EXPERIMENT MANUAL

CLIMATE & WEATHER

WARNING — Science Education Set. This set contains chemicals and/or parts that may be harmful if misused. Read cautions on individual containers and in manual carefully. Not to be used by children except under adult supervision.

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WARNING!

Not suitable for children under 10 years. For use under adult supervision.

→ Children under 8 yrs. can choke or suffocate on uninflated or broken balloons. Adult supervision required. Keep uninflated balloons from children. Discard broken balloons at once. Not for children under 3 yrs. Use an air pump to inflate the balloon. Balloons made of natural rubber latex, which can cause allergies.

→ Contains incense cones, which should be handled as instructed.

→ Read the instructions before use, follow them, and keep them for reference.

→ Do not allow the incense cones to come into contact with the mouth and eyes.

→ Keep small children and animals away from experiments.

→ Keep the experimental set out of reach of children under 10 years old.

→ Keep the packaging and instructions, as they contain important information.

Warning! Contains functional sharp points or edges that pose a risk of injury.

Safety Rules

→ Prepare your work area and materials before each experiment.

→ Conduct only the experiments described in this manual.

→ Handle the breakable glass thermometer carefully.

→ If you accidentally get something in your eye, such as a splash of vinegar, rinse the eye with plenty of water.

→ In case any accidents should happen please follow the first aid information.

→ Some of the experiments use incense cones. For these experiments, please note the following:

→ The experiments using the incense cones must absolutely be conducted with close adult supervision.

→ Keep a glass of water close at hand so that you can extinguish the incense.

→ When finished using the incense cone each time, extinguish the tip by quickly dipping it in a glass or saucer of water.

→ Make sure that the burning end of the incense cone never comes into contact with any other material. There is a risk of fire.

→ Never leave a lit incense cone unattended.

→ Never hold a lit incense cone in your fingers.

Dear Parents,

This kit will give your child a broad overview of climate and weather. Experiments and background information will provide him or her with basic information about this fascinating topic, one of extreme importance and interest to both adults and children.

The topic is complex and the experiments are not always simple, so they should be carried out with thought and care. Please be prepared to stand by your child to offer help and advice and provide support whenever it may be needed. If an experiment does not work as expected the first time, you may need to try it again.

The climate is a massive natural system, but despite its enormous size, often phenomena or changes in the climate are very subtle and hard to detect in a short amount of time. The experiments in this kit model aspects of the climate on a smaller scale, thus making them easier to observe. However, some of the experiments will yield very subtle results, and you will have to look closely to see them. Encourage your child to be a good detective and look closely to see the results of the experiments.

Read through the instructions together before beginning the experiments and follow them. Pay attention to the safety information on the inside front cover and be sure both you and your child review the safety warnings that are provided with the individual experiments.

In particular, pay close attention to the experiments requiring the use of incense cones (to produce small wisps of smoke) and a flame to light them. An adult must always be present for these experiments. You must be especially careful that no one gets burned and that nothing catches on fire. If you or your child are overly sensitive to the smoke or the smell of the incense, discontinue use immediately. Use the incense in a well-ventilated area.

We wish you and your young researcher lots of fun and success with the experiments.

665006-02-230516

What's in your experiment kit:

Checklist: Find – Inspect – Check off

✔	No.	Description	Qty.	Item No.
☐	1	Transparent half-spheres	2	706346
☐	2	Die-cut cardboard sheet	1	706376
☐	3	Globe sticker sheet	1	706378
☐	4	Transparent plastic sheet for basin	1	706381
☐	5	Cork stopper	1	071118
☐	6	Pins	5	706382
☐	7	Wooden sticks	3	020042
☐	8	Incense cones	5	706385
☐	9	Balloon	1	701060
☐	10	Black disk	1	706387
☐	11	Black equator strip	1	706442
☐	12	Tubing	1	706384
☐	13	Thermometer with case	1	232105
☐	14	Petri dish	1	700408
☐	15	Sponge	1	000585
☐	16	Tealight containers	3	706377
☐	17	Paper clips	4	020040
☐	18	Pipette	1	232134
☐	19	Clay (50 g)	1	000588
☐	20	Rubber band	2	529122
☐	21	Drinking straw	1	704257
☐		Polystyrene foam tray holding:		706373
☐	22	Sphere with indentations	1	
☐	23	Hemispheres	2	
☐	22	Ramp	1	

Additional things you will need:

Craft glue, flashlight, paper, tape, felt-tip pen, table lamp, empty plastic bottle, insulated flask (e.g. Thermos), watch, lighter, scissors, knife, ink, white bowl, salt, plastic wrap, baking powder, vinegar, paper towels, teaspoon

Any materials not contained in the kit are marked in *italic script* in the "You will need" boxes.

→ Please check all the parts against the list to make sure that nothing is missing.

→ If you are missing any parts, please contact Thames & Kosmos customer service.

CONTENTS

The Climate System

Earth's climate system is awesome and complicated. It consists of several systems, called spheres, such as the envelope of air around Earth, called the **atmosphere**, and the layer of water composed of oceans, seas, rivers, and groundwater, called the **hydrosphere**. Earth's areas of snow and ice, the **cryosphere**, and its expanses of soil, the **pedosphere**, and of rock, the **lithosphere**, are other parts of the climate system. All these systems affect one another. They all store water and heat, and exchange water and heat with each other. The sun is the driving force behind the interactions between the different partial systems. It supplies energy and is crucial for life on Earth.

Our planet possesses yet another sphere: the **biosphere**. That is the part of the top layer of Earth, Earth's surface, and its atmosphere, that offers habitats to living organisms. The development of life is inseparably connected to the climate system.

The term **climate** refers to the environmental conditions in a particular region over a long period of time. It also includes daily and seasonal fluctuations — for example, whether it is usually cool and dry or hot and muggy in a given location in summer.

Several factors influence the climate: the sun's radiation, the distribution of land and ocean masses, the height above sea level, the composition of the atmosphere, and wind systems. The interaction of these factors determines when and for how long the sun shines, and whether it is cold, cloudy, rainy, stormy, or snowy.

When people talk about **weather**, they mean the state of the atmosphere at a given moment. The weather is directly perceivable as sunshine, cloudiness, rain, heat, or cold. So weather and climate describe similar characteristics, but climate is general to a region over a period of time, and weather is specific to a particular location at a particular time.

EXPERIMENT 1

Your own globe

YOU WILL NEED

→ 2 polystyrene hemispheres from the polystyrene tray
→ 2 rubber bands
→ wooden stick
→ globe sticker sheet
→ globe stand from the die-cut sheet
→ *glue or tape*

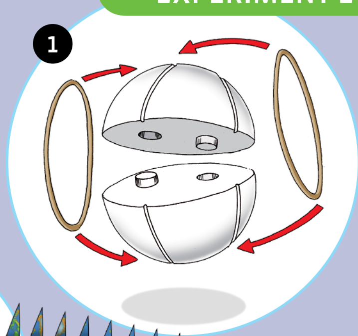
HOW'S HOW

1. Remove the two polystyrene hemispheres from the tray, smooth out any ragged edges, and join them together into a sphere. Stretch two rubber bands over the sphere so that they are lying flat in the indentations.

2. Insert a wooden stick through the sphere at the points where the rubber bands cross. That is where your poles are, and the stick is the axis around which your Earth rotates. Take the globe sticker sheet, remove it carefully from its backing, and stick it onto the sphere so that its edges meet at the poles. Smooth out any wrinkles.

3. Remove the globe stand from the die-cut sheet, remove the black circular piece from it, fold it, and tape or glue the flaps together. You will be using this stand for several experiments. For now, insert your model Earth's wooden stick into the small hole in the stand, as shown here. Your globe is ready.

1



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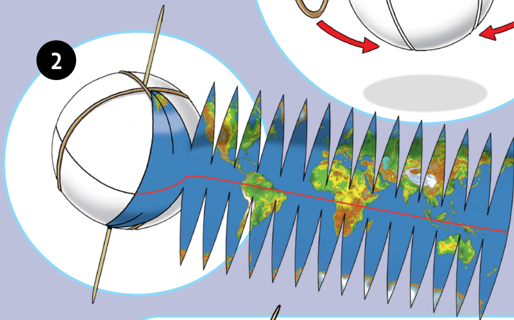

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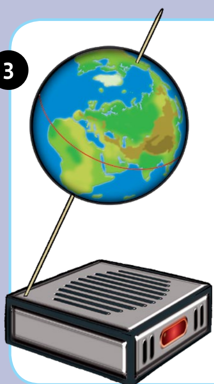
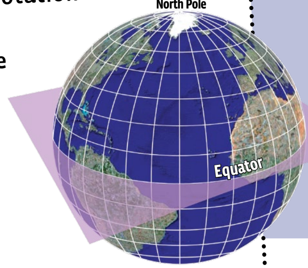


The stand has two sides. One has a large hole; this will serve as a holder for later experiments with your transparent sphere. You can insert the rotational axis of your Earth model into the small pre-punched hole on the other side, and it will stand up as long as the Earth is positioned directly above the stand.

→ WHAT'S HAPPENING?

The Earth's axis of rotation is, of course, not really visible. It is an imaginary line around which the Earth rotates. In the model, it is represented by your wooden stick. In all heavenly bodies, the places where the axis of rotation emerges from the globe's surface are known as poles. On Earth, these are known as the North Pole and South Pole.



EXPERIMENT 2

Day or night?

YOU WILL NEED

→ globe from Experiment 1
→ pin
→ *flashlight or table lamp*

HERE'S HOW

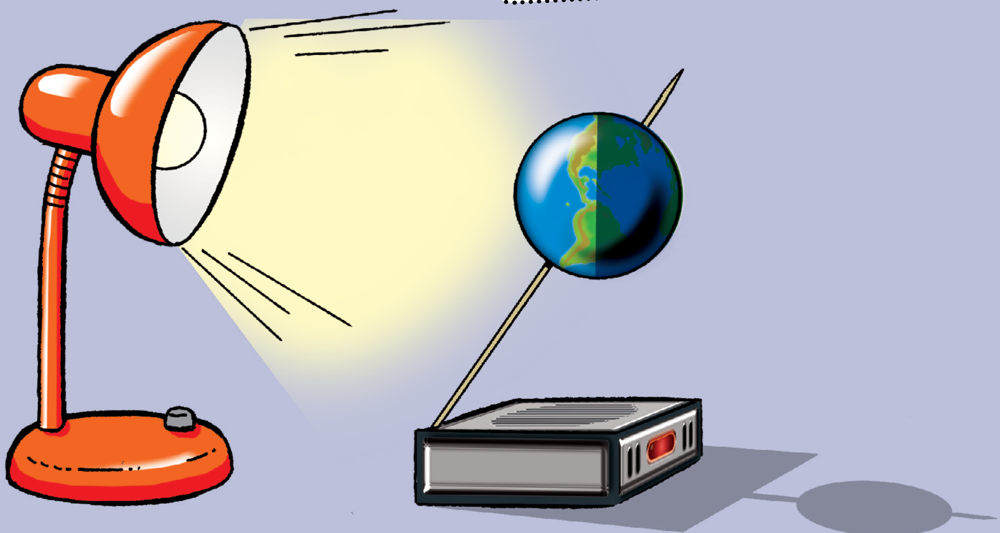
1. Use the pin to mark a specific location on the globe, such as where you live. Set the globe in front of you on a table and point a bright flashlight or a desk lamp at it from the side. That will represent the sun.

2. You can see that half of the Earth, namely the half turned away from the sun, lies in shadow. It is night there, and on the other side it is day.

3. Slowly turn the axis (wooden stick) and watch your pin. This works best in a dark room.

→ WHAT'S HAPPENING?

Earth turns once around its axis in a little under 24 hours. The side of the Earth turned toward the sun sees bright daylight, and the side turned away from the sun sleeps in the darkness of night. The rotation causes an ongoing change to take place, which we see as the sun going up or down. In fact, however, it is the Earth, not the sun, which is moving.

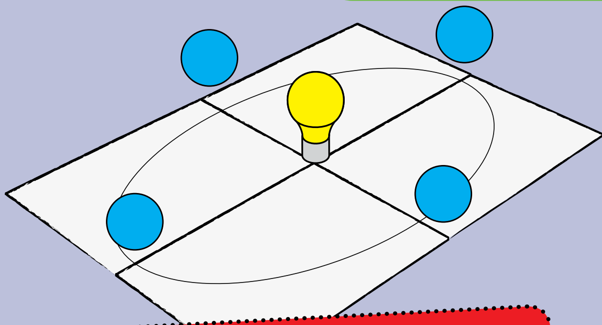


EXPERIMENT 3

The seasons

YOU WILL NEED

→ globe from Experiment 1
→ pin
→ *4 sheets of letter paper*
→ *tape*
→ *felt-tip marker*
→ *lamp without shade with a 60- to 75-watt frosted light bulb*



HERE'S HOW

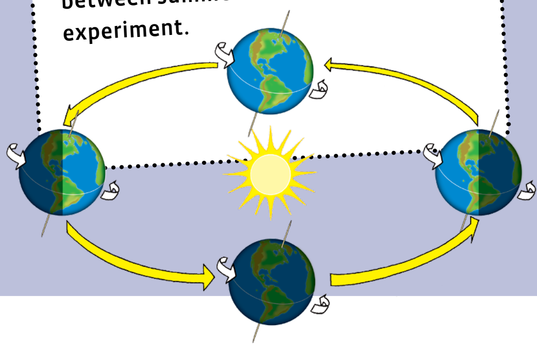
1. Tape four sheets of paper together as shown (or use one big piece). Draw an ellipse (an oval) as shown in the illustration here. Place a lamp in the center of the ellipse to act as the sun. Mark the position of the Earth in the various seasons around the ellipse. If you don't have a lamp without a shade, you can use a powerful flashlight if you always point the light at the model.

2. The Earth's axis of rotation is a little tilted. In the northern hemisphere, its upper end points toward the sun in the summer, and it points away from the sun in the winter.

3. As you did in Experiment 2, use the pin to mark where you live. Guide the Earth slowly around the light following the ellipse you drew and, always keeping it at the same angle, place it at each of the four seasons' positions in turn. Observe the light and shadow above and below the equator as you turn the Earth around its axis of rotation.

→ WHAT'S HAPPENING?

One full revolution of the Earth around the sun on its elliptical path is what we experience as one year. Due to the tilt of the Earth's axis, different parts of the Earth are illuminated in different ways — both in terms of the length of the day and the angle at which the sun's rays hit the Earth. During our summer months, the northern hemisphere is tilted toward the sun. The sun's rays hit the Earth's surface there at a steeper angle than in the winter. That provides a given surface area with a lot of solar radiation and energy. The days are longer and the temperatures are warmer. In the winter, on the other hand, the sun's rays are flatter as they hit the Earth — we see the sun as being lower in the sky. The flatter rays supply less energy and warmth for a shorter time, and the temperatures stay colder. You can see these differences between summer and winter in the next experiment.



