CLOUDS
Get out of the fog!

This worksheet gives students the opportunity to learn about the different types of clouds, their formation and the weather phenomena related to them. It is interdisciplinary as the subject of clouds can be addressed both in geography lessons and in science classes. Even though the exercises focus primarily on clouds, there are mathematics and geometry exercises on the theme of snowflakes.

The “WEATHER” worksheet complements this one. It introduces large air currents, high- and low-pressures systems, winds, and weather forecasts. It also proposes the construction of weather instruments.

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LIBERTÉ ET PATRIE

Concepts covered

Physics

- Phase changes
- Energy transformation
- Pressure
- Lightning and electricity

Sciences

- The water cycle
- Meteorology and clouds

Mathematics

- Geometric Constructions
- Isometrics

Activity duration

Clouds – presentation and exercises: 3 periods

Hydrometeors, lightning and snowflakes – presentation and exercises: 3 periods

Cutting activity: 1 period

If the students are not yet acquainted with the weather systems formed by high and low-pressure areas or with the weather forecasts presented in the WEATHER worksheet, we recommend showing the 26-minute video below, before or after handing out this worksheet, as it will give them a good overview on the subject:

http://www.youtube.com/watch?v=IdlhPV5uOjk

C'est pas sorcier, *Météo - Le bulletin des sorciers*

IS IT A CUMULUS, A STRATUS OR A CUMULONIMBUS?

Clouds have always fascinated due to their diversity, lightness, mysterious forms and devastating effects. For centuries, cloud classification kept coming up against the same obstacle: clouds constantly change shape and grow, spread, stretch, fade away, etc. The strength of Luke Howard's nomenclature lay in starting with their basic shape and taking into account the mechanisms that control the transition from one shape to another.

At present, meteorologists have classified ten clouds families with 27 varieties that pilots need to know to be able to decipher the weather forecast!

CLOUD FORMATION

The student worksheet describes the overall mechanism of cloud formation. Depending on the case, condensation and cooling can be caused by various factors. Similarly, the presence or absence of moving air masses during the formation of clouds will promote their development and change their shape.

Exercise 5 uses of a graph with a dew point curve. It provides insight into the phenomenon of saturation. Using a simplified model and reading the graph, the student will be able to calculate the altitude of the base of a stratus.

This is a nice French weather website with various topics related to the weather, including one about clouds with beautiful illustrations:

http://comprendre.meteofrance.com/pedagogique/dossiers

météofrance, les dossiers, *nuages*

Challenge

Collect clouds!

This is a long-term challenge for the class. You can make it easier by using online search photos. Many sites give examples of each type of cloud. However, this challenge can be interesting because it encourages children to look around. They will be able to collect their clouds throughout the year, in different weather conditions and places (ski camps, holidays).

In the meantime, you will find some pictures to classify in the quiz.

Quiz

A. Cumulus congestus*
B. Stratus (fog)
C. Cumulus fractus**
D. Cumulus congestus*
E. Altocumulus
F. Cirrus
G. Altostratus
H. Cirrostratus

* Cumulus that develop into cumulonimbus

** Fragmented cumulus

To determine the type of cloud they are looking at, students need to try to assess the height of the cloud base. This is not an easy exercise, but the Jura and the Alps can provide reference points in Switzerland.

THE CUMULONIMBUS, THE AVIATOR'S SWORN ENEMY!

Here are some links to videos that clearly explain the principle of cloud formation, with a particular focus on thunderstorms:

http://www.meteo-world.com/dossiers/dossier3.php
Météo World, *Condition de formation d'un orage*

http://www.youtube.com/watch?v=k6O-RG6rW0Q
C'est pas sorcier, *Orages : les sorciers ont le coup de foudre*

On cloud nine...

When there is a drop in temperature, which translates to a loss of energy, humid air can become saturated with water vapor. Water vapor will then transition into a solid or liquid phase and condense.

