



Kingdom of Cambodia
Nation - Religion - King

Low-Cost Experiments for Earth and Environmental Science Education

Part 1: Astronomy

Part 2: Weather and Climate



Part 1: Astronomy
Part 2: Weather and Climate

Published by the Ministry of Education, Youth and Sport of the Kingdom of Cambodia

Printed in Cambodia, 2013 (First edition)

The development and publication of this document has been funded by the General Directorate for Development Cooperation and Humanitarian Aid (DGD) with technical support from the Flemish Association for Development Cooperation and Technical Assistance (VVOB). The Flemish and the Belgian governments cannot be held responsible for the content of this publication.

Copyright Notice

Unless otherwise noted in the materials excluded and rights reserved list below, material in this publication is licensed under a Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported License. This means that you may distribute, copy, remix and build upon this work non-commercially without prior permission of the publisher, as long as you credit and license your new creations under identical terms. More information on this license is available at <http://creativecommons.org/licenses/by-nc-sa/3.0/>

Material excluded and rights reserved

Some material in this publication is not being made available under the terms of this license. These are Third-Party materials that are being used under fair use or with permission. The publisher will not be liable on any legal basis (including negligence) for any loss or damage suffered through the use of Third-Party material.

Prologue

The main objective of this manual is to enable science teacher trainers and teachers to introduce practical activities to their students, thus improving their critical thinking and problem solving skills. All experiments are designed with low-cost materials that are easy to find in Cambodia.

This manual is complementary with other learning materials developed by the Ministry of Education, Youth and Sport, in cooperation with VVOB. These include short videos of the experiments in the manual, a manual on student centred approaches for science education, science posters and various multimedia to support the teaching of earth & environmental science.

To ensure an effective use of the experiments in this manual, we suggest the following:

1. Prepare all materials for the experiment before the start of the lesson.
2. Allow students to think, predict, observe and explain during the practical activity. In this way, you will get the most out of the practical activity and students will grow familiar with the scientific method.
3. Allow as much as possible hands-on time for students.
4. Revise student understanding after doing the experiment and adjust your lesson plan if necessary.

The Ministry of Education, Youth and Sport would like to express sincere thanks to the authors, technical assistants of VVOB, EEQP and Open Institute for their effort in producing these materials.

The Ministry hopes that you all will make the best use of the materials to improve the quality of science education.

Phnom Penh, 21 September 2012

H.E. Nath Bunroeun
Secretary of State, Ministry of Education, Youth and Sport

Preface

This manual was developed by the Ministry of Education, Youth and Sport, in cooperation with VVOB.

Its objective is to improve science teacher training by introducing student centred approaches in lessons. This manual consists of a set of science experiments that will help students to understand the main concepts outlined in the RTTC curriculum. All experiments have been tested by teacher trainers and teachers.

Complementary to the manual is a set of DVDs with short movie clips of all experiments in order to help teacher trainers with integrating experiments in their lessons. For each experiment we include a set of objectives, a link to the relevant lesson in the curriculum, the material needed to do the experiment, a detailed description of the procedure, observations, an explanation and additional questions. Where appropriate we add ideas for variations.

We are convinced that this manual will contribute to an improvement of science education in Cambodia. However, do not hesitate to send us your comments and suggestions.

We are looking forward to receiving your comments. We wish you an inspiring experience and many satisfying science lessons with this manual.

The authors

Manual Development Committee

Management Committee

H.E. Im Sethy	Minister, Ministry of Education, Youth and Sport
H.E. Nath Bunroeun	Secretary of state, Ministry of Education, Youth and Sport

Approval Committee

Mr. Leang Seng Hak	Director, Teacher Training Department
Mr. Eng Kimly	Director, Department of Curriculum Development
Mr. Eung Ngor Hok	Director, General Secondary Education Department

Committee of Authors

Mr. Oeur Sokmeng	Vice-director, RTTC Kandal
Mrs. Srey Chansophea	E&ES Teacher Trainer, RTTC Kandal
Ms. Veng Sreymon	E&ES Teacher Trainer, RTTC Kandal
Mrs. Pen Raksmeay	E&ES Teacher, Hun Sen Sereypheap High School
Mr. Phan Ny	E&ES Teacher, Aknuwat Lower Secondary School
Mrs. Phon Socheat	E&ES Teacher, Hun Sen Takhmao High School
Ms. Tim Bunthen	E&ES Teacher, Hun Sen Kampong Kantuot High School
Mr. Keo Mono	Technical Advisor/Facilitator, VVOB
Mr. Philippe Mollet	Technical Expert, Mira Observatory, Grimbergen, Belgium
Mr. Stefaan Vande Walle	SEAL Programme Coordinator, RTTC Kandal