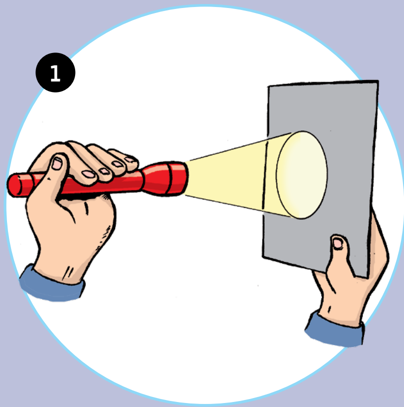
EXPERIMENT 4

How the sun's rays strike Earth

YOU WILL NEED

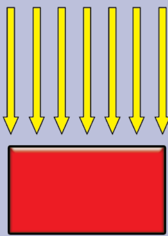
→ *sheet of white paper*
→ *flashlight*

HERE'S HOW

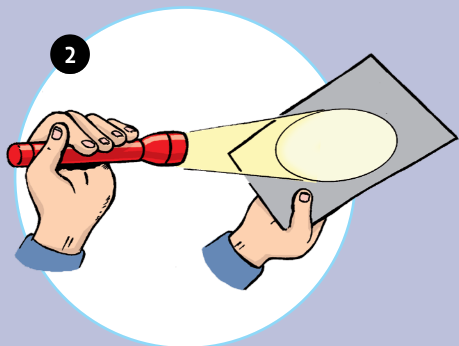


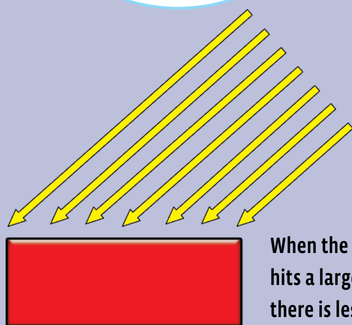
1. Hold the sheet of paper vertically and illuminate it from the front with the flashlight. The rays of light create a round circle on the paper. This works better in a dark room. Trace the circle.

2. Holding the flashlight in the same position, gradually tilt the paper backward. Watch how the patch of light changes on the paper's surface. Trace the oval.



When the sun is high, there is a lot of energy per unit of surface area.





When the sun is low, it hits a larger area, so there is less energy per unit of surface area.

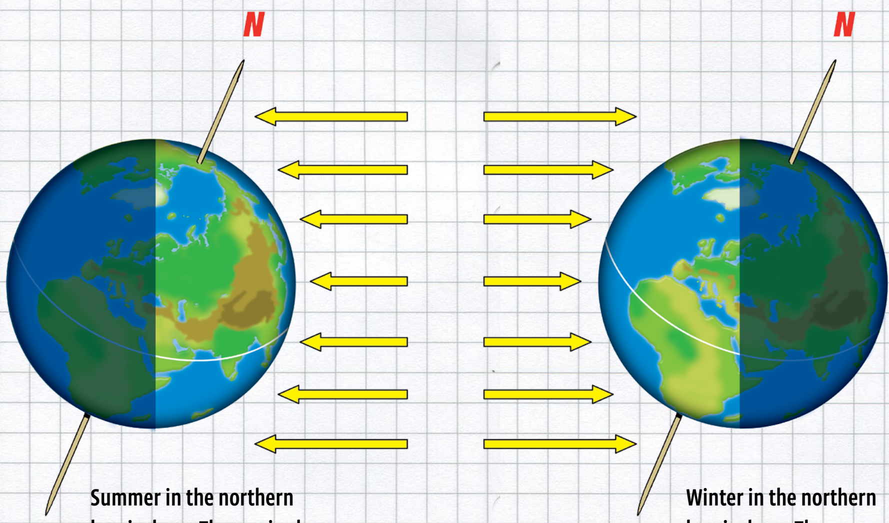
→ WHAT'S HAPPENING?

The greater the slant at which the flashlight's beam hits the paper, the larger the patch of light. The same amount of energy is therefore distributed across a larger surface area. This is the way it works with the sun's rays, too. If the sun is high, it supplies a lot of energy, warmth, and light per unit of surface area. If the rays are flat, the energy input for the same area is much less.

What determines the seasons is the tilt of the Earth's axis, and not (as many people believe) the distance from the sun. In the southern hemisphere, the seasons are exactly the opposite: Summertime in the northern hemisphere is wintertime there and vice versa.

CHECK IT OUT

Summer and Winter



S

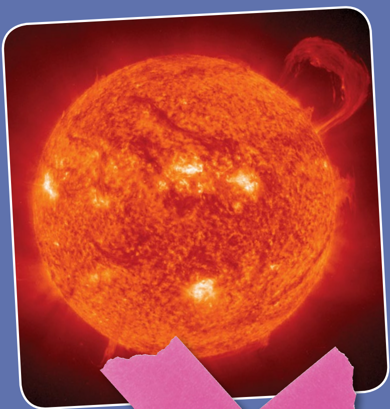
Summer in the northern hemisphere: The sun is always shining at the North Pole.

S

Winter in the northern hemisphere: The sun never shines at the North Pole.

At the North and South Poles, the varying paths of the sun have the greatest effect. There, half a year will go by without the sun sinking under the horizon or rising above it. Polar night or polar day lasts for months.

At the equator, on the other hand, the sun's position hardly varies over the course of a year. There are practically no seasons, and for the entire year day and night are almost equally long, namely about 12 hours.



SOLAR RADIATION

You have probably noticed how strong an effect the sun's angle can have on the temperature over the course of a single day. If you are sitting in the sun at noon on a summer day, you will quickly get hot. With the approach of evening on the same day, as the sun gradually sinks to the horizon and its rays are coming from the side rather than above, it will be just pleasantly warm.

You can also tell what the position of the sun is by looking at your shadow. In the morning, your shadow is very long. As noon approaches, it gets shorter and shorter until the sun reaches its highest point. Then, you can hardly see your shadow anymore. As the day wears on, it will get longer again until the sun sets.

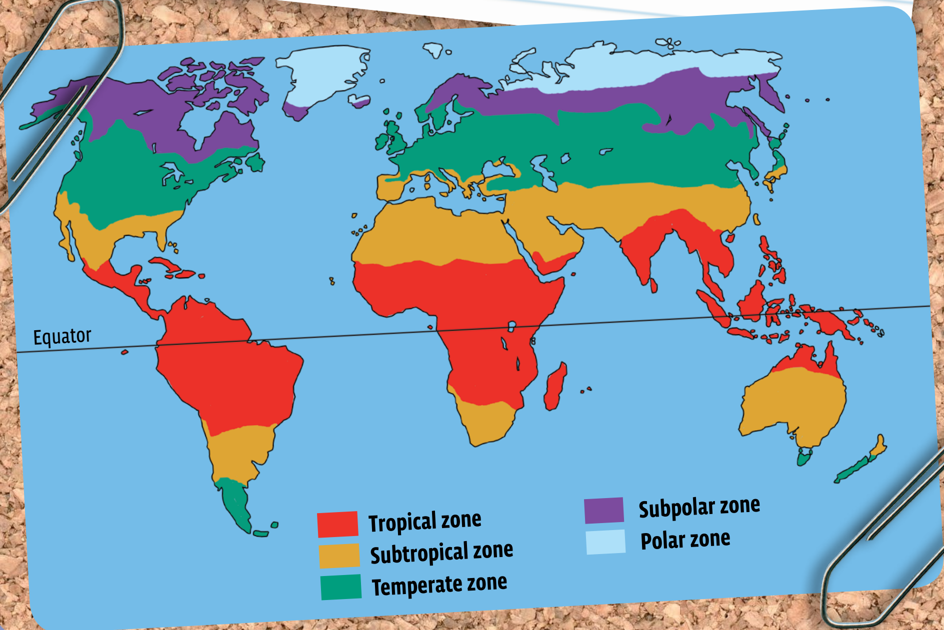
CHECK IT OUT

CLIMATIC ZONES

The Earth is divided into climatic zones based on various climatic conditions. The reason the climatic conditions are not all the same has to do with the different degrees of intensity of solar radiation. The climatic zones run from the North Pole to the South Pole, more or less parallel to the lines of latitude. The zones are mirror images of each other in the northern and southern hemispheres.

The most extreme seasonal temperature differences are found near the poles. Overall, the climate there is very cold, and only above freezing in summer if at all. Closer to the equator, the climate gets warmer. At the equator, the weather is hot and humid the whole year around. The seasons are less pronounced there.

Most of North America is in the temperate zone. The temperate zone is characterized by four distinct seasons and differences between day and night that vary considerably with the seasons. Temperature, humidity, and precipitation are also quite variable. The temperate zone can be divided into many smaller zones, and is not the same everywhere. The most important factor in dividing the temperate zone into smaller zones with similar climatic conditions is the proximity of the region to the ocean.



Atmosphere and Hydrosphere

Even though we can’t see it, air is not made out of nothing. When parachutists jump out of airplanes, they are diving into a substance just like divers do when they jump into the water. The resistance of the air is far less than that of the water, but the fact that there is resistance at all gives us proof that air has substance. The air around us consists of countless tiny, invisible particles — atoms and molecules — flying through empty space.

EXPERIMENT 5

Are you stronger than air?

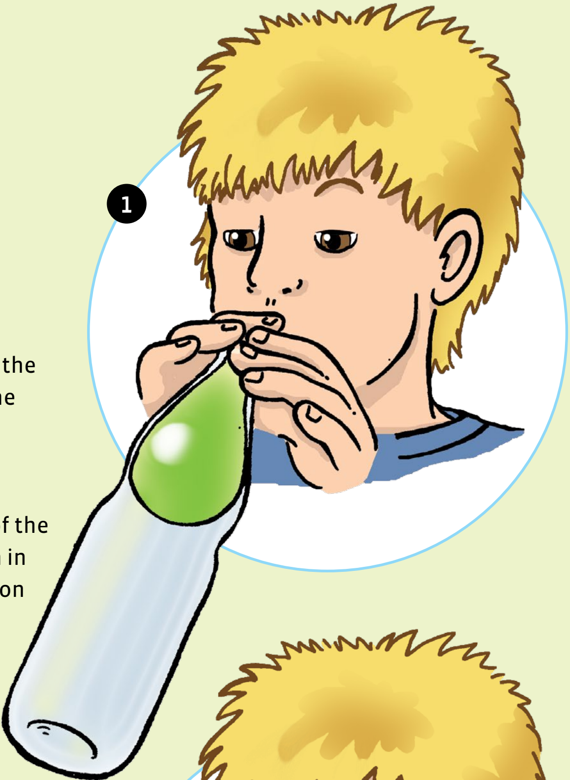
YOU WILL NEED

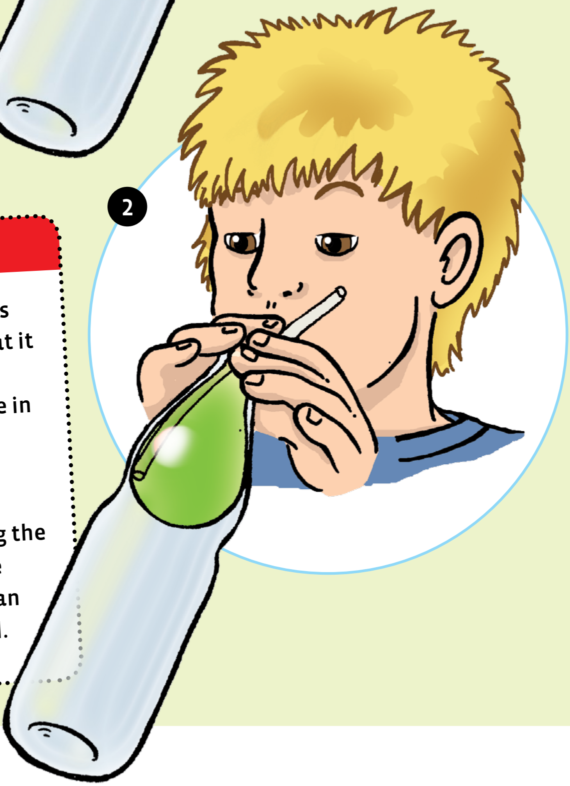
→ balloon
→ drinking straw
→ *empty plastic bottle*

HERE'S HOW

1. Insert the balloon into the neck of the bottle and try to inflate it inside the bottle.
   Can you do it?

2. Now place a straw along the side of the balloon inside the bottle as shown in the picture. Try to inflate the balloon inside the bottle.
   Can you do it this time?





→ WHAT'S HAPPENING?

The bottle is filled with air. As soon as your balloon grows to a size such that it seals the neck, the air can no longer escape. The air takes up all the space in the bottle and pushes so strongly against the balloon that you can't manage to inflate it against that pressure. You can only do it by using the trick of inserting the straw past the balloon into the bottle, so the air can escape and the balloon can expand.

Earth's Atmosphere

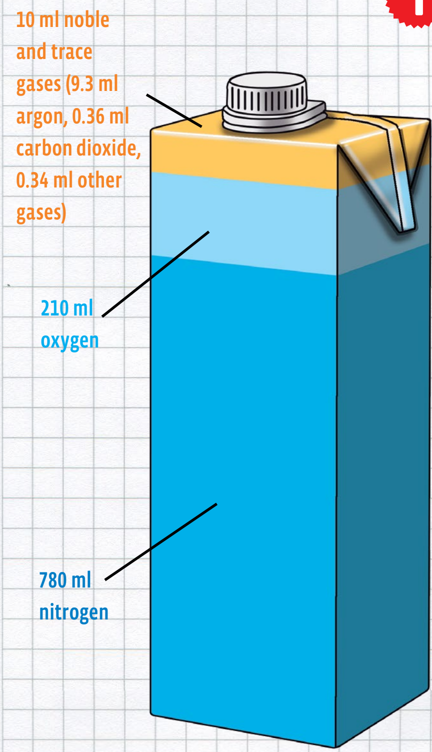
The air that we breathe is a mixture of various gases. The largest component is nitrogen. If you could capture just a tiny quantity of the particles, four out of five of them would probably be nitrogen. The fifth would be oxygen. Besides nitrogen and oxygen, there are noble gases and trace gases contained in the air. But just one out of a hundred particles is a noble gas. Air also contains a small, variable proportion of water vapor, which is responsible for clouds and other weather patterns.

If you look at 10,000 particles, fewer than four of them would be carbon dioxide. Because it is only present in quite small quantities, carbon dioxide belongs to the group of trace gases. Other members of that group are methane, ozone, and CFCs (which stands for chlorofluorocarbons). Even though they make up only a small part of the air, they are of great importance to our climate.

Together, all of these gases form a thin envelope around the Earth called the atmosphere. Like all objects on Earth, the atmosphere is attracted and held in place by the Earth's gravitational field. Altogether, the atmosphere is about 640 kilometers (400 miles) thick and weighs about 5 x 10^{18} kilograms — that's a 5 with 18 zeros after it. That is about 11 x 10^{18} pounds.

The atmosphere is composed of several layers, and the density of the air molecules, i.e. the number or mass of air molecules in a given volume of air, becomes less and less as you go higher. The bottom 90 kilometers (56 miles) of atmosphere has a relatively uniform composition. The lowest 10–15 kilometers (6–9 miles), called the troposphere, is where clouds are formed and weather patterns play out. But compared with the diameter of Earth, which is 12,800 kilometers (8,000 miles), it is a thin skin.

CHECK IT OUT



Atmosphere in a bottle: If the atmosphere were scaled down to fit in a 1 liter (1000 ml) bottle, it would contain the gases in the quantities shown here.