When there is a sea of fog, the temperature under the clouds is lower than the temperature in the mountains above the clouds. This is called a temperature inversion. If the base of the stratus is not even and has ragged patches, this means that the condensation forms above humid patches, non-uniformly. However, above the stratus, the temperature is warmer. Up there, at a fixed altitude, the prevailing temperature is homogeneous and above the dew point. The water is transformed back into vapor, which is taken up by the surrounding air.

During sunny and warm enough days, stratus clouds will dissipate over the course of the day.

HYDROMETEORS

Frost can be fatal to airplane. The video below shows a news report with more information on this subject:

http://www.ina.fr/video/3922392001036

ina.fr, *Crash de l'airbus A330 : la piste du givre*

Here is another documentary about the weather and aviation (~ 45 min). It highlights the process of scientific research and the application of its results to practical life:

http://www.youtube.com/watch?v=_qWkd5Wr20c

Arte, *Orage et sécurité aéronautique*

LIGHTNING

The student worksheet does not address the cause of the accumulation of negative or positive charges in different areas of the cloud. Current research proposes several conflicting theories. The oldest one focuses on the collisions between ice particles and water droplets within the cloud. The former are charged negatively. The latter, which are charged positively, are carried to the top of the cloud by convection. Whatever the origin of the separation of charges, it is certain that the origin of the electric potential energy stored in the atmosphere comes from the sun's energy.

Here is a link to a video with safety instructions to follow during thunderstorms:

http://www.wat.tv/video/voiture-sol-plastique-voici-6d8qp_2i6xp_.html

Wat, *Voiture, sol, plastique... Voici comment se protéger des orages*

To further develop this theme, the concept of static electricity can be addressed. School science rooms are usually well equipped to study this subject. Here is an opportunity to use it!

Here is a link to a video showing an experiment with the Faraday cage:

http://video.mit.edu/watch/faradays-cage-3625/

MIT video, *Faraday's Cage*

It is also possible to tell students about Benjamin Franklin's research on lightning and his invention, the lightning rod:

http://www.rtbf.be/lapremiere/article_invention-le-paratonnerre?id=7396773

rtbf, *Invention : le paratonnerre*

Bibliography

A comprehensive and illustrated book that lists the different types of clouds:
Richard Hamblyn, *Nuages : le guide d'identification*, Delachaud et Niestlé

An extensive general guide:
Pierre Kohler, *Comprendre la météorologie*, Hachette

ALL THIS IN NUMBERS...

Exercise 1

a) A lapse of 1 second corresponds to a distance of: $1:3 = 0.\bar{3}\,\text{km}$
The distance corresponding to an eight second gap is: $0.\bar{3} \cdot 8 = 2.\bar{6}\,\text{km}$

b) Since each km is equivalent to a 3 second gap, it will be: $3 \cdot 7 = 21$ seconds

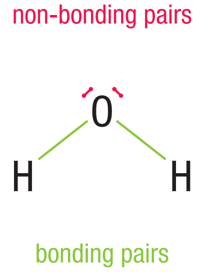
Exercise 2

Students should note the symmetry of the crystals and see that they are hexagonal.

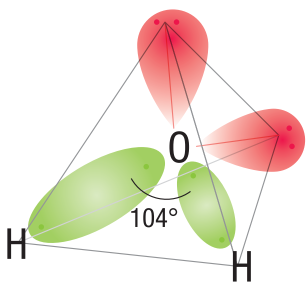
The beginning of the observation of crystal dates back to Kepler (1571-1630). He wrote a treatise called "nix sexangula." He noted their hexagonal symmetry. This research was pursued by Descartes, and then by Hooke, who published drawings of his observations through his microscope. But the work of Wilson Bentley deserves a special mention. At the beginning of the photography era in 1885, he came up with a device that allowed him to take photographs of snowflakes. He took pictures of more than 5,000 snowflakes, including the ones depicted in this exercise.

Today, scientists can grow ice crystals in the laboratory. This allows them to test the factors that lead to their shapes. This helps them to better predict how crystals agglomerate, transform and eventually form snow layers that, for instance, can provoke avalanches.