Editorial Committee

Mrs. Sambath Eath	Officer, Teacher Training Department
Mr. Sok Vuthy	Officer, Department of Curriculum Development
Mr. Sin Vath	Officer, Teacher Training Department
Mrs. Nareth Polyvine	Officer, General Secondary Education Department

Technical Advisor

Mr. Chea Phon	Vice-director, Teacher Training Department
---------------	--

Low-Cost Experiments for Earth & Environmental Science Education

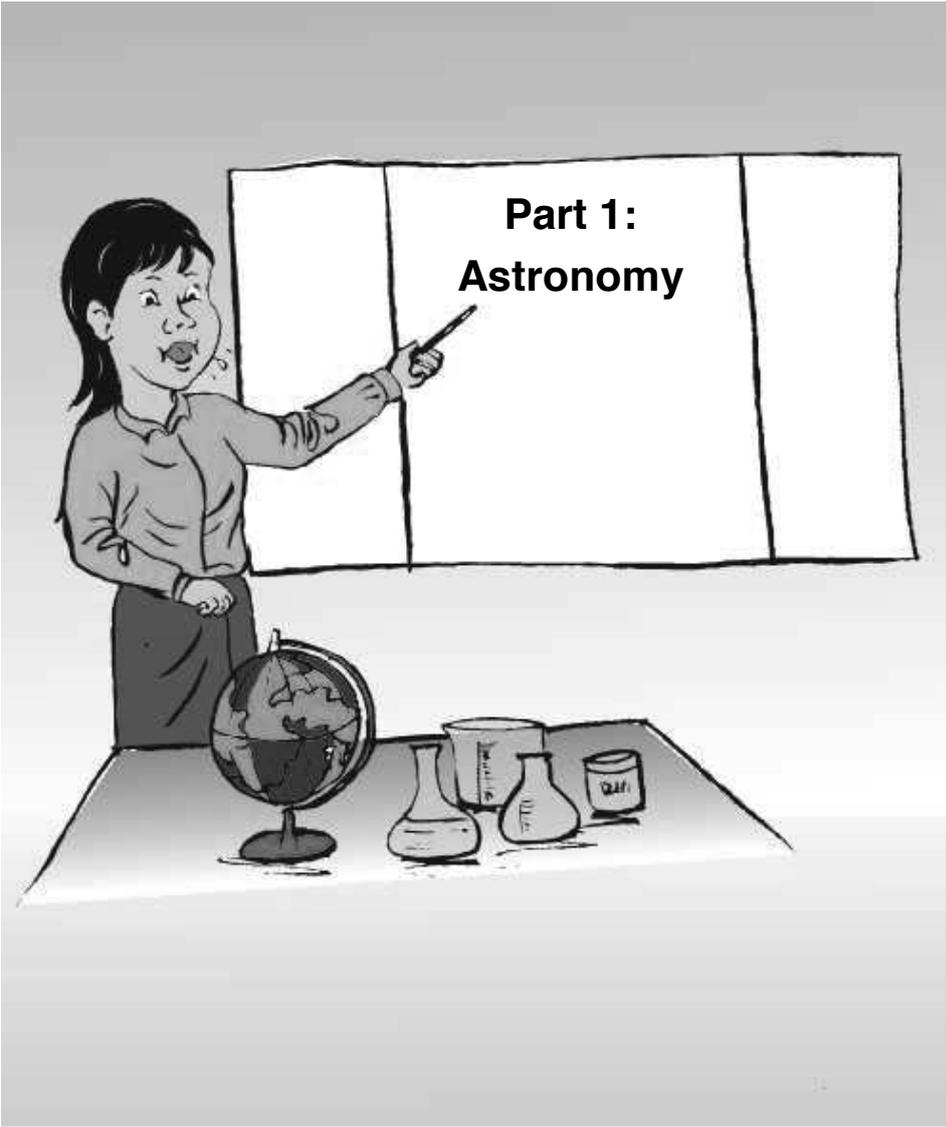
Part 1: Astronomy

Part 2: Weather and Climate

Table of Contents

PROLOGUE	3
PREFACE	4
MANUAL DEVELOPMENT COMMITTEE	5
<i>Management Committee</i>	5
<i>Approval Committee</i>	5
<i>Committee of Authors</i>	5
<i>Editorial Committee</i>	5
<i>Technical Advisor</i>	5
LOW-COST EXPERIMENTS FOR EARTH & ENVIRONMENTAL SCIENCE EDUCATION.....	6
PART 1: ASTRONOMY	6
PART 2: WEATHER AND CLIMATE	6
TABLE OF CONTENTS	7
1. <i>Making a sundial</i>	10
2. <i>Summer Solstice activity</i>	14
<i>Part 1: Observing and recording the daily movement of the Sun</i>	14
<i>Part 2: Calculating the Sun’s Angle</i>	17
3. <i>Tracing the path of the Sun</i>	21
4. <i>Craters on the Moon</i>	23
5. <i>Making an observation chart of the night sky</i>	26
6. <i>Analysing Light with Spectroscopes</i>	32
7. <i>Building a Comet</i>	38
8. <i>Constructing & Demonstrating a Solar System Scale Model</i>	43
9. <i>Observing the Sun with Sunspotter telescopes</i>	49
10. <i>How does a telescope work?</i>	52
INTRODUCTION	60
MAIN CONCEPTS	60
ACTIVITIES ON HEAT ENERGY AND GREENHOUSE EFFECT	63
1. <i>How does the Greenhouse Effect work?</i>	63
2. <i>Why is it hotter at the equator than at the poles?</i>	67
3. <i>Diffusion of heat energy</i>	70
ACTIVITIES ON AIR PRESSURE, DENSITY AND DIFFERENTIAL HEATING	72
4. <i>Effect of colour on temperature</i>	72
5. <i>Effect of material on temperature</i>	76