A Protective Layer of Air

Our atmosphere protects us in two ways. For one thing, it prevents the full energy of the sun from heating the Earth. If that were to happen, temperatures would get much too high to permit life as we know it to exist. At the same time, the atmosphere keeps the heat from the sun that does reach the Earth from being completely given off (reflected or radiated) back into space. If this were to happen, nights on Earth would be bitterly cold.

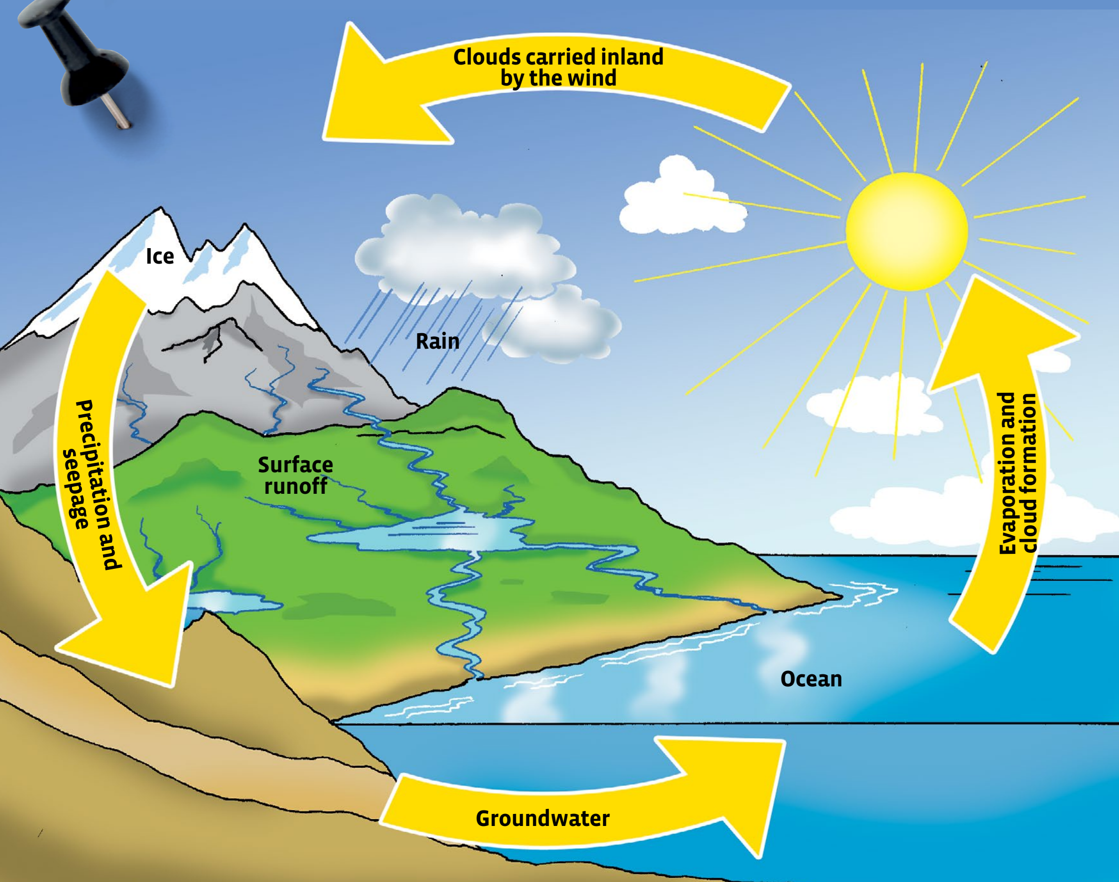
CHECK IT OUT

The Water Cycle

The oceans, rivers, seas, and groundwater form the hydrosphere, the layer of water covering Earth. But that is only the water that sits on and under the Earth's surface. Water also shows up in lots of other forms. The forms that you probably know best are the rain and snow that fall from the sky. Water is also contained in the air, even though you don't see it because it is present as invisible vapor. All of these forms interconnect and create a continuous, natural water cycle.

Some of the rain seeps into the groundwater. Some of it flows directly across the surface into rivers. Groundwater also feeds into the rivers that empty into the oceans after their long journeys. If it's hot on Earth's surface, the water vaporizes and enters the atmosphere as water vapor. This process is called **evaporation.**

The water vapor then forms clouds by a process known as **condensation**. The water in the clouds falls to Earth in the form of rain or snow. Snow and ice melt and flow into the groundwater, rivers, or the ocean. Through this cycle, water changes its state several times, but none of it is lost. Precipitation is the most important means of water supply in most regions of the world. The quantity of precipitation decides how much vegetation can be supported in a region.

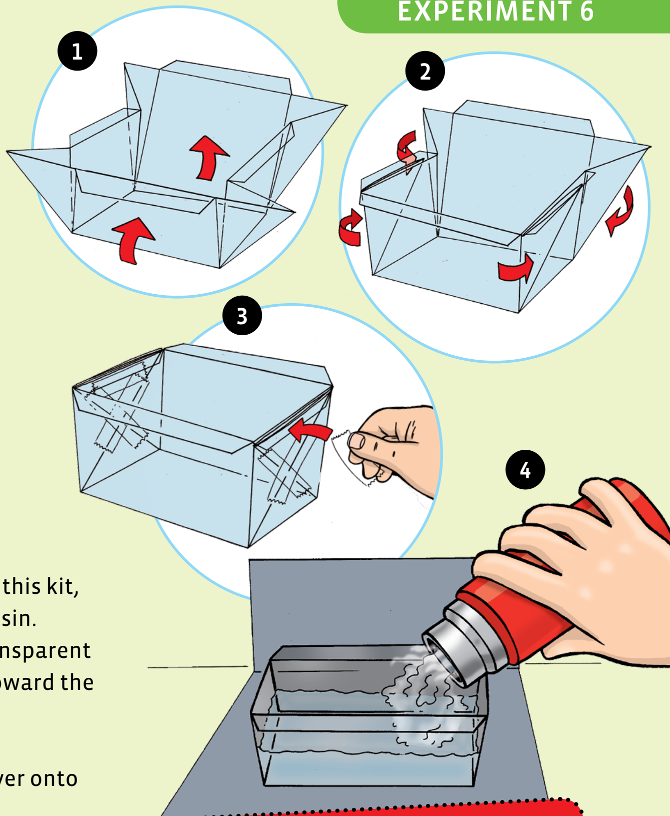


EXPERIMENT 6

Make your own clouds

YOU WILL NEED

→ transparent plastic basin
→ *tape*
→ *water*
→ *insulated flask (Thermos) or glass jar wrapped in wool*
→ *flashlight*
→ *towel or cloth*



HERE'S HOW

1. For a few of the experiments in this kit, you will need an experiment basin. Remove it from the sheet of transparent plastic. Fold the long sides in toward the middle.

2. Now fold the triangular flaps over onto the short sides.

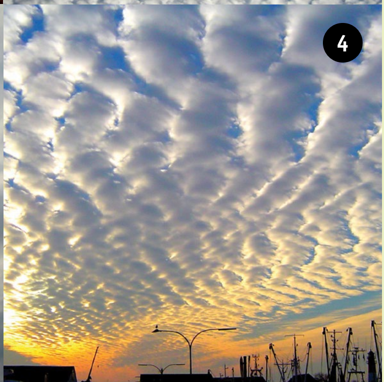
3. Secure the flaps to the sides well with clear tape, so that the basin stands up stable and straight.

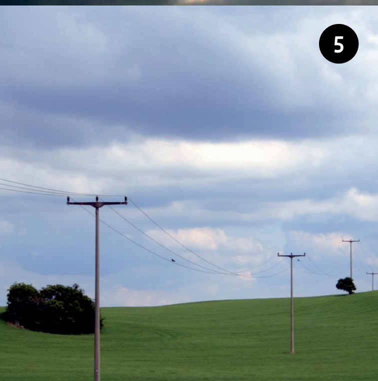
4. Place an empty, uncapped insulated flask in the freezer for one hour. Fill the basin about halfway with warm water. Take the flask from the freezer and immediately cover the opening with a towel or cloth. Quickly bring the flask over to the basin and tip the flask over the basin as if you were trying to pour water out of it. As you do this, the flask opening must be quite close to the surface of the water. Watch the surface of the water beneath the flask opening very closely! What do you see?

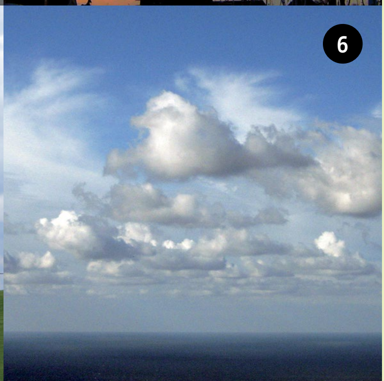
→ WHAT'S HAPPENING?

The heavy cold air from the insulated flask pours onto the warm air above the basin and cools it. The air's capacity to absorb water decreases, some of the water contained in it condenses, and small clouds form. You can see these wisps of cloud particularly clearly in the beam of a flashlight coming from the side in a darkened room.

Rain clouds are likely to form when cold air masses slide under warm and humid ones and lift them up, and when damp ocean air gets pushed up and cooled by mountains and hills. But it also happens when damp air that is warmed during the day cools off at night. This is typical in tropical rainforests.







Cloud Types

Clouds fall into three main categories: thin, wispy **cirriform** clouds; sheet-like **stratiform** clouds; and pillowy, heaped **cumuliform** clouds. These are subclassified into genus types.

1. Cirrus clouds are thin, wispy clouds that form at very high altitudes.

2. Cirrocumulus clouds are small tufts that form in patches or rows at high altitudes.

3. Altostratus clouds are like a thick gray sheet, high in the sky. Wind is needed to create these.

4. Altocumulus clouds are like cirrocumulus, but each cloud is larger and darker.

5. Stratus clouds are flat, low altitude clouds that can bring drizzle or fog.

6. Cumulus clouds look like little pieces of fluffy cotton wool and are too small to bring rain.

7. Stratocumulus clouds are like cumulus clouds, but all lumped together.

8. Cumulonimbus clouds are tall, dense clouds that can bring heavy rain showers and thunderstorms.

CLOUD MAKING

A cubic meter, or 1,000 liters, of air can contain up to 40 liters of evaporated water (water in the form of gas). The warmer the air is, the more water it can absorb. But for any air temperature there is a limit, or degree of saturation, beyond which the air can't get any wetter. When that happens, its **relative humidity** is 100%.

The air typically contains very fine particles, such as tiny particles of dust or sea salt crystals. If the water content of the air keeps rising (or the temperature drops), the water vapor gets converted and forms tiny water droplets around these tiny particles, called **condensation nuclei.** In technical language, what takes place is the condensation of water into clouds or fog. The water droplets are so fine and light that they practically float freely. As they collide, the droplets collect together, get larger and heavier, and then eventually fall to Earth as raindrops.

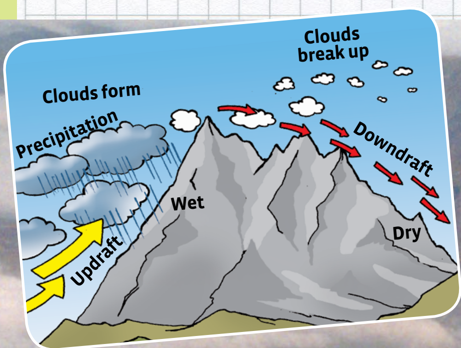
If it's cold enough, the cloud droplets freeze and become tiny ice crystals. As they collide, the droplets collect together, get larger and heavier, and due to their weight, eventually fall to Earth as snow. If the ice crystals melt on their way down, they will turn to raindrops.

CHECK IT OUT

HUMIDITY

Relative humidity (or relative air moisture) is measured as a percentage. Using a percentage, you can express how much of the maximum possible amount of water vapor the air actually holds.

If the relative humidity is 50%, it doesn't mean that half the air consists of water. Instead, that measurement indicates that the air has absorbed half of the maximum possible quantity of the water it can hold. This maximum possible quantity depends on the temperature. Warm air can absorb more water than cold air. So if you heat the air without adding any water vapor, its relative humidity will drop.

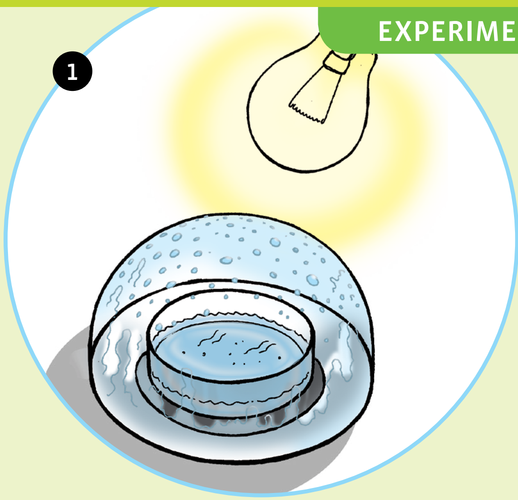


Mountain Rain

The distribution of land and water masses over the Earth largely determines where rain falls. Rainfall is also influenced by large mountain ranges and plains, and by air pressure regions. In the interior areas of the continents, dry climates prevail with colder winters and nights, and hotter summers and days. Maritime climates determine the weather on the coasts, with mild winters and cool summers. Desert climates generally prevail over large land masses bordered by mountain ranges against which clouds release their rain. For example, the Sierra Nevada mountain range in California catches the rain from the moist Pacific Ocean air as it flows eastward. On the ocean side of the range, you will find thick forests and fertile valleys. On the other side, to the east, is where the hot California desert begins.

Clouds collect on the Sierra Nevada.

How do rain drops form?



YOU WILL NEED

→ half-sphere
→ black rubber disk
→ petri dish
→ *tape*
→ *table salt*
→ *water*
→ *lamp*
→ *teaspoon*
→ *cup or glass*

HERE'S HOW

1. Dissolve one teaspoon of salt in a cup of water. Set the petri dish on the black foam rubber disk and then place both on a flat surface in the sun, or under a strong lamp (at least 60 watts). The distance from the bulb should be about 10 centimeters. Fill the petri dish with just enough salt water to cover the bottom, and place the clear half-sphere over it. For now, cover the measurement hole and axle holes in the half-sphere with tape. After a while — at least half an hour — the dome will cloud up on the inside, and increasingly larger drops will form.

2. The drops will keep growing if you take the light away and let the dome cool. When the drops are large enough, they will run down the sides of the dome. Taste the water of condensation. Is it still salty?

→ WHAT'S HAPPENING?

The water evaporates from the dish and condenses on the dome. If your experiment were to run long enough, all the water would evaporate and the salt would remain behind in the petri dish. This technique can be used in an emergency to make drinking water out of seawater. However, the evaporated and condensed water would lack important minerals.

Only pure water evaporates from the oceans, leaving the salt behind. The water condenses in the air and collects into larger droplets, which eventually rain down again as fresh water. That is why rainwater is never salty, even near the ocean.

Evaporation does not only occur above bodies of water. Evaporation also takes place over land, from water stored in the ground and, above all, in plants. That is why you have to water the garden so often in summer when temperatures are high.

