphere in the areas that are less covered by the magnetosphere, this is the areas close to the poles. These particles are what cause the northern and southern lights.

Another important fact is that the magnetosphere is the responsible for compasses working.

To see how compasses work we will make a homemade one. For that we will need a needle, a magnet, some light floating material, for example plastic foam, and a big bowl with water. To make it we just need to magnetize the needle by passing the magnet on it, always in the same direction, for at least 50 times. Then, we will pin the needle into the side of the plastic foam and we will place the foam on the water. The needle should stay parallel to the water but not touching it. The needle will turn the foam until it points North.

The way it works is very simple. The needle is made out of iron, and, we could say, it has thousands of “small magnets” inside, but they are not aligned, they are pointing to different directions. By using the magnet, we align them, making them all point to the same place because they will try to follow the biggest magnet around. Once we leave the needle in the water, it will still look for the biggest magnet around. This is the Earth, so it will point to the North pole of the Earth.

## What do we need to prepare?

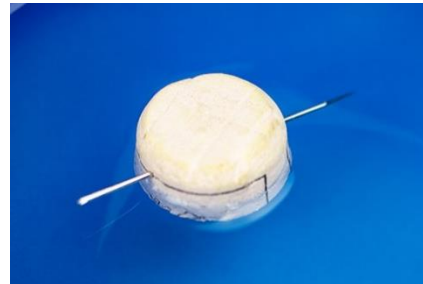
- One bowl with water per student

- One needle per student
- One magnet per student
- A piece of plastic foam per student

## Class session

As we already stated above, the theory behind magnetism is very complex. Therefore, we will introduce the basic theory about the magnetosphere, how it works and why it is important for our life, taking the opportunity to review a bit about the inner layers of the Earth. We will discuss with the student the questions they might have, but we will not engage going too deep in theory.

Once the concepts are clear, every student will build a compass following our instructions. While magnetizing the needle, we will explain what is happening inside the needle. After they place it in the water we will try to help them deduce why, then, it points to the North.



Picture 29 Homemade compass

*We finished our class here, but in the next session we asked the students to use a compass and we realized that, even if they could make one, they had no idea about how to use one. So, we think that before dismissing the session it would be a good idea to dedicate some minutes to learn how use a compass and where each cardinal point is in relation to the North.*

## Showcase

Divided in groups, the students will present the layers of the Earth, the tectonic plates and its consequences, and the layers of the atmosphere and our effect on it. They will use any material they want, from PowerPoint to posters.

## Exam

Using a compass, the students will have to find and answer questions in a treasure hunt.

*We let them use the compass on their phones, but it would be possible to ask them to make one like in session 10, that would need to be magnetized before each use.*

The students will be divided into teams and each one will start in one different station. In each station there will be one question and three possible answers. Together with this document there is a file with the three sets of questions that we used. Each answer, will give the students an instruction like the following;

*Walk 50 steps towards the NW*

Two of the instructions will direct them to a dead end, while the correct one will lead them to the next station of the treasure hunt. If they go to the wrong place, they will simply have to go back and try to answer the question again. This will make them lose time, what could lead them to fail, since they need to do the whole round in less than one hour.

Once they finish all the stations they will have to go back to the room, where they will have to face the final challenge: building a world map that is cut out in the shape of the tectonic plates.

## EXTERNAL SOURCES

- Extra explanation of the proofs of the heliocentric model  
<https://www.wired.com/story/earth-orbits-the-sun-physics/>
- Deep explanation of Ptolomeo's geocentric model  
<https://explainingscience.org/2017/11/10/geocentric-cosmology/>
- Plate tectonics experiment and explanation  
<https://educationalresource.org/earth-science-demonstration-chocolate-plate-tectonics>
- Gravity in space and a simulation of gravity  
<https://www.youtube.com/watch?v=MTY1Kje0yLg>
- Instructions to build the space simulator  
<https://www.youtube.com/watch?v=2JOf1ub9US0>
- First level explanation on how tides work  
[https://www.youtube.com/watch?v=3RdkXs8BibE&ab\\_channel=AtomicSchool](https://www.youtube.com/watch?v=3RdkXs8BibE&ab_channel=AtomicSchool)
- Deeper explanation on how tides work  
[https://www.youtube.com/watch?v=yg6t2rZBWGY&ab\\_channel=Higgsinophysics](https://www.youtube.com/watch?v=yg6t2rZBWGY&ab_channel=Higgsinophysics)
- Explanation of the greenhouse effect for kids  
[https://www.youtube.com/watch?v=SN5-DnOHQmE&t=133s&ab\\_channel=NASASpacePlace](https://www.youtube.com/watch?v=SN5-DnOHQmE&t=133s&ab_channel=NASASpacePlace)
- Warming a jar with CO<sub>2</sub> experiment  
<https://www.steampoweredfamily.com/activities/the-greenhouse-effect-experiment/>