6. <i>Atmospheric Pressure (1)</i>	81
7. <i>Atmospheric Pressure (2)</i>	83
8. <i>Atmospheric Pressure: Falling Parachutes</i>	86
9. <i>Effect of Heating and Cooling Air on Air Pressure (1)</i>	88
10. <i>Effect of Heating and Cooling Air on Air Pressure (2)</i>	90
11. <i>Effect of Heating and Cooling Air on Air Pressure (3)</i>	92
12. <i>Effect of Heating and Cooling Air on Air Pressure (4)</i>	94
13. <i>Effect of Heating and Cooling Air on Air Pressure (5)</i>	97
14. <i>Functioning of a Barometer</i>	100
ACTIVITIES ON AIR PRESSURE, LOCAL AND GLOBAL WIND SYSTEMS.....	102

15.	<i>Rotating mobile</i>	102
16.	<i>Wind model</i>	104
17.	<i>The Coriolis Effect</i>	106
ACTIVITIES ON CONVECTION AND CURRENTS		109
18.	<i>Experiment on Air Inversion</i>	109
ACTIVITIES ON HUMIDITY AND CLOUDS		113
19.	<i>Evaporation and Condensation</i>	113
20.	<i>Measuring Relative Humidity</i>	115
21.	<i>Constructing a Hygrometer</i>	118
22.	<i>Formation of Clouds (1)</i>	120
23.	<i>Formation of Clouds (2)</i>	122
ACTIVITIES ON OTHER WEATHER PHENOMENA		124
24.	<i>Scattering of light and the blue sky</i>	124
REFERENCES		128



1. Making a sundial

Objectives



- Students can make a simple functional sundial.
- Students can explain the relationship between the Earth's rotation and the movement of the gnomon's shadow.
- Students are stimulated to use their creativity to develop experiments with local materials.

Link to curriculum



Grade 7, chapter 1, lesson 2 (2009)

Grade 7, chapter 2, lesson 1&2 (2009)

Material

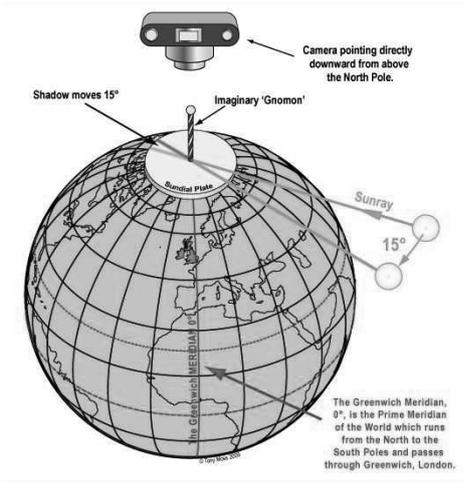


- a large nail (approximately 20 centimetres long)
- a piece of wood (20 centimetres by 20 centimetres)
- another piece of craft wood to serve as a wedge
- three brass screws
- wood glue
- a compass
- a protractor
- a black marker