EXPERIMENT 8

Build a rain gauge

YOU WILL NEED

→ *glass jar*
→ *ruler*
→ *rubber band*
→ *permanent market (optional)*
→ *transparency film (optional)*
→ *scissor (optional)*
→ *clear tape (optional)*

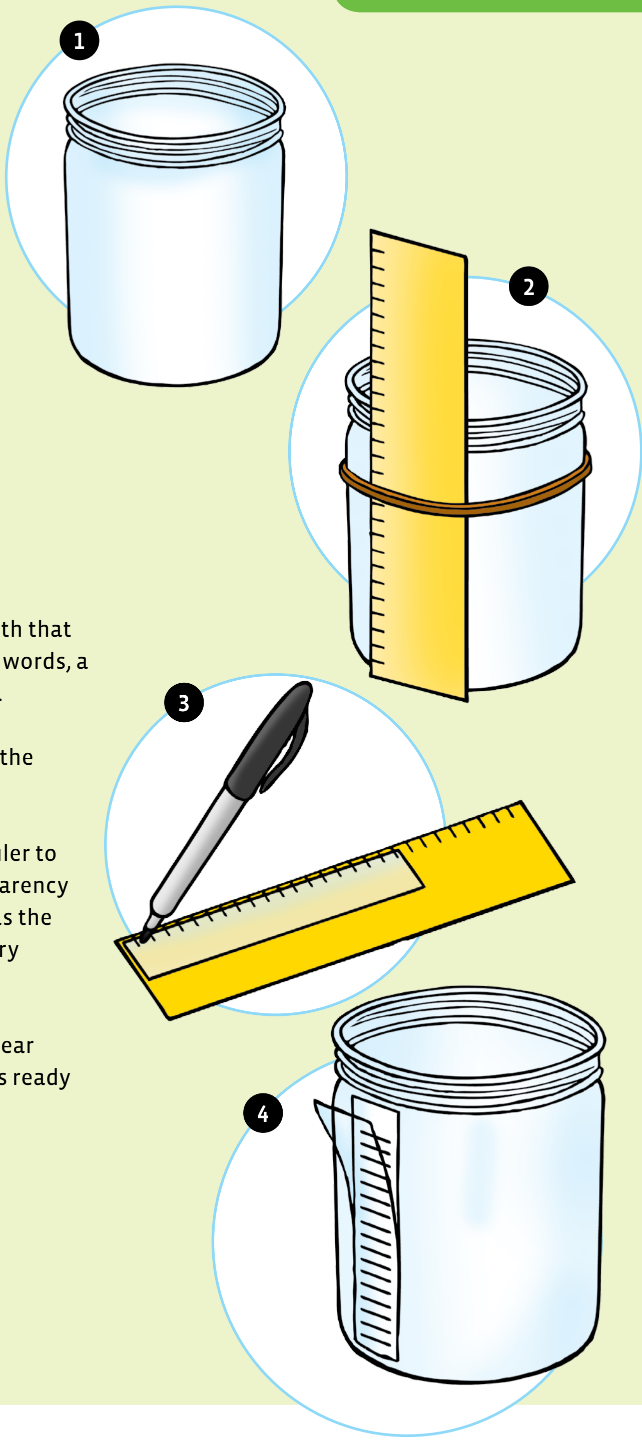
HERE'S HOW

1. Find a large glass jar with a mouth that is as wide as its base — in other words, a wide-mouth, straight-walled jar.

2. Attach the ruler to the jar using the rubber band as shown.

3. Alternatively, you can use the ruler to draw a scale on a strip of transparency film. The strip should be as tall as the side of your jar. Draw marks every quarter-inch.

4. Tape the scale to your jar with clear adhesive tape. Your rain gauge is ready for Experiment 9!



EXPERIMENT 9

Tracking rainfall

YOU WILL NEED

→ **rain gauge from Experiment 8**
→ **graph paper and pencil**

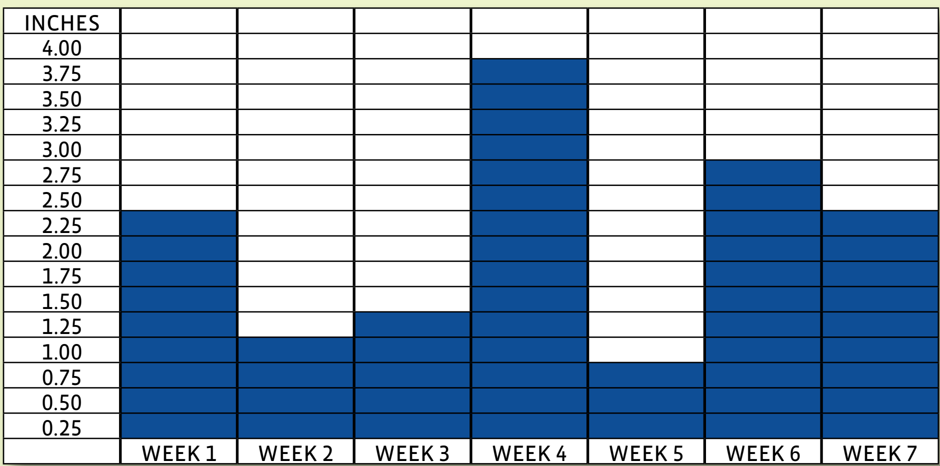
Rain is only one part of the larger water cycle on Earth. Water evaporates from oceans, lakes, and rivers into the atmosphere. It is then returned to the Earth in the form of rain. If you could scoop up all the water from all over the Earth (oceans, lakes, ground, and air) and watch it for a year the total amount wouldn't change very much. However, if you only looked at the water near your home, for example, you could see a dramatic change on a monthly, weekly, or even daily basis! That's because water is always in motion. Keeping a daily, weekly, or monthly rainfall log can be a fun and easy way to see how rainfall changes with time in your area.

HERE'S HOW

1. Create a rainfall log like the example below. Each column represents a time period. Decide if you would like to measure rainfall every day, week, or month. If it is relatively dry where you live, you might want to start with a monthly log. If it rains a lot where you live, it might be interesting to keep a daily log. Weekly logs fit somewhere in between.

2. The vertical axis of the graph is used to plot the number of inches (per unit area) of rainfall during the time period. Look up the average rainfall statics for your area to determine how high your chart should go.

3. Set up your rain gauge, wait the appropriate length of time, and then record how many inches of water are in your gauge by the end of the period. Empty the rain gauge and repeat for each time period. By the end, you'll have a bar graph of rain fall over time!



Heat, Pressure, and Temperature

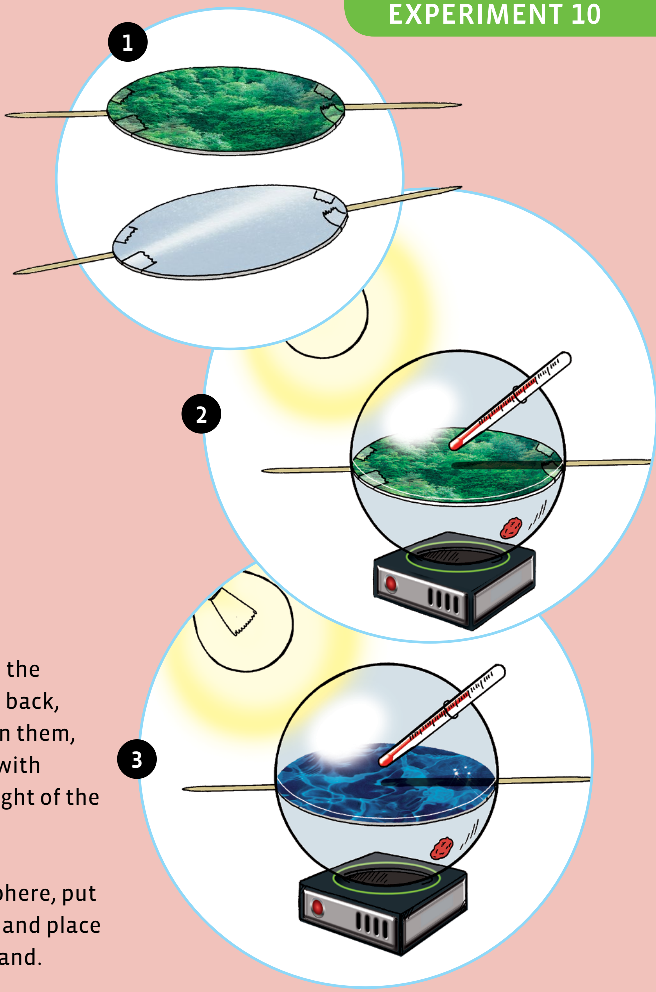
Like most physical bodies, air reacts to being warmed by expanding. So if air is heated, its molecules require more space, and its density decreases. Conversely, the volume of a body of air will decrease if it cools, and its density increases. Cold air is therefore heavier than warm air, because in the same volume of space there are more air molecules in cold air than in warm air. Understanding this relationship between pressure and temperature is critical to understanding how Earth's climate and weather systems work.

EXPERIMENT 10

Heat reservoirs

YOU WILL NEED

→ transparent half-spheres
→ landscape disks (forest, ocean, ice)
→ thermometer
→ stand from the die-cut sheet (globe side up)
→ wooden stick
→ *tape*
→ *clay*
→ *lamp*
→ *watch*



HERE'S HOW

1. Place the green forest disk and the white ice disk together back to back, slide the wooden stick between them, and secure the disks together with pieces of tape to the left and right of the wooden stick.

2. Lay the disks inside one half-sphere, put the two half-spheres together, and place the combined sphere on the stand.

3. Set the sphere in the sun or under a lamp (at least 60 watts) so that the white ice side of the landscape disk is illuminated directly. Push the thermometer into the hole and seal it off with some clay. Seal off the hole on the underside with clay too. Support the end of the thermometer with something placed under it, e.g. books, or by securing it with clay or tape to a support like a glass or block of wood.

4. Make a note of the time and temperature, and wait until the temperature has stopped rising. This may take 10 or 20 minutes. Remove the thermometer, wait until it has returned to about its starting temperature, turn the sphere upside down and repeat the measurement with the forest disk.

5. Finally, try it with the ocean disk laid over one of the other disks. The darker the surface, the higher the temperature.

CHECK IT OUT

Earth's Energy Store

Most of Earth's surface is covered with oceans. Water is very good at storing heat. The solar radiation hitting the ocean's surface is almost completely absorbed, and heat can be stored in water for a much longer period of time than in the ground. For this reason, the oceans are giant energy stores.

→ WHAT'S HAPPENING?

Energy comes to Earth from the sun in the form of radiation. Light is the visible portion of radiation. Other forms are infrared (IR) radiation and ultraviolet (UV) radiation, which is responsible for sunburns. On Earth, the radiation is converted into another form of energy, namely heat. This process of converting radiation into heat is known as absorption. The darker a surface is, the better its absorption capacity and the more it will therefore heat up.

Earth's surface is certainly many different colors. However, if you look at the Earth's surface from a great distance, small differences in color disappear. From space, the oceans appear a uniform dark blue, the ice regions appear white, and other landscapes look yellow, brown, or dark green.

HEAT ABSORPTION

The features of a particular area of Earth's surface play an important role in evaporation and cloud formation for that area — for example, whether it is covered by water or not, how much vegetation there is, and the composition of the soil.

But Earth's surface also has another kind of impact on Earth's climate. The sun delivers heat to the Earth. Oceans, seas, and rivers, as well as the land and the air, absorb the sun's warmth during the day. The amount of sunlight that an area of Earth's surface absorbs is primarily determined by its color. Dark objects absorb more heat than light-colored ones, because light-colored objects are reflecting the light while dark-colored ones are absorbing it.

The experiment with three different-colored landscape disks showed that different-colored bodies hold different quantities of heat.

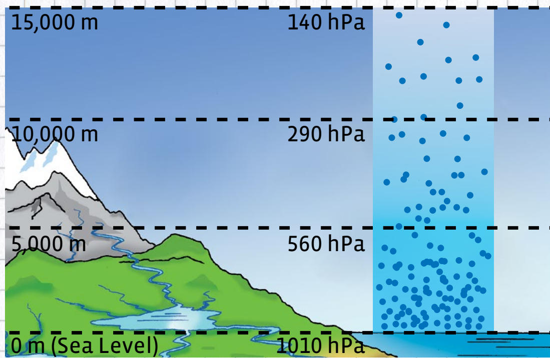
CHECK IT OUT

AIR PRESSURE

As you learned in Experiment 5, air is not nothing. Air is made up of tiny molecules that take up volume and have weight. Air pressure is the force exerted on objects by the combined weight of all these tiny molecules above them. Air can be compressed into smaller volumes. The more air molecules there are in a space with a set volume and temperature, the higher the air pressure in that space.

Because of the force of gravity, there are more air molecules at sea level than there are at high altitudes. The air pressure is highest at sea level, and steadily decreases as the altitude increases. The standard air pressure at sea level is 1013.25 hPa or 29.92 inches of mercury.

At approximately 30,000 feet (or 9,000 meters, or the height of Mt. Everest) the air pressure is only 320 hPa. At the edge of outer space, 100 km above sea level, the air pressure is virtually zero.



How is air pressure is measured?

The air pressure surrounding us is about 1,000 hPa. You can check this on a **barometer**, a device that measures air pressure. If you do not have one at home, you can find the current barometric pressure in the weather forecast.

"Pa" stands for Pascal, the unit for pressure in the metric system. The "h" stands for hecto, a prefix that means 100. 1,000 hPa is, therefore, 1,000 x 100 Pa, or 100,000 Pa. The atmospheric pressure varies somewhat. Inside a high-pressure area it can be around 1,050 hPa, whereas inside a low-pressure area, it may only be 960 hPa.

The pressure in a car tire is about 2,000 hPa above the atmospheric pressure. In a bicycle tire, there may be an overpressure of up to 7,000 hPa. The pressure also increases rapidly under water. For every centimeter that you dive down, the pressure rises by about 1 hPa. Therefore, at the bottom of a 2 meter deep swimming pool, the pressure is 200 hPa higher than at the surface.

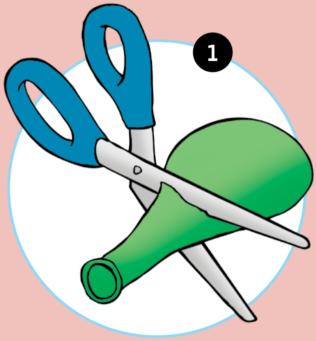
In the U.S., air pressure is often measured and reported in "inches of mercury" in weather reports. One inch of mercury equals 3,386 pascals.