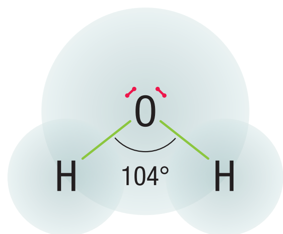
By using the Lewis formula and the geometry of a water molecule, it is possible to understand how water crystallizes in a hexagonal structure. The Lewis structure consists in representing the location of the atom's outermost electrons – its valence electrons – on top of or between the molecule's atoms. In this representation, unpaired electrons are denoted by dots and shared pairs are denoted by lines. The pairs may be localized on an atom, as lone pairs or non-bonding pairs, or between atoms, as bonding pairs that form covalent bonds. Water (H_2O) is composed of an oxygen atom bonded to two hydrogen atoms.



Here, oxygen is surrounded by four electron pairs: two bonding pairs and two non-bonding pairs. Since electrons repel each other, they will try to remain as far as possible from each other. This is why they are arranged like the vertices of a tetrahedron with the oxygen atom in the center. This is also why the water molecule forms a 104° "elbow."



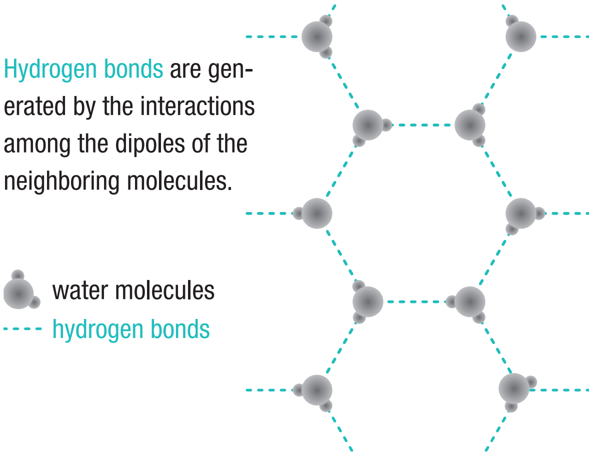
Non-bonding pairs take up more space than bonding pairs , so the angle between the bonds is 104° instead of 109°, which would be the angle at the center of a tetrahedron.



In addition, the bonding pairs are not evenly dis- tributed in the atoms. There is a small negative charge on the oxygen since it attracts more elec- trons. This creates a small positive charge on both hydrogen atoms. The water molecule tus has two opposing charges that are very similar to each other. We say that the molecule has a dipole. This dipole creates electrical forces among nearby water molecules.

For this reason, the molecules assemble into a hexagon when the water crystallizes.

Hydrogen bonds are generated by the interactions among the dipoles of the neighboring molecules.

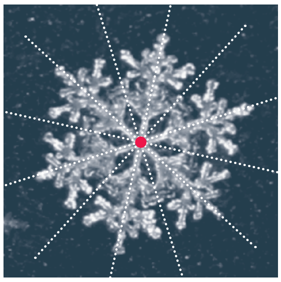


Therefore, snowflakes grow over the base of a hexagon, which generates the six branches. Why are the branches symmetrical? This remains a mystery... A first hypothesis is that they grow under the same pressure and temperature conditions, and thus develop the same shape. A second hypothesis is that their growth could be coordinated by an internal mechanism such as the magnetic field.