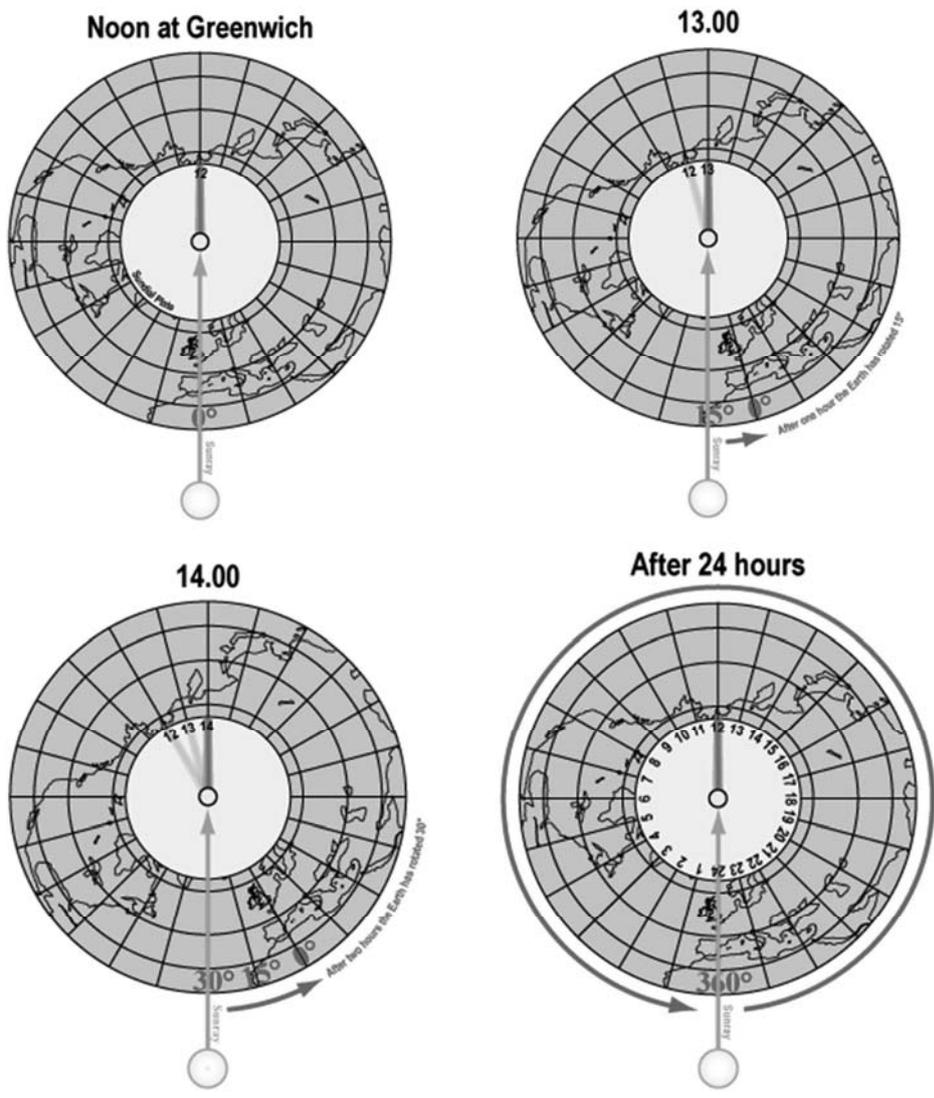
Procedure

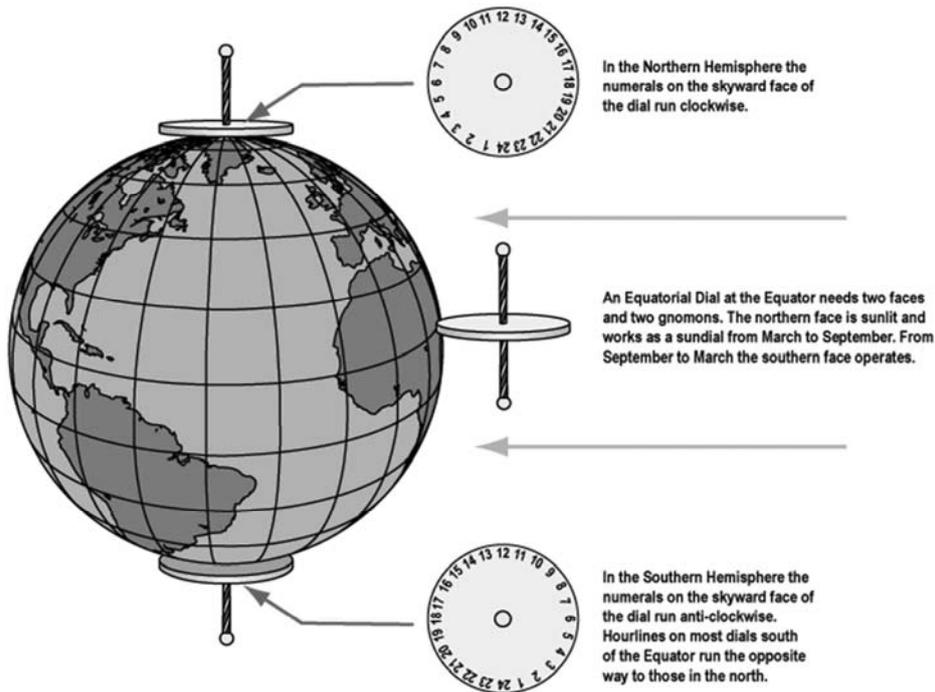


1. Using the marker and the protractor, mark out the design shown in the picture above. The angle between each hour should be 15 degrees. The line representing six o'clock is parallel to the top of the board and approximately two centimetres down.
2. Hammer the nail partially into the craft wood or drill a hole and glue in the piece of dowel.
3. Attach a wedge, using screws and glue, to tilt the sundial at the required angle away from the vertical – use the table below to determine your latitude. Latitude is a measure of your location, in degrees, north or south of the Equator. For example, a sundial built for Canberra (35 degrees south of the equator) is tilted 35 degrees from the vertical, or 55 degrees from the ground.
4. Using the compass, place the sundial in the sunlight with the '12' facing south (or north if you are in the Northern Hemisphere).
5. The shadow of the nail or dowel will tell you the time.

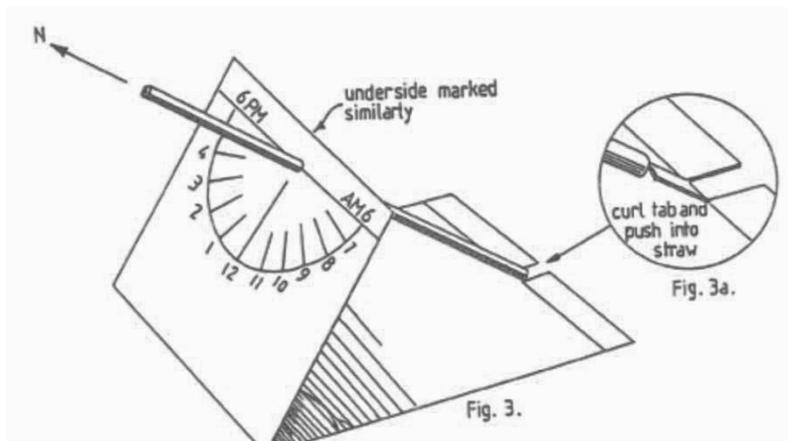


Source: The British Sundial Society





Source: The British Sundial Society



Source: The British Sundial Society

Explanation



From the earliest times people have regulated their lives by the apparent motions of the Sun and the shadows cast by its rays. We say 'apparent' because of course it is the rotation of the Earth on its axis which causes the moving shadows we observe every day. When the Earth rotates 15° it is just as though the Sun had moved 15° around its daily track.

Perhaps the best place to begin an understanding of how sundials work would be to imagine a pictorial view of the Earth at the North Pole. In this diagram it is the Sun which seems to move at 15° every hour. The shadow-casting element of a sundial is usually called the 'gnomon'.