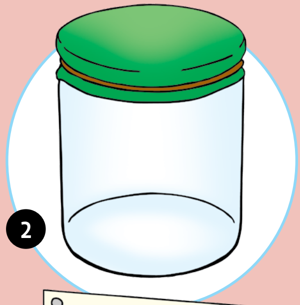
EXPERIMENT 11

Build a simple barometer

YOU WILL NEED

→ *empty glass jar, or empty coffee or soup can*
→ *scissors*
→ *rubber balloon*
→ *rubber bands*
→ *pin or toothpick*
→ *drinking straw*
→ *paper and pen*

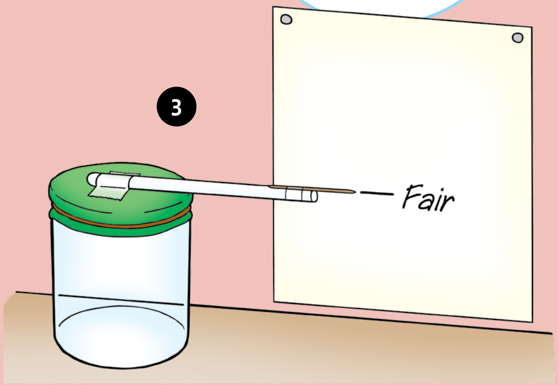




HERE'S HOW

1. Blow up the balloon to stretch it out. Cut the neck off of the balloon. Stretch the larger top portion over the top of the jar, creating an airtight seal.

2. Secure the balloon in place with a couple of rubber bands.



3. Tape your pin (or toothpick) onto one end of your drinking straw. Tape the other side of your straw securely to the center of the balloon. Place a piece of paper on the wall and move your barometer next to it. Set this away from direct sources of heat and sunlight. Record your initial measurement by marking the paper at the exact pin point and noting the day's weather.

4. Continue to mark the weather periodically throughout the week. Do you see any patterns? What is the weather usually like when the pin points upward, and what is the weather usually like when it points downward?

→ WHAT'S HAPPENING?

Higher pressure pushes the balloon into the jar and moves the pin point upward. Lower pressure does the opposite. You should see that higher pressure relates to nicer weather, while lower pressure relates to stormy or rainy weather. See the next page for an explanation of why this happens.

CHECK IT OUT

Forecasting the Weather

Analyzing changes in air pressure can help you forecast changes in the weather. Generally speaking, the weather will get nicer when pressure increases, and rainier or stormier when pressure decreases. When a low pressure air mass is on its way, it's likely rain or snow will follow. This is because the low pressure air is lighter, so it rises up into the atmosphere where it is colder, and condenses to form precipitation. Conversely, when a high pressure air mass is on its way, it's more likely that there will be clear skies.

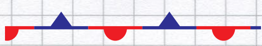
WEATHER FRONTS

Meteorologists, or scientists who study the atmosphere, use special symbols and maps to track weather patterns. These weather maps show the positions of large masses of air in which the conditions — temperature, pressure, and humidity — are consistent. Monitoring the movement of these air masses allows them to forecast the weather. The air masses move at different speeds around the globe. When one air mass meets another, the boundary between them is called a **front**. There are often precipitation and stormy weather along fronts. There are four major types of fronts.

When a cold air mass moves into a warm air mass, a cold front forms. Cold air is denser than warm air, so it sinks under the warm air, pushing the warm air up. This creates cumulus clouds, precipitation, and storms along the front. As the front passes, the temperature drops and the skies become clear. Cold fronts move about twice as fast as warm fronts.

A warm front forms when a warm air mass moves into a cold air mass. The warm air is less dense, and thus flows over the cold air. This forms cirrus or stratus clouds along the front, and sometimes precipitation. As the front passes, the temperature rises and the skies clear.

An occluded front occurs when a cold front overtakes a warm front, because it was moving more quickly. The weather can be unpredictable here.



A front that does not move for a period of time is called a stationary front. Mild winds and precipitation occur along stationary fronts.

EXPERIMENT 12

Tracking the temperature

YOU WILL NEED

→ thermometer
→ *graph paper and pencil*

HERE'S HOW

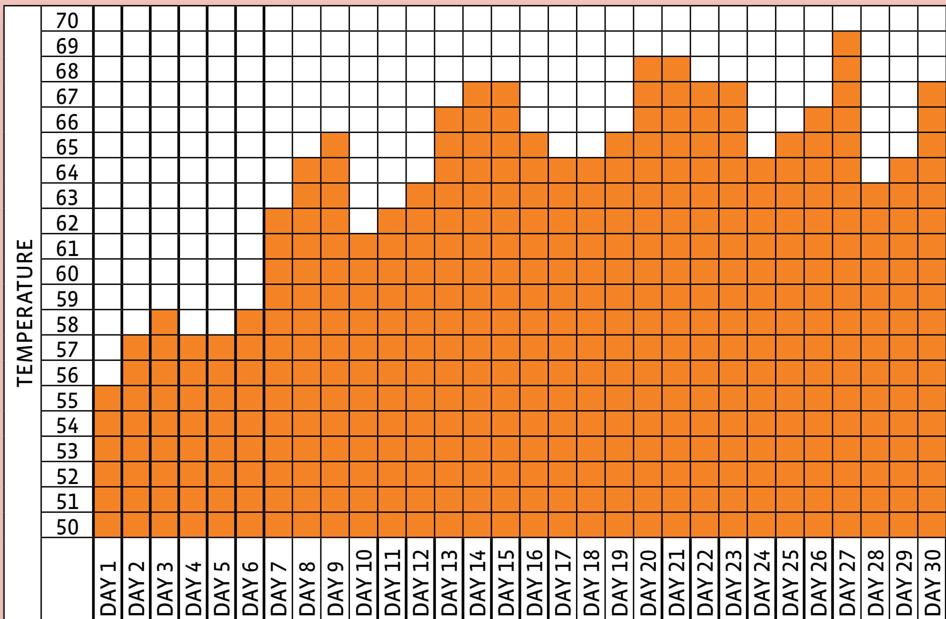
1. Create a graph like the example below.

2. At the same time every day, put the thermometer outside in a spot out of direct sunlight. Wait 5 minutes for the thermometer to adjust to the temperature and then record the temperature in your graph.

3. When your graph is complete, compare your data to the actual temperature data for the same period as well as the average historical temperature data, which you can easily find online.

→ WHAT'S HAPPENING?

Temperature is the measure of the average kinetic energy of the particles in a sample of matter. The temperature of a cup of hot water is higher than the temperature of a cup of cold water. This means that the particles in the hot water have a higher average kinetic energy than those in the cold water. Kinetic energy is simply motion energy. So the particles in the hot water are moving faster than those in the cold water.



Wind

The air in the atmosphere is not like a rigid shell. Its movements range from soft breezes to heavy storms. The main cause of wind is differences in air pressure between different air masses. The air masses are always trying to reach a state of equalized air pressure. Air particles from areas with a higher air pressure (high pressure regions) flow into areas with low air pressure (low pressure regions). Think of it like this: When 30 people at a party are in one crowded room, and a door opens to another adjacent empty room, half of the people are likely to move into the second room, to balance out the space.

The greater the difference between air pressures, the more powerful the movement of air masses and the stronger the wind. Why are there different pressures? As you just learned, air pressure is caused by the weight of the column of air over Earth's surface. Changes in air pressure are caused by temperature differences between air masses and movements of air masses.

Gliders use thermals to gain height.

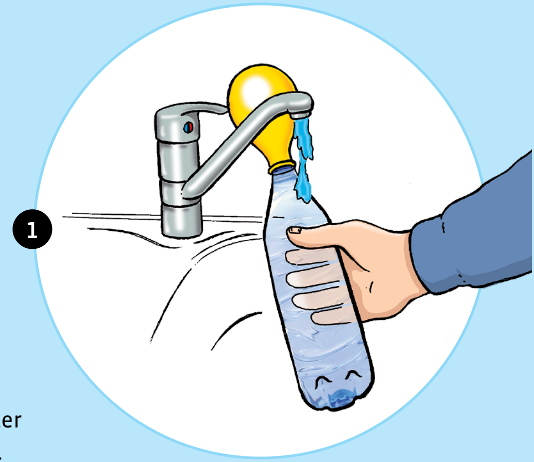
EXPERIMENT 13

Warm air and cold air

YOU WILL NEED

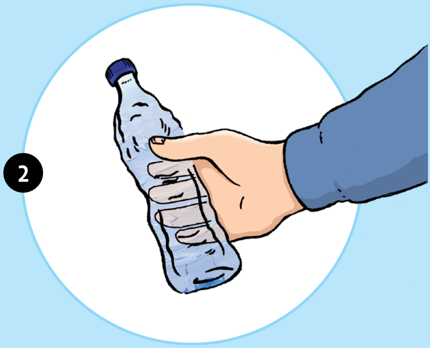
→ balloon
→ *empty plastic bottle*
→ *water*

HERE'S HOW



1. Pull the balloon over the mouth of an empty plastic bottle, and hold the bottle under warm running water. After a little while, the balloon will expand.

2. You will get the opposite effect if you tightly screw the top onto the bottle and leave it overnight in the freezer. The next morning, the bottle will be crumpled. Save the balloon for other experiments.



→ WHAT'S HAPPENING?

Under warm water, the air in the bottle is warmed. Warm air expands and spreads out into the balloon, which offers resistance and is stretched tight.

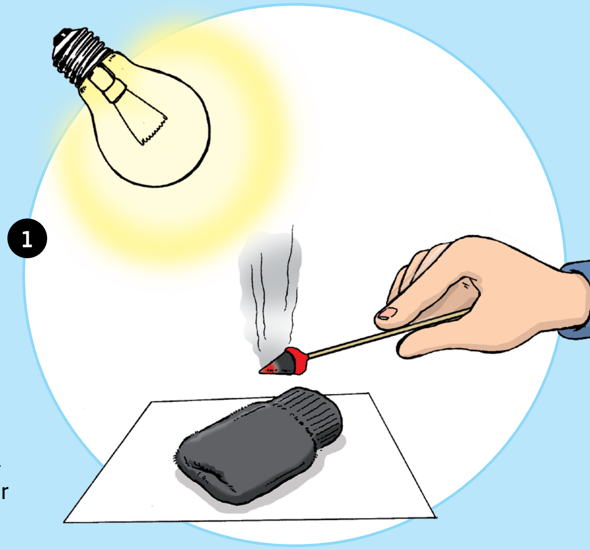
When air cools, its volume decreases. So in the bottle left in the freezer, a vacuum forms and its walls crumple inward.

EXPERIMENT 14

Warm air rises

YOU WILL NEED

→ incense cone
→ wooden stick
→ clay
→ *a black wool sock*
→ *lighter*
→ *sheet of white paper*



HERE'S HOW

1. Place a black wool sock on a sheet of white paper and set this for about a quarter of an hour in the sun or under a 60-watt light. Mount the flat end of your incense cone firmly onto the tip of a wooden stick with a piece of clay. The stick will allow you to hold the incense cone at a safe distance without burning your fingers, and it will let you keep your hand far enough away to avoid swirling the smoke. Now light the incense cone and move it slowly over the paper and the dark wool.

2. Observe how the smoke behaves. Extinguish the incense afterwards with a little water.

→ WHAT'S HAPPENING?

The smoke rises. Above the white paper, it will make slow swirls, while above the black sock it shoots suddenly and quickly upward in a straight line.

The dark wool absorbs much more heat than the light-colored surface of the paper. It also gives off more heat. The smoke rises up along with the warm air thermal emanating from the sock.

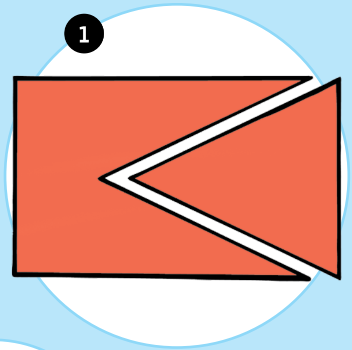
WARNING! See the warnings about the incense cones on page 34.

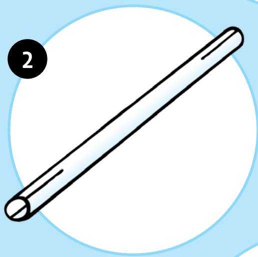
EXPERIMENT 15

Build a simple wind vane

YOU WILL NEED

→ *pencil with eraser*
→ *pin or thumbtack*
→ *straw*
→ *index card (or paperboard)*
→ *scissors*
→ *glue*





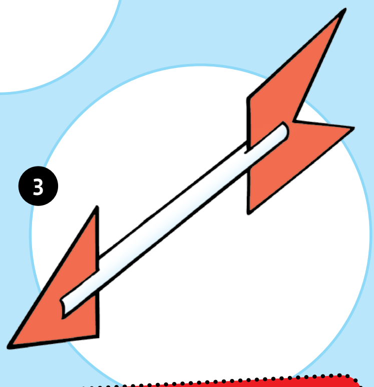
HERE'S HOW

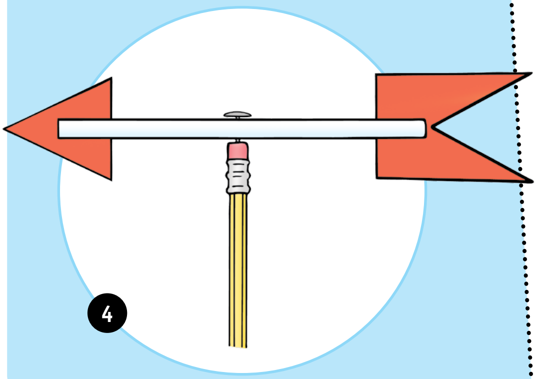
1. Cut your index card into the shapes shown. You should have a triangular point and arrow tail when finished.

2. Cut a one inch slit in both ends of the straw.

3. Insert and glue the point on one side and the tail on the other.

4. Stick the pin through the middle of the straw, and then into the pencil's eraser, making sure your straw can spin around easily. Experiment with your wind vane outside.



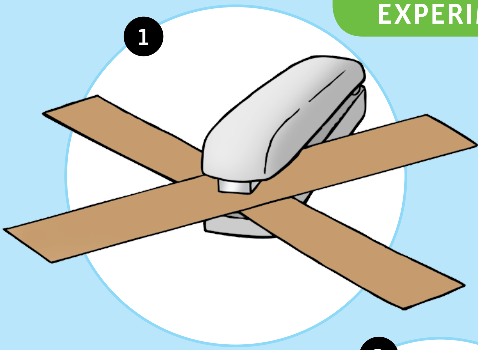


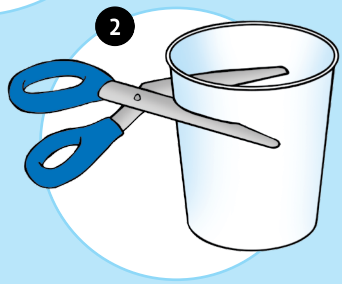
→ WHAT'S HAPPENING?

As the wind hits your wind vane, it will push on the larger tail surface causing the smaller surface area of the arrow to point at the direction the wind is coming from. This direction can tell you what the weather is going to be like depending on where you live and what direction a storm will travel. Wind is identified by the direction from which it comes. So a westerly wind comes from the west and blows to the east, and a northerly wind comes from the north and blows toward the south.

EXPERIMENT 32

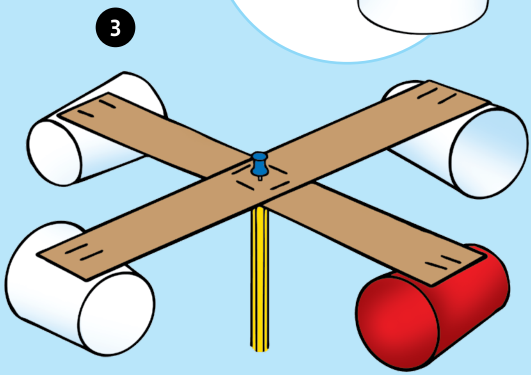
Build a simple anemometer





YOU WILL NEED

→ *2 strips of cardboard from a thin cardboard box (12 inches long and 1 to 1.5 inches wide)*
→ *straight pin or thumbtack*
→ *pencil with a full eraser*
→ *marker*
→ *4 small paper or polystyrene cups*
→ *stapler*
→ *scissors*



An anemometer is a meteorological device used to measure the speed of the wind.