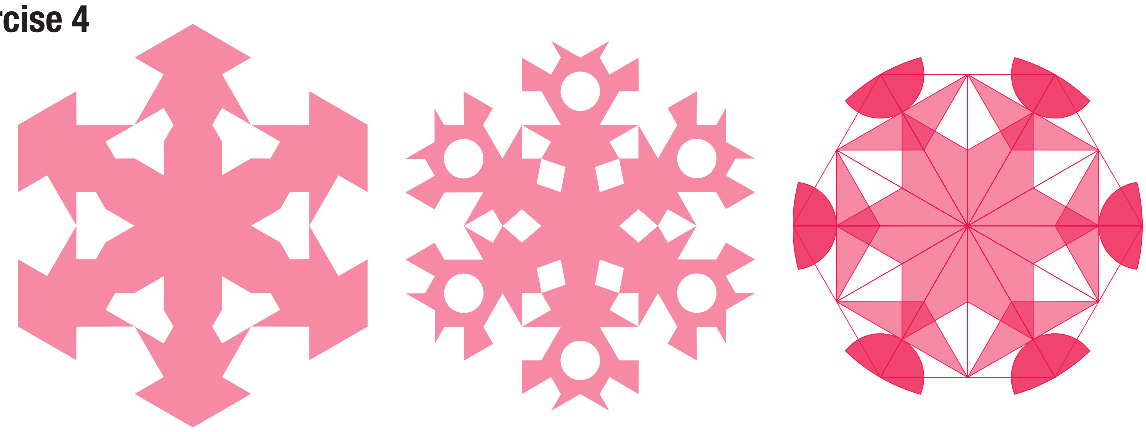
Exercise 3

We can identify three types of isometries on a snowflake (leaving aside its imperfections):

- A central symmetry whose center is the middle of the snowflake •.
- 6 axial symmetries whose axes intersect in the middle of the flake • at 30° angles.
- Rotations, the centers of which are all located in the middle of the flake •. The rotations are of 60° and multiples of 60°.



Exercise 4



Extension: It is possible to draw flakes using a dynamic geometry software. The use of the symmetry elements may allow to simultaneously construct the snowflake's six branches and to remodel it at will.

Exercise 5

In this exercise, the model was simplified as much as possible. When trying to forecast the formation of clouds using a more realistic model, air pressure also has to be taken into account. This varies with passing high- and low-pressure areas, but also with the altitude. The curve shown here is valid at constant pressure.

a) When reading the graph, we can see that there is approximately 8 g of water in 1 kg of dry air at 30 °C when the relative humidity is 30 %.
Therefore, there will be $8 \cdot 5 = 40\,\text{g}$ of water in 5 kg of air.

b) According to the graph, the temperature is below 21°C.

c) In Malaysia, there are about 26 g of water per kg of air.
During the day, the relative humidity was about 45 %.
During the night, for the same absolute humidity, we pass below the dew point if the temperature drops below 13 °C.

d) According to the graph, the dew point is reached at a temperature of 10 °C and a humidity of 70 %. Consequently, it is necessary to ascend 500 m for the temperature to drop 5 °C and to reach the stratus.

TO EXPLORE FURTHER…

Exercise 6

x represents the distance between the lightning and the observer corresponding to a 3 second gap between the observation of the lightning flash and the thunder.

$$\frac{x}{340} - \frac{x}{299{,}792{,}460} = 3 \qquad \Big| \cdot 5{,}096{,}471{,}820$$

$$14{,}989{,}623\,x - 17\,x = 15{,}289{,}415{,}460$$

$$14{,}989{,}606\,x = 15{,}289{,}415{,}460 \qquad \Big| : 14{,}989{,}606$$

$$x = 1{,}020\text{ m}$$

That is why we obtain a very good approximation of the distance to the lightning in km by dividing the number of seconds between the lightning and the thunder by three.

Exercice 7

The volume of air in the bathroom is: $2.5 \cdot 3 \cdot 2.5 = 18.75\,\mathrm{m3}$
The corresponding air mass is: $\rho \cdot V = 1.17 \cdot 18.75 \approx 21.94\,\mathrm{kg}$
The fact that there is steam on the bathroom mirror means that we reached the dew point and that the relative humidity is 100 %.
According to the graph in Exercise 5, there are about 20 g of water per kg of air.
Therefore, there are $21.94 \cdot 20 \approx 440\,\mathrm{g}$ of steam in the air contained in the room.

RECREATIONAL ACTIVITY

This activity includes a research phase. Students have to determine the proper way to fold a piece of paper to give their snowflakes a hexagonal symmetry. An efficient way to do this is to fold the paper in half and then fold it in three as shown below. The outer folds form an angle of 60°. Then fold it in half again. Cut away the edges to keep only the part with twelve layers of paper.

With that, the students have free rein to express their creativity!

To simplify the activity, the teacher can show students how to do the folding.

To complicate the exercise, the teacher can give students a snowflake pattern and ask them to reproduce it. The students can observe and measure the unfolded model.