Conclusion



A sundial allows us to measure the 'apparent' movement of the Sun. The movement is apparent because it is the rotation of the Earth which causes the moving shadows. When the Earth rotates 15° it is just as though the Sun has moved 15° around its daily track.

2. Summer Solstice activity

Part 1: Observing and recording the daily movement of the Sun

Objectives



- Students can determine and record the movement of the Sun during the solstice.
- Students can explain why the daily movement of the Sun is different each day.
- Students can explain why the daily movement patterns stays at the northern/southern side of the pin.
- Students improve their observation and data recording skills.

Link with curriculum



Grade 10, Chapter 4, Lesson 1 (2010)

Material

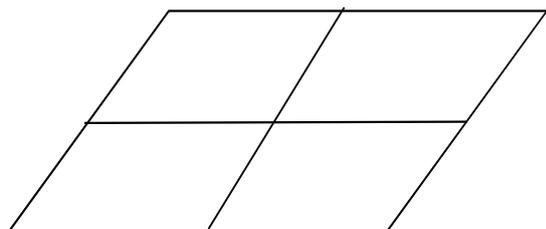


- Pin
- A4 paper box cover
- compass
- A4 paper
- ruler
- Scotch tape

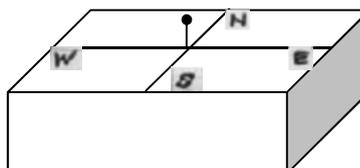
Procedure



1. On an A4 paper, draw a line connecting the middle points of the two widths and another line connecting those of the two lengths.



2. Stick the A4 paper to the back of box cover using clear sticky tape.
3. Stick the pin to the meeting point of the previous two lines to an exact measured depth and ensure that the depth does not vary for the whole experiment. If the height of the pin is not fixed, the result of shadow's measurement will not be valid.
4. By using a compass, mark N (North), S (South), E (East), W (West) on the four middle points of the A4 paper's sides.



5. Place this material in an open space with enough sunlight with N pointing to the North according to the compass.
6. Every set time period (e.g. every hour or every 10 minutes), mark the shadow of the pin and take note of the time for each measurement.