HERE'S HOW

1. Make an X with the two strips of cardboard. Staple them together in the center.

2. Cut the tops off of the paper cups to make them lighter.

3. Color the outside of one cup with a marker. Staple one cup to the end of each cardboard strip. Make sure the openings face a consistent direction. Place your pin in the very center of the cardboard X and push it through the cardboard into the eraser of your pencil.

4. With your completed anemometer, test the wind speed outside or in front of a fan. Place your pencil in a base of modeling clay or into the ground.

5. Determine the revolutions per minute by counting how many times the colored cup spins around in 60 seconds. Multiply the revolutions per minute by the circumference of the circle (3.14 feet), to get the velocity of the wind in feet per minute. Convert this to miles per hour by dividing by 88.

6. Test wind speeds on different days and at different times of day.
   Do you notice any differences? What are the other weather conditions during these times?

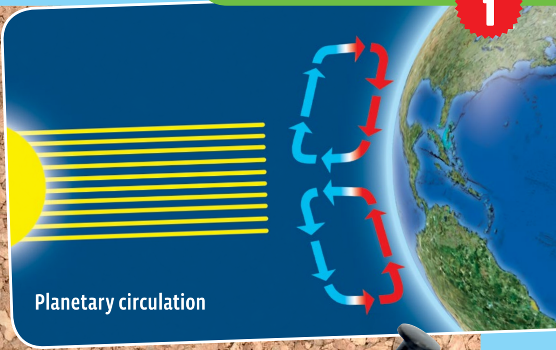
Global Circulation

Air doesn't just circulate within small areas. If you look at Earth as a whole, large-scale wind patterns may be observed, stretching over the entire planet. This is known as **global circulation**. The source of energy for these global wind movements is, once again, the sun. You learned at the beginning that, due to the spherical shape of Earth, the overall radiation of the sun lessens as you get near Earth's poles. It is strongest at the equator. So a lot of energy is delivered to areas near the equator, and not as much is delivered to the poles.

At the equator, warm air rises up. At ground level there, a low pressure region develops, and a high pressure region develops much higher up. At the poles, on the other hand, the cold air lies heavily on the ground. A high pressure region forms there, while a low pressure area forms above it. So the temperature gradient between the equatorial tropics and the poles gives rise to a difference in pressure, called a pressure gradient, that is equalized by large-scale wind movements. Warmed air moves near the ground from the poles to the equator, and rises at the equator. When it rises, it cools and moves higher up back towards the poles, where it sinks again. These movements of air create the air mass exchange of the global wind system.

You can observe this kind of air flow in Experiment 18. The black strip corresponds to Earth's warm equatorial belt, while the ice disks represent the polar caps.

CHECK IT OUT

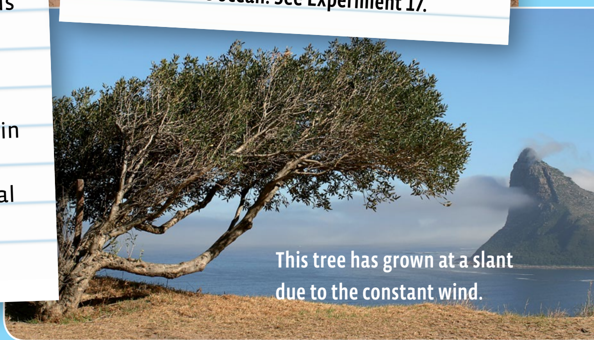


Planetary circulation

Local Winds

If a given landscape is heated more strongly by the sun than the area around it, the warm air will rise, because it is lighter than the surrounding cold air. That can happen, for example, where a ripe field of grain borders on a forest. At ground level, cold air follows the warm air, and is in turn warmed and rises up. In this way, a tunnel of constantly upward-moving warm air is formed. This is known as an updraft or thermal. Birds and gliders like to take advantage of thermals to get a free elevator ride into the heights.

Because mountains and valleys have differences in elevation and temperature, they also have differences in air pressure. When air masses flow over a mountain range, this difference in air pressure usually causes so-called **fall winds**. This is nothing other than an exchange between cold and warm air, and happens, for example, along seacoasts where the land is mountainous and colder than the ocean. See Experiment 17.



This tree has grown at a slant due to the constant wind.

EXPERIMENT 17

Fall wind

YOU WILL NEED

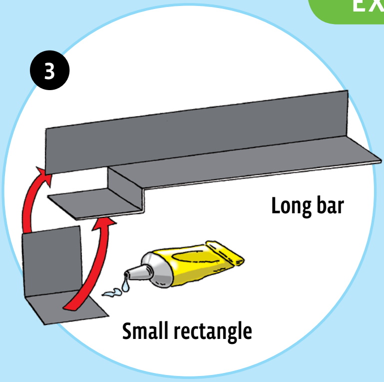
→ experiment kit box
→ black ramp (die-cut sheet)
→ transparent plastic window
→ tealight container with ice cube
→ tealight container with warm water
→ empty tealight container
→ incense cone
→ *scissors*
→ *lighter*
→ *tape*
→ *glue*
→ *glass of water*
→ *flashlight*
→ *utility knife*

HERE'S HOW

1. Fill an empty tealight container with water and place it in the freezer. Use a knife to cut open the box along the solid line on its rear side and fold the rectangle inward along the dotted line. This will create a hole over which you can glue the transparent plastic window (from the plastic sheet). See the illustration at the bottom of page 35.

2. Set the box on its long edge and open the short end at the lower side of the window, as shown in the illustration.

3. Remove the long black bar and the small black rectangle from the die-cut sheet and bend them along the folding lines. First fold the long bar in the middle (black surfaces to the inside). Then fold out the small protruding square part like a step (see illustration). Fold the small rectangle in half and glue or tape it to the bottom of the square step area on the long bar and to the protruding end of the long bar.



WARNING! In these experiments, you will learn about air circulation. The experiments are not very easy and the results will be subtle. Don't give up right away if they don't work the first time, but keep your cool and try again.

To make the movement of air masses visible, you will be using an **incense cone.** An adult must always be present to help you with these experiments. You must be especially careful that no one gets burned and that nothing catches on fire.

To be safe, you should also always keep a glass of water close by, so you can quickly extinguish the incense cone if necessary. Because incense cones create an aroma and some smoke, it is necessary to conduct the experiments in a well-ventilated area, to air the room out after the experiment, and/or to do the experiment with the window open.

If you are overly sensitive to the smoke or the smell of the incense, discontinue use immediately.

Because you will only need the incense for a short time in order to achieve the desired effect, you can dip the lit end in some water at the end of each experiment. When the incense is dry, just scrape off the burnt end and reuse it.

EXPERIMENT 17

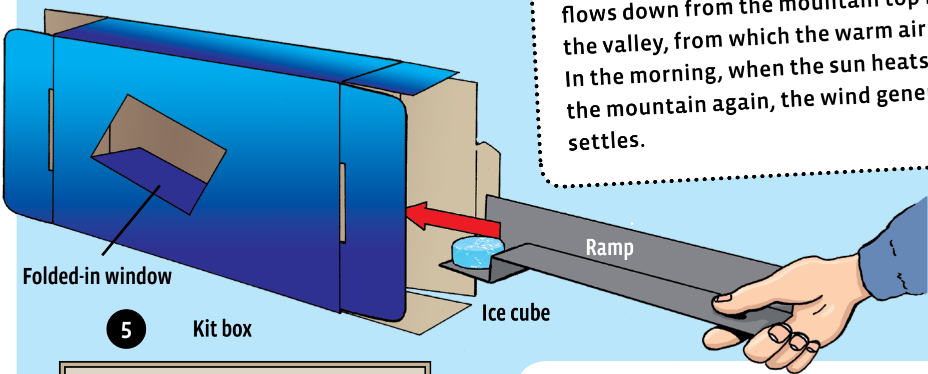
4. The outer edges of the rectangle and of the bar should line up, which will keep the ramp folded at a right angle. The little step will be your ice cube holder. You will place your frozen tealight container on this later on. When the glue has dried, slide the bar with the ice cube holder area into the box, until the ice cube holder area is resting behind the open window of the box. Now the bar will lie securely on top of it, and can't slip to the front. This will be your mountain slope.

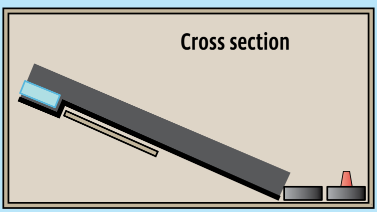
5. When the water in the tealight cup has frozen, perhaps after an hour or two, fill a second container with warm water. Set the frozen tealight on the bar's ice cube holder, and place the tealight cup of warm water on the floor of the box at the foot of the black ramp, which represents our mountain slope. Next to the warm water cup, place a third, tealight cup with an incense cone inside it. To be safe, you can tape the bottom of the cup to the box.

6. Light the incense cone and close the side flaps of the box, being careful that nothing tips over. Now watch what happens through your viewing window. Darken the room and shine the flashlight into the window at an angle.

→ WHAT'S HAPPENING?

By watching the smoke through your viewing window, you can see how the heavy, cold air flows down the slope. With the ice cube and the warm water, you are modeling relationships found in nature, where the ocean acts as a heat store, able to absorb a lot of heat and hold it for a long time. In the mountains, the air cools off quickly, and a noticeable temperature difference arises between the colder mountain and the warmer valley and ocean. At night, the cold air flows down from the mountain top into the valley, from which the warm air rises. In the morning, when the sun heats up the mountain again, the wind generally settles.





WARNING! Be careful that neither the tealight cup with the incense nor the box itself tip over. When you have finished the experiment, it is best to open the box by an open window, because a lot of smoke will come out. As soon as the box is open, you should extinguish the incense cone.

The global wind system

YOU WILL NEED

- → white (whole) polystyrene sphere
- → 2 half-spheres
- → 2 tealight cups
- → wooden stick
- → incense cone
- → 3 pins
- → black foam rubber strip
- → drinking straw
- → stand from the die-cut sheet
- → clay
- → *water*
- → *lighter*
- → *lamp*
- → *scissors*
- → *cup of water*

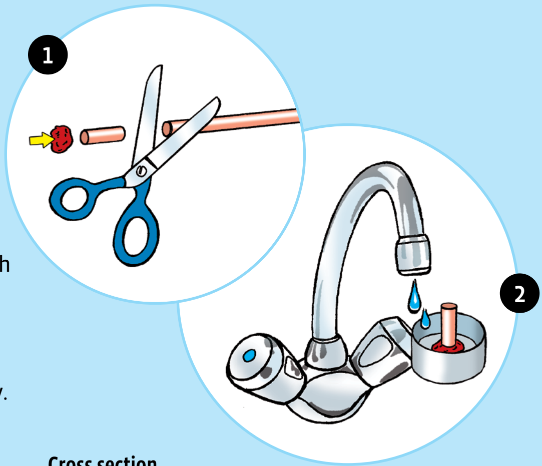
HERE'S HOW

1. The night before the experiment, you will have to make two "poles" of ice with your tealight cups. Cut two sections of drinking straw about two centimeters each in length and seal the bottom opening of each with a small ball of clay.

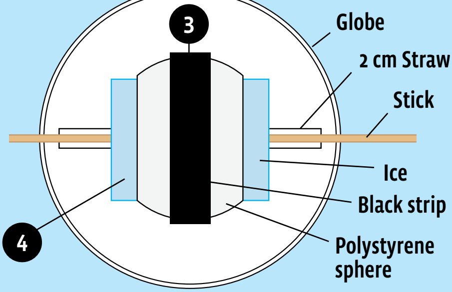
2. Set each straw upright in the center of an empty tealight cup. Fill the cups with water up to five millimeters from the bottom (the clay will prevent water from getting into the straws), and place them in the freezer. Be careful that the straws don't tip over when you do this.

3. The next day, wrap the black strip around the equator section of the polystyrene ball and secure it in place with two pins. Push the ball onto the wooden stick, which represents Earth's axis. You will use this to rotate the sphere inside the globe made of the two clear half-spheres. Place the polystyrene ball with the black strip in direct sunlight or under a lamp (at least 60 watts), to warm up the black equator strip. Keep turning the ball so that the entire strip gets warm.

4. Now take the two frozen tealight cups out of the freezer and remove the ice blocks from them. Slide an ice block onto each side of the wooden stick, so that the part of the straw that sticks out is pointed away from the ball. When you do this, the clay will be pushed out of the straw. The two ice



Cross section



EXPERIMENT 18

blocks fit perfectly into the indentations in your polystyrene ball. Set your Earth with its wooden stick into one of the half-spheres, join the two half-spheres together to form a single spherical shell, and place the assembled shell on the stand so that the Earth's axis is horizontal. It is ideal if the straws are just long enough that the polystyrene ball won't slide around inside the shell. Seal the lower of the two measurement holes with clay.

5. Stick the incense cone onto a pin. Hold the free end of the pin, light the incense cone, and hold the incense for a few seconds in the open measurement hole by the end of the pin, in order to get some of the smoke inside.

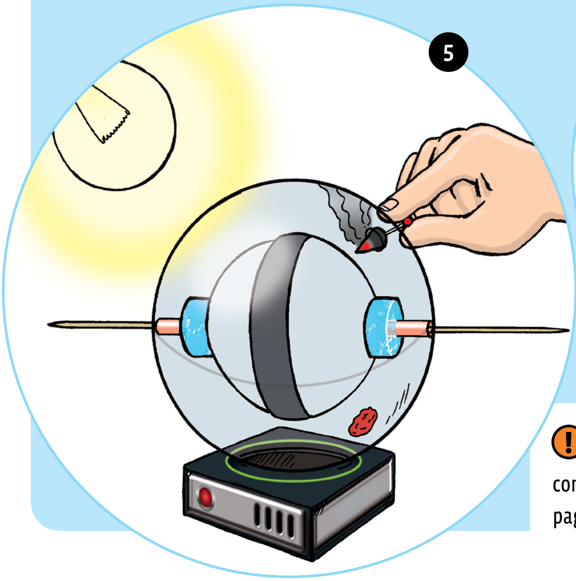
6. Wait for the flow of air to start. After a few seconds, the wisps of smoke will reveal the upper and lower currents. The effect is particularly easy to see under the light of a flashlight shining from the side in an otherwise darkened room.

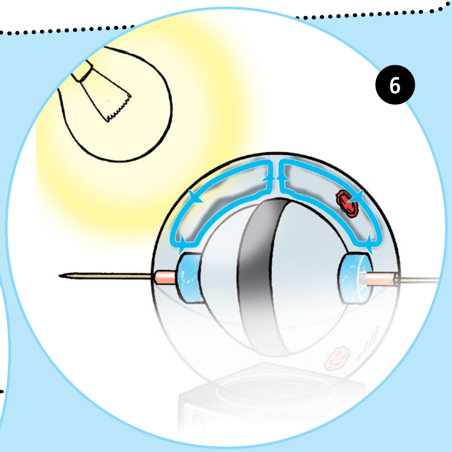
7. Once you have seen the air flow, open the shell again and remove the ice pieces, because otherwise they will melt and get your workplace wet.

Keep the setup for the next experiment!

→ WHAT'S HAPPENING?

Warm air rises above the warm black strip (your equator). It cools off and sinks down again above the disks of ice. The whole process gives rise to a cycle comparable to the large-scale exchange of air masses over Earth. In reality, neither Earth's axis nor the poles lie in the horizontal position in which you have them in your experiment. Instead, the poles would actually be oriented north and south, i.e. up and down, with a slight tilt of 23°. We made the Earth model "lie down" in this experiment for the sake of simplicity.





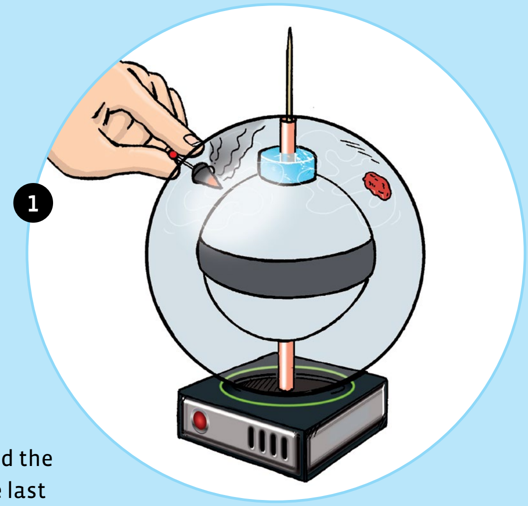
WARNING! Do not let the glowing end of the cone touch the edges of the measurement hole! See page 34 for additional warnings.

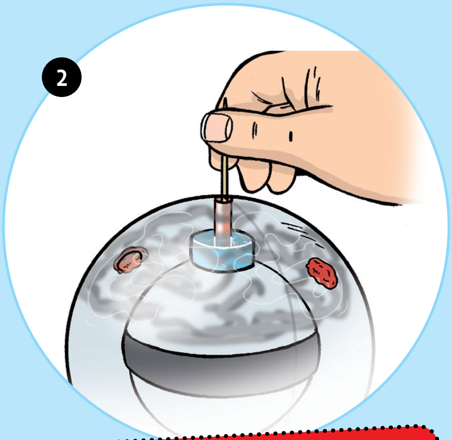
EXPERIMENT 19

Winds and vortices

YOU WILL NEED

→ setup from the last experiment
→ tealight cup with ice
→ drinking straw
→ *scissors*





HERE'S HOW

1. For this experiment, you will need the same setup that you used for the last one, except this time you will orient the Earth's axis vertically (which is closer to the actual orientation) and do away with the bottom pole (ice cube). Instead, insert a second section of straw over the bottom wooden stick, so that the polystyrene Earth is held in the center of the transparent shell. As in the last experiment, let some smoke flow into the shell and wait for the wisps to flow from bottom to top and back again. Pull the incense cone out again and extinguish it with some water.

2. Now rotate the Earth slowly on its axis and observe what happens to the smoke. You will get some turbulence corresponding to the highs and lows in the actual large-scale climate. To avoid reflections of the surroundings on the transparent shell, you can go into a darkened room immediately after warming the setup (or turn off the light), let the smoke in, and watch what happens by the light of a flashlight held from the side.

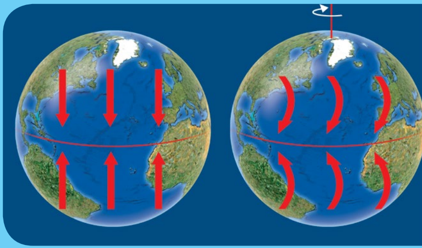
→ WHAT'S HAPPENING?

In this experiment, you can observe the influence of Earth's rotation, or the Coriolis force, on air currents. If the Earth stands still, the wisps of smoke run parallel to the Earth's axis from bottom to top. If the Earth starts turning, the wisps of smoke are pulled with it and start to swirl.

CHECK IT OUT

The Coriolis Force

Experiment 18 showed you the principle of global air currents. According to this principle, near the ground in the northern hemisphere you would only get a north wind, and in the southern hemisphere, only a south wind. But in the experiment, we ignored the fact that Earth rotates on its own axis.



You saw in Experiment 19 that because Earth turns from west to east, the air currents are thrown off in the direction of this movement. A mass of air flowing toward the equator will be turned into a northeasterly wind in the northern hemisphere, or a southeasterly wind in the southern hemisphere. The force responsible for this is known as the **Coriolis force.** At high altitudes, in the region of moderate or middle latitudes between pole and equator, we also get an opposing air current. The cause of this is, once again, the Coriolis force. The winds there are diverted parallel to the lines of latitude into a very powerful westerly wind current, the so-called **jet stream.**

The jet stream is a strong high-altitude wind, and it pulls the lower layers of air with it, causing turbulence. This gives rise to the dynamic high and low pressure regions that influence the weather. High pressure regions are known as **anticyclones**, while low pressure regions are called **cyclones**. They rotate in a virtually circular manner. When viewed from space, cyclones in the northern hemisphere rotate in a counterclockwise direction, while anticyclones rotate the opposite way.

A typical tropical hurricane rotating in a counterclockwise direction

The current patterns of the atmosphere are easily recognizable in clouds seen from space.

CHECK IT OUT

MEASURING WIND STRENGTH

Wind strength is measured in Beaufort numbers (bft), named after the British admiral who created this multipart scale in 1806.

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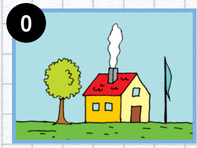
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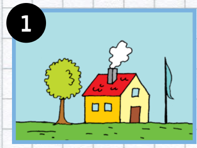
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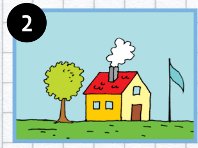
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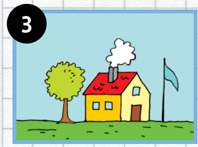
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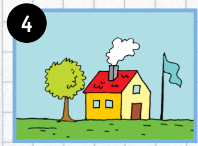
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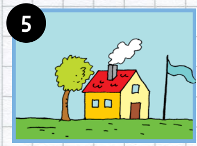
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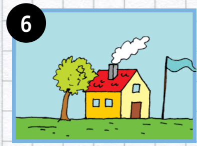
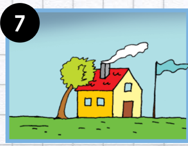


Beaufort	Name	Description
0	Calm	Smoke rises straight up
1	Light air	Leaves move in the treetops
2	Light breeze	Smoke blows, light movement in the tips of grasses
3	Gentle breeze	Smoke blows quickly, flags, grasses, and the tips of bushes move lightly
4	Moderate breeze	Wind can be felt, tops of trees and bushes move and make a soft rustling sound
5	Fresh breeze	Wind is clearly felt, tops of trees and bushes obviously move with rustling sound
6	Strong breeze	Trees and branches move strongly, waves and white foam form on water's surface
7	Near gale	Trees make whooshing noise, leaves are torn off, water forms whitecaps
8	Gale	Entire trees in motion, twigs break, the wind starts to howl, high waves on the water
9	Severe gale	Thin branches break, the wind howls, strong whitecaps on the water
10	Storm	Trees are uprooted, significant damage occurs
11	Violent storm	Heavy storm damage
12	Hurricane	Catastrophic hurricane damage

7

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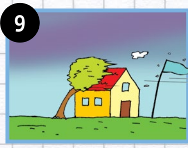
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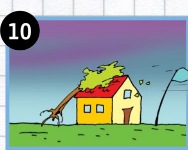
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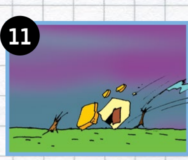
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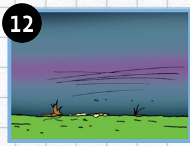
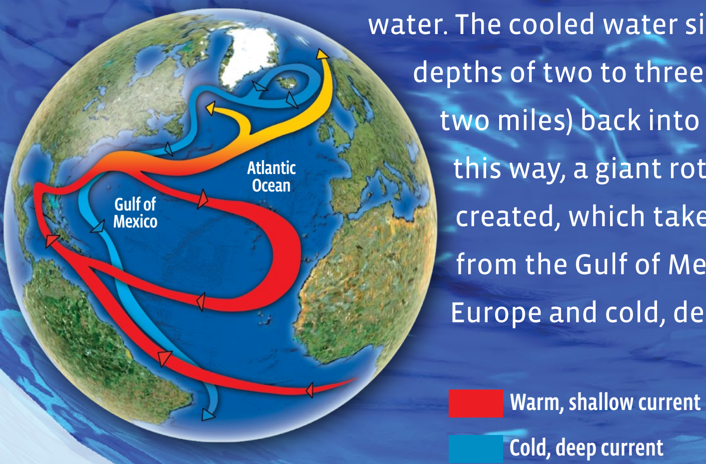


Ocean Currents

It is not just masses of air that move due to differences in temperature and density. Heated masses of water in the oceans also flow toward colder ones along several global routes. In addition, these currents are driven by varying salt concentrations in the water. One particularly powerful ocean current is known as the Gulf Stream. It begins as a shallow current in the Gulf of Mexico, where the Atlantic absorbs large quantities of heat from the atmosphere and transports them northward along the east coast of North America. The Gulf Stream continues as the North Atlantic Current, flowing past Ireland and England into the European North Sea. There, the water is cooled off by arctic air masses.

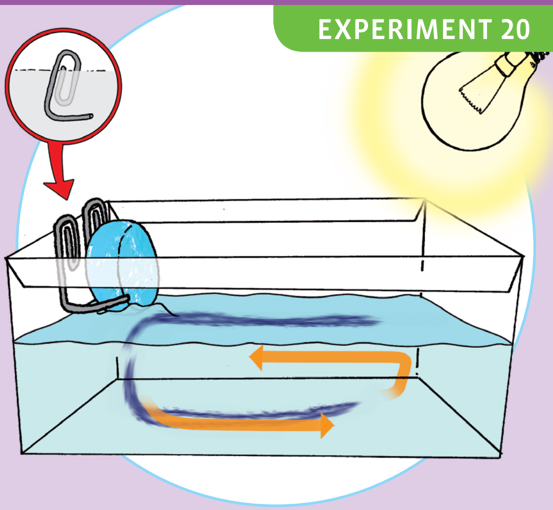
Cold water is denser and therefore heavier than warm water. The cooled water sinks and pushes at depths of two to three kilometers (one or two miles) back into the Caribbean Sea. In this way, a giant rotational movement is created, which takes warm surface water from the Gulf of Mexico to northern Europe and cold, deep water back again.



Ocean currents

YOU WILL NEED

→ transparent plastic basin
→ 2 paper clips
→ 2 or 3 tealight cups with ice
→ pipette
→ *ink or food coloring*
→ *lamp*
→ *large white shallow dish*
→ *ice*



HERE'S HOW

1. Make an ice cube holder by bending two paper clips as shown in the illustration, so a tealight cup fits onto it.

2. Fill several tealight cups with water and put them in the freezer. Take the experiment basin and place it in a large, white, shallow dish, such as a casserole dish, near a desk lamp.

3. Fill the basin a little over halfway with water. Point the desk lamp at the water at one end of the basin, from a distance of a few centimeters away. This will be your Gulf of Mexico. The lamp should never touch the water!

4. Hang your ice cube holder from the opposite narrow edge of the basin — this will be your northerly frozen sea — and set an ice cube into it (without the tealight cup). To remove the ice cube from the tealight cup, you will have to warm it briefly in your hands. Keep a second and third ice cube ready, because the ice melts quickly.

5. Use the pipette to add one or two small drops of ink (or food coloring) to the surface of the water under the lamp. Some of it might sink to the bottom, but the rest will remain on the surface and move in streaks to the "north," toward the ice cube, along with the invisible portion of the current. There, the current starts to dive down in front of the ice, and then flow at a lower level back to the "equator," i.e. to the warmth. Before long, the ink will spread through the entire current and become thinner. After a few minutes, a clear border will form at mid-depth, above which the return current flows. This is something like what happens in the Gulf Stream. To see the cycle more clearly, put a few drops of ink into other areas of the basin as well. They will all move along the same path.

→ WHAT'S HAPPENING?

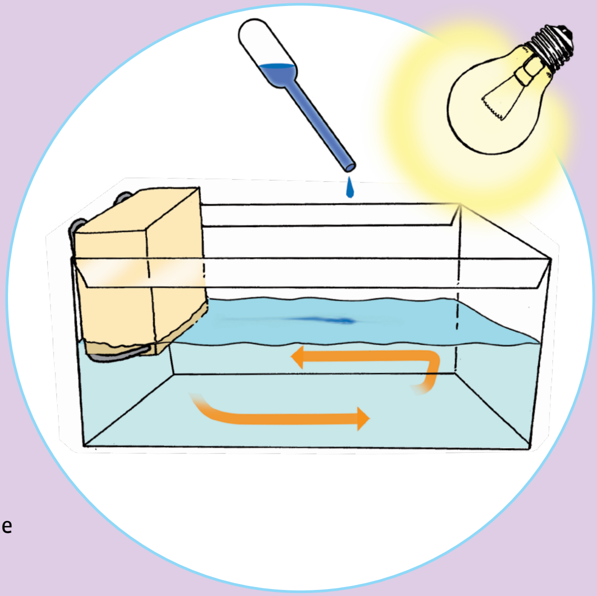
The water under the lamp is heated and flows near the surface toward the cooler water. Under the ice cube, it gets cooled off and sinks, and then flows back along the bottom. As long as the temperature difference is maintained, circulation will take place.

EXPERIMENT 21

Salt as an engine

YOU WILL NEED

→ transparent plastic basin
→ paper clip ice holder
→ sponge
→ pipette
→ *ink or food coloring*
→ *water*
→ *table salt*



HERE'S HOW

1. Fill the basin from the previous experiment up to the paper clip ice holder with cold tap water.

2. Dissolve a heaping teaspoon of salt in half a glass of cold water. Dip the sponge into this salt solution, lift it out again and squeeze it out a little (not entirely), so it doesn't drip. Then place it on the ice holder so it barely touches the water. Drip a few drops of ink or food coloring in a few spots on the water's surface. Do you see the paths that the threads of ink take?

→ WHAT'S HAPPENING?

The threads of ink flow toward the salt. Just as with temperature, a difference in salt concentration causes the water to strive to attain a balance.

The salt solution in the sponge tries to dilute itself, and pulls the fresh water toward it. Also, the salt water is heavier than the fresh water, so it sinks down beneath the sponge and moves along the basin bottom. If you look closely, you can see the salt water sinking down below the fresh water. This gives rise to a circular flow in the basin. This movement stops when the salt content has evened out.