Explanation

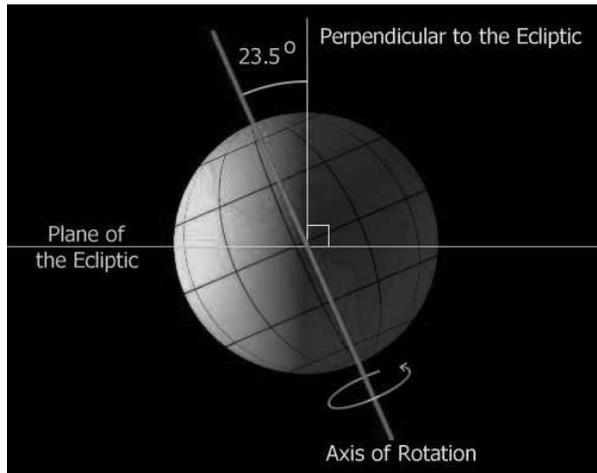


As day and night go by, we can see the Sun rise from the East and set into the West. This apparent movement of the Sun is actually caused by the rotation of the Earth. Does the Sun appear to describe the same path in the sky every day?

Conclusion



All year long, the Sun keeps changing her path between Northern hemisphere and Southern hemisphere. We are doing the above experiment in June in Cambodia. As a result, all the shadows of the pin fall on Southern part of the paper meaning the Sun is moving on the Northern hemisphere. If we repeat this experiment in December in Cambodia, the shadows are going to fall on the Northern part of the paper instead. This is the basis to prove that the Sun does appear to move on different paths during different times of the year.



Source: startswithabang.com

Questions



1. From the observation, shadows of the pin stay only on the Southern or (Northern) part of the paper. What is a possible explanation for this observation?
2. When is the shadow the shortest?
3. Why does the length vary from one shadow to another with time?

Part 2: Calculating the Sun's Angle

Objectives



- Students calculate the angle made by the Sun's rays and the Earth's surface using observations and a tangent table.
- Students can make accurate observations;
- Students know how to verify empirical results with the theoretical calculation of the Sun's angle, given the latitude of the location.
- Students can explain why this experiment is best done during a solstice or equinox.



Link with curriculum



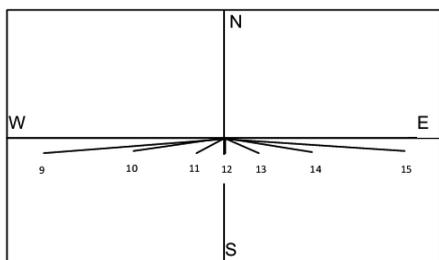
Grade 10, Chapter 4, Lesson 1 (2010)

Material



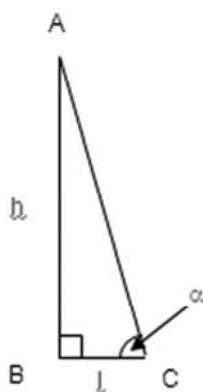
- A4 paper worksheet from experiment "Observing and Recording the Daily Movements of the Sun"
- Ruler
- Protractor
- Tangent table
- Scientific calculator

Procedure



1. On the experiment worksheet, 5 shadows were drawn at 9 a.m., 10 a.m., 11 a.m., 12 a.m., 1 p.m., 2 p.m. and 3 p.m. respectively. Around 12 am measure every 10 minutes, e.g. at 11.30 am, 11.40 am, 11.50 am etc. to determine the shortest length of the shadow with more detail. The shortest length does not necessarily occur at 12.00 am exactly. You can let student teachers discuss why this is the case (*To ease communication, the Earth's surface is distributed into time zones, each with the same time. As a consequence, the Sun does not reach its highest point exactly at 12.00 am everywhere within the time zone. At some places it will be a bit before 12.00 am and at other places it will be a bit later than 12.00 am*).
2. The shortest shadow is the one drawn at 12 a.m. Measure the length of this shadow (l).
3. Using the height of the pin (h) and the length of the shortest shadow (l), draw a right triangle like the one shown below. In the triangle:
 - $[AB] = h$ represents the height of the pin
 - $[BC] = l$ represents the length of the shortest shadow
 - $[AC]$ represents the ray of the Sun on surface of the earth
 - α = the angle made by one of the Sun's rays on flat surface of the earth
4. With the formula **Tan α : h / l** and the tangent table we can find the value of the angle.

Sun 



Tan α : h / l

Where h is the height of the right triangle, representing the needle
 l represents the shortest shadow of the needle

Explanation



From the previous experiment we know that the Sun does not appear to move on the same path throughout the year. At a particular time of the year, the Sun is at a perpendicular position on one particular spot on earth. In other words, the Sun's rays fall at a right angle to the Earth's surface at that particular spot. Meanwhile, the rays fall at an angle with surface of other spots on earth. How can we calculate those angles? This experiment learns how to calculate these angles.