Climate Change

You have probably heard of the **greenhouse effect** in connection with climate change. It is often claimed that the greenhouse effect is caused by humans. But that isn't the whole story. There is a natural greenhouse effect, without which life on Earth as we know it wouldn't even be possible in the first place! This natural greenhouse effect is responsible for the fact that the heat reflected back from Earth's surface doesn't simply leave the atmosphere. Instead, it is first absorbed by trace gases in the atmosphere, known as greenhouse gases, and also by clouds.

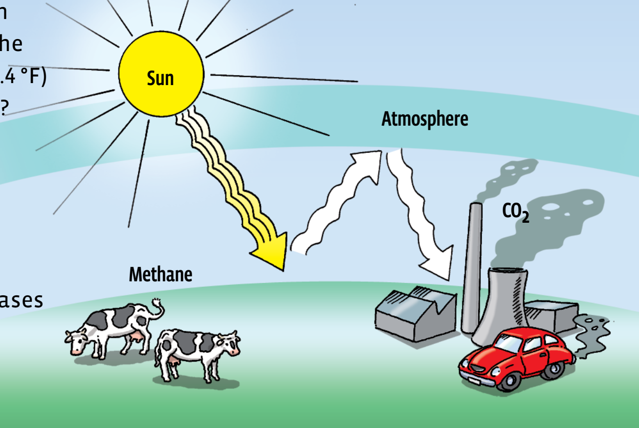
The trace gases and clouds then give some of this energy off into space, but also radiate some of it back in the direction of Earth's surface, which is thereby heated even more and once again radiates energy into the atmosphere, which in turn sends energy back toward Earth's surface, and so on.

The accumulation of heat brought about in this manner in the lower atmosphere is a natural greenhouse effect. Without it, the temperature on Earth would be so much colder that life would not be possible. The average temperature would be -18 °C (-0.4 °F) instead of 15 °C (59 °F). Pretty cold, right?

The natural greenhouse effect has functioned since the Earth and its atmosphere existed, and has its own mechanisms of self-regulation. Natural variations in temperature — both increases and decreases — caused by the natural greenhouse effect occur only over very long periods of time, and nature finds ways to react and adjust to them.

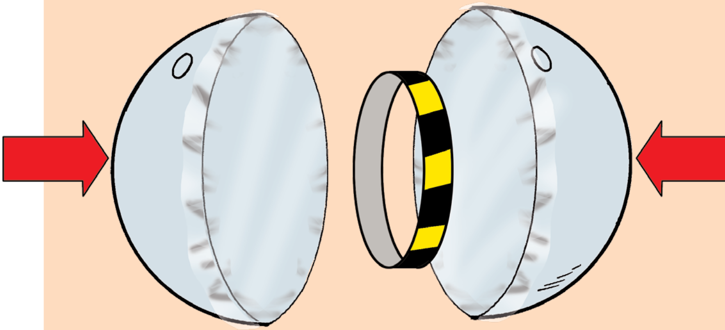
Since the beginning of the Industrial Revolution, humans have contributed to an increase in the concentrations of natural greenhouse gases — such as **carbon dioxide** (CO_2), methane (CH_4), nitrous oxide (N_2O), and ozone (O_3) — and added new greenhouse gases in the form of CFCs. That has intensified the greenhouse effect and led to a noticeable increase in Earth's surface temperature.

The greatest and most important recent change in the atmosphere is in its carbon dioxide content. During the last 100 years, the concentration of CO_2 in the atmosphere has risen by over a third. Current levels are the highest they've been in the last 650,000 years. It is believed that carbon dioxide is responsible for more than half (60%) of the man-made portion of the greenhouse effect. Let's become climate researchers and take a closer look at the effects of carbon dioxide.



EXPERIMENT 22

The climate measurement station



YOU WILL NEED

- → stand from the die-cut sheet
- → transparent half-spheres
- → thermometer
- → clay
- → striped spacing strip from the die-cut sheet
- → balloon
- → cork
- → tubing
- → *2 pieces of plastic wrap (about 15 cm x 15 cm)*
- → *tape*
- → *baking soda*
- → *vinegar*
- → *teaspoon*
- → *sheet of paper*
- → *scissors*
- → *glue*
- → *lamp*
- → *watch*

HERE'S HOW

1. Read through this entire experiment first to get an idea of how it all works, because some steps must be performed quickly.

2. With a small strip of tape, seal the small holes for the Earth's axis at the edges each transparent half-sphere. Remove the spacing strip from the die-cut sheet, make a closed loop out of it, and tape the ends together. Cut two squares of plastic wrap that are about 15 centimeters by 15 centimeters and stretch each square over the mouth of each half-sphere. Set one of the half-spheres in front of you and place the spacer ring in the center of the plastic wrap. Now, fit the two half-spheres firmly together with the spacing strip in between and the measuring holes at the same level, and you will get two separate measuring chambers.

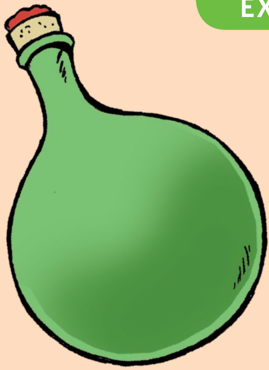
3. Trim the extra plastic wrap away from the sphere, and place the sphere in the round depression of the base, so the measuring holes are pointing up. You may want to tape the sphere together in a few spots.

4. Insert the thermometer through one of the measurement holes into the center of the shell. Use some clay to seal the hole around the thermometer. (See the illustration on page 47). While you are performing your experiments with the sphere, you will want to make sure that the thermometer doesn't topple over. You may want to support the thermometer with books or blocks. Your measurement station is now ready.

WARNING! The thermometer is made of glass, and it can shatter under strong pressure. Be very careful with it! You might get injured!

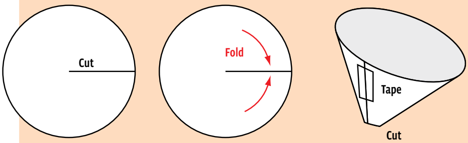
The climate measurement station

HERE'S HOW IT CONTINUES



Carbon dioxide is created during combustion of fossil fuels. But it's also quite easy to produce with this simple chemical reaction.

5. This part of experiment is best carried out over the sink. Inflate the balloon to stretch the rubber, and then let the air out. Seal the opening in your cork with a little ball of clay, and keep the cork ready. Cut a circle out of the sheet of paper and then cut halfway through the circle, from the outside of the circle to its center point. By folding the paper over itself along this cut, you will get a nifty funnel. You'll just have to tape it down and cut off the tip.



6. It is easier if you have two people for the next few steps. One person should hold the balloon open with the mouth facing up. The other person should use the funnel to put two teaspoons of baking soda into the balloon.

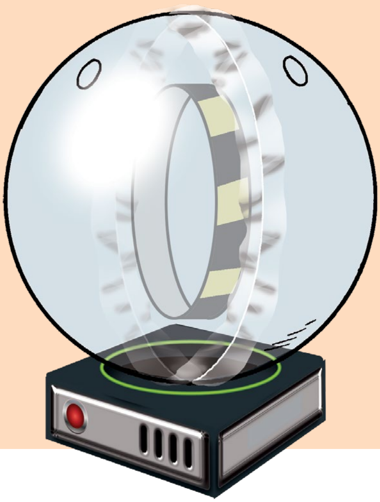
7. With the first person still holding the balloon open, the second person should fill the balloon at least halfway with vinegar.

8. Right away, you will hear fizzing and hissing sounds from the balloon. Some foam may even bubble out of the balloon.

9. Quickly seal the neck of the balloon with the cork. Be careful that the cork stays on really tightly. A lot of pressure will build up in the balloon, which could push it out.

10. The balloon will swell quite a bit. If this doesn't happen, try it with a little more baking soda or vinegar. It's important not to open the balloon for too long and to reinsert the cork slowly

11. Immediately proceed to your measurement station with the inflated balloon. You will want to work quickly.



EXPERIMENT 22

The climate measurement station

HERE'S HOW IT CONTINUES

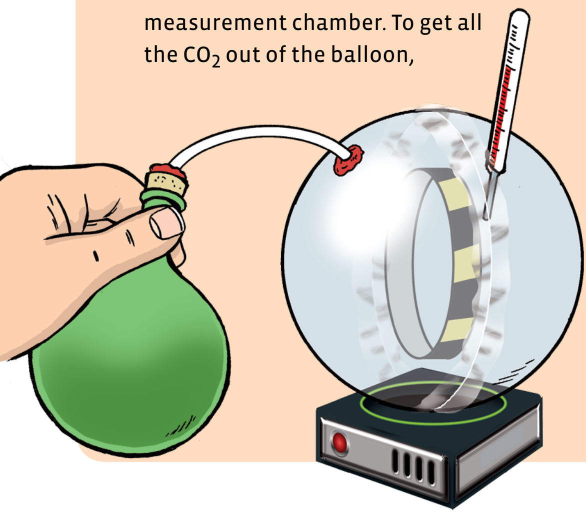
12. Insert the flexible tubing into the free measurement hole. Seal the hole around the tubing with a ring of clay, but don't collapse the tubing.

13. Quickly remove the clay plug from the cork in your balloon, and stick the end of the tube into the cork, sealing it with a ring of clay. The clay around the tube must form a good seal with the cork, because otherwise the CO_2 will escape. The CO_2 will now start to flow through the tube into the measurement chamber.

14. Agitate the balloon a little to help the CO_2-forming reaction along. Continue to let the gas flow out of the balloon into the measurement chamber. Because CO_2 is heavier than air, it will sink to the bottom of the measurement chamber. To get all the CO_2 out of the balloon, gently squeezing the balloon. Try to keep liquid from getting into the tube. When the balloon is limp and only has liquid in it, pull the end of the tube out of the measurement station and immediately seal the chamber opening with clay.

15. Now, you have normal air in one measurement chamber, and CO_2 in the other. In the measurement chamber with the thermometer, you can observe how normal air heats up. Set the apparatus in direct sunlight or shine a 60-watt lamp at it (from 10 centimeters away), in such a way that plastic wrap separating the chambers is aligned directly with the sun or light and both halves of the sphere get the same amount of light. Note the time and temperature, and wait until the temperature in the first measurement chamber has stopped rising.

16. Now insert the thermometer into the other measurement chamber. You'll have to work quickly. First remove the clay plug from the measurement hole, insert the thermometer so it reaches the middle of the sphere, and seal the hole again with clay. Observe what happens to the temperature in the CO_2-filled chamber.



→ WHAT'S HAPPENING?

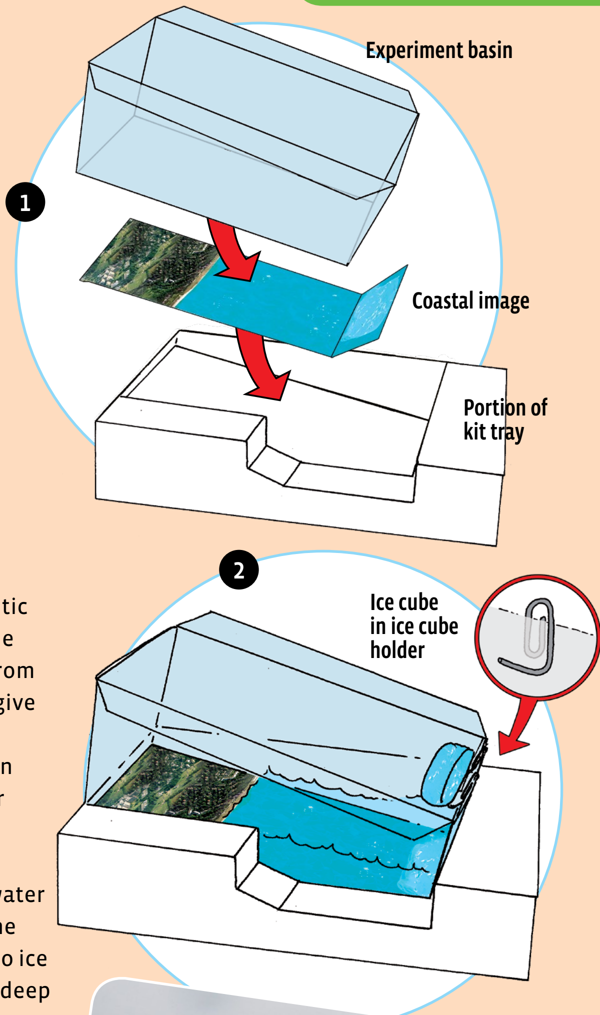
CO_2 heats up considerably more than normal air. What you normally get in this experiment is a temperature difference of about 1.5 to 2 °C (2.5 to 4 °F), sometimes even more than that. This experiment reveals the effect of air pollution on Earth's temperature. The proportion of CO_2 in the atmosphere is increasing. The more CO_2 in the air, the higher the air's temperature gets.

EXPERIMENT 23

Is the ocean rising?

YOU WILL NEED

→ polystyrene insert
→ experiment basin
→ ice cube holder
→ coastal image from die-cut sheet
→ 2 or 3 tealight cups with ice
→ *lamp*



HERE'S HOW

1. Prepare two or three ice cubes by placing the tealight cups filled with water into the freezer. Set your plastic basin on the ramp of the polystyrene insert and slide the coastal image from the die-cut sheet under it. This will give you a schematic model of a coastal landscape at one end, and the frozen landscape of Greenland at the other end.

2. Fill the basin with water, until the water level just reaches the coastline in the coastal image. Then place one or two ice cubes in the ice cube bracket at the deep end of the basin. In order to accelerate the melting of your "ice sheet," warm the ice with the lamp.

→ WHAT'S HAPPENING?

The melting of the ice cubes results in a rise in the water level, and the coastal town gets flooded!

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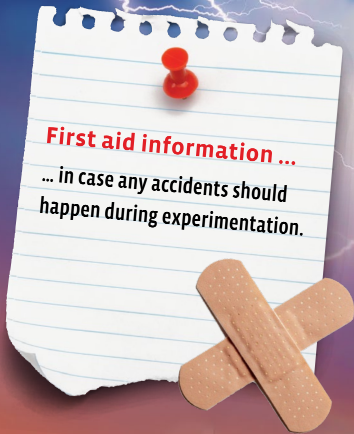

When conducting experiments with chemicals:

→ In case of eye contact: Wash out eye with plenty of water, holding eye open if necessary. Rinse from the nose outward. Seek immediate medical advice.

→ If swallowed: Wash out mouth with water, drink some fresh water. Do not induce vomiting. Seek immediate medical advice.

→ In case of inhalation: Remove person to fresh air. For example, move person into another room with open windows or outside.

→ In case of skin contact and burns: Wash affected area with plenty of cold water for at least 10 minutes. Cover burns with a bandage. Never apply oil, powder, or flour to the wound. Do not lance blisters. For larger burns, seek immediate medical help.

→ In case of cuts: Do not touch or rinse with water. Do not apply any ointments, powders, or the like. Dress the wound with a germ-free, dry first-aid bandage. Foreign objects such as glass splinters should only be removed from the wound by a doctor. Seek the advice of a doctor if you feel a sharp or throbbing pain.

→ In case of doubt seek medical advice without delay. Take the chemical and/or product together with the container with you.

→ In case of injury, always seek medical advice.

Poison Control Centers

In case of emergency, contact the United States Poison Control Centers at

1-800-222-1222

Elsewhere, record the telephone number of your local hospital or poison center here:

665006-03-230516