Questions



1. Why do we need to use the shortest shadow?
2. Why is a solstice the best time to do this experiment?
3. Can we also conduct this experiment without solstice or equinox phenomena?

Conclusion



The angle of the Sun can be calculated both from observations as from theory. This offers students the chance to verify their data. Through this experiment, the path of the Sun is over the Northern hemisphere. From calculation of the angle made by the Sun's rays and the shortest shadow of the pin during a solstice, we can figure out the height of the Sun when it is almost at perpendicular position to the Earth's surface using the Tangent table and the formula stated above.

Table of Angles and their Tangents							
Angle	Tangent		Angle	Tangent		Angle	Tangent
0	0.0000		30	0.5773		60	1.7317
1	0.0175		31	0.6008		61	1.8037
2	0.0349		32	0.6248		62	1.8804
3	0.0524	°	33	0.6493	°	63	1.9622
4	0.0699	°	34	0.6744	°	64	2.0499
5	0.0875		35	0.7001		65	2.1440
6	0.1051		36	0.7265		66	2.2455
7	0.1228		37	0.7535		67	2.3553

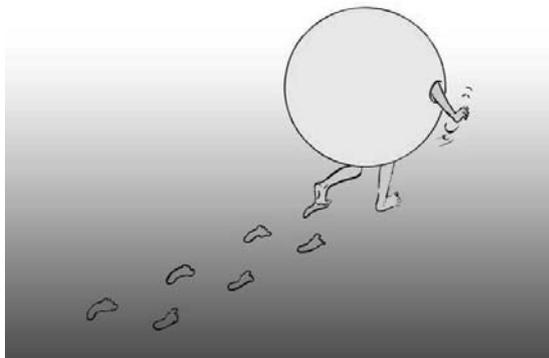
8	0.1405	38	0.7812	68	2.4745	
9	0.1584	39	0.8097	69	2.6044	
10	0.1763	40	0.8390	70	2.7467	
11	0.1944	41	0.8692	71	2.9033	
12	0.2125	42	0.9003	72	3.0767	
13	0.2309	43	0.9324	73	3.2698	
14	0.2493	44	0.9656	74	3.4862	
15	0.2679	45	1.0000	75	3.7306	
16	0.2867	46	1.0354	76	4.0091	
17	0.3057	47	1.0722	77	4.3295	
18	0.3249	48	1.1105	78	4.7023	
19	0.3443	49	1.1502	79	5.1418	
20	0.3639	50	1.1916	80	5.6679	
21	0.3838	51	1.2347	81	6.3095	
22	0.4040	52	1.2798	82	7.1099	
23	0.4244	53	1.3269	83	8.1372	
24	0.4452	54	1.3762	84	9.5045	
25	0.4663	55	1.4279	85	11.4157	
26	0.4877	56	1.4823	86	14.2780	
27	0.5095	57	1.5396	87	19.0404	
28	0.5317	58	1.6001	88	28.5437	
29	0.5543	59	1.6640	89	56.9168	

3. Tracing the path of the Sun

Objectives



- Students identify and mark the path of the Sun over the period of one year.
- Students strengthen observation and data collection skills.
- Students can explain the reason why the movement of the Sun appears to change everyday.



Link to curriculum



Grade 7, chapter 2, lesson 1&2 (2009)

Material



- a flat surface clear of shadows
- a pole or similar (school flagpole). The longer the clearer the measurements.
- rocks (or similar markers)
- a spirit level or plumb line

Procedure



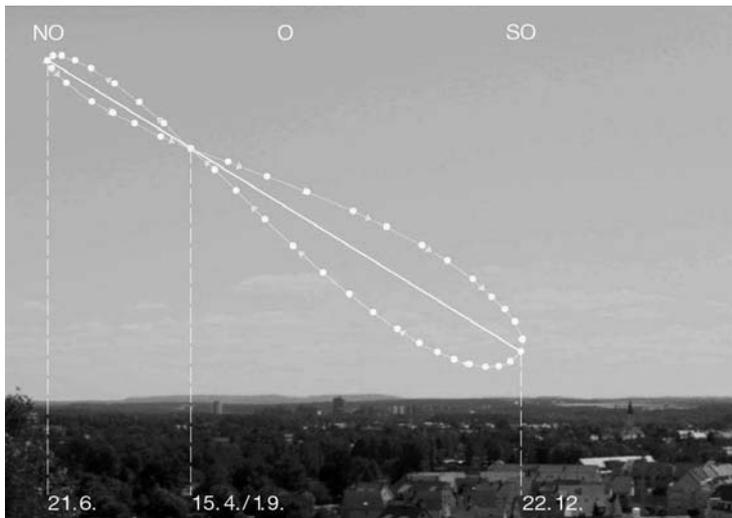
1. Place the pole in the ground, leaving at least 50 centimetres above ground. Using the spirit level or plumb line ensure that the pole is upright and that it will remain fixed and immobile for a year.
2. Every few days, at the same time of day use a rock or tent peg to mark where the tip of the shadow falls.
3. Keep in mind that these marks have to last for an entire year.
4. After a year, join the dots to trace out a figure of eight shape.

Observation



Over the course of a year you will discover that the shadow of the Sun doesn't just move up and down along the ground, but also from side to side, tracing out a figure eight.

This shape is called an analemma, and it's been known to astronomers and geographers for centuries.



Source: Wikimedia Commons

Explanation



The closer a satellite is to the object it orbits, the faster it needs to go. The orbit of the Earth around the Sun is not a perfect circle; it's an ellipse. At times it is close to the Sun and must go faster, when it is further away it goes slower. This causes the Sun to appear 16.4 minutes ahead of our clocks at the end of October, and 14.2 minutes behind them in February.

This fast and slow movement causes the shadow to move in the east-west direction, while the tilt of the Earth's axis, coupled with its orbit around the Sun, causes the shadow to move in a north-south direction.

When these two movements are combined, we see that the Sun traces the figure eight on the ground, provided we plot its position at the same time every day.

Conclusion

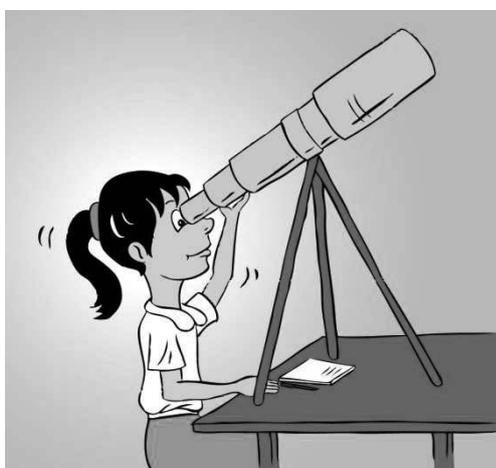


The different speed of the Earth in its orbit around the Sun and the tilt of the Earth's axis make that the Sun's position at the same place at the same time changes little every day. Over the course of a year the Sun describes an eight-formed shape.

4. Craters on the Moon

Objectives

- Students can explain why there are craters on the moon.
- Students can describe the relation between meteor size, meteor speed and crater size.
- Students can explain why nearly all craters are circular.
- Students strengthen their data collection and graph making skills.
- Students can explain why we don't see as many craters on Earth as on the moon.



Link with curriculum

Grade 7, chapter 1, lesson 5 (2009)



Material

- bag of flour
- packet of cocoa
- spoon
- flat tray made of metal or cardboard
- chair
- three different sized spherical objects to use as meteors (orange, golf ball, marbles, etc.)
- newspaper
- ruler
- pencil
- paper



Procedure



a) Testing meteor size

1. Place the flour into the tray. Use the spoon to make it flat. The flour should be about five centimetres deep.
2. Sprinkle some cocoa on top of the flour. The contrast in colour will make it easier to see the craters.
3. Place the tray on the floor on top of some newspaper.
4. Take the smallest 'meteor' and measure and record its diameter in centimetres.
5. Hold the object in front of you at arms' length and drop it into the flour. For accurate results, don't throw your meteor.
6. Remove the object from the flour and look closely at the crater. Measure and record its diameter and any other observations (shape, spread of material around the crater...).
7. Use the spoon to smooth the surface of the flour so it's ready for the next meteor impact.
8. Repeat Steps 4 to 7 for each object from smallest to biggest. It is important to drop each meteor from the same height. Do you notice a pattern?
9. Record your data in a table and make a graph. Discuss what you will put on the X-axis (*size of the meteor*) and the Y-axis (*size of the crater*).

You can use non-spherical objects to see if they make different shaped craters than spherical objects. You could also try using objects of different weights and see what effect they have on the size of the craters. Instead of dropping, you can throw one (smaller) "meteorite" under a very oblique angle (watch out, this will make a great mess, with all the flour and cocoa flying around the place). You'll notice how the crater is still nearly circular!

To get an elongated (elliptical) crater one needs to throw the "meteorite" almost horizontal, "skimming" over the surface. Astronomers have discovered only a few elongated craters on the Moon or Mars. Such "horizontal impacts" by a meteorite can be powerful enough to eject Lunar or Martian material into space, and become meteoroids themselves!

b) Testing meteor speed

1. Dropping an object from a greater height increases its speed. Begin with the smallest meteor. Holding your arm as high as you can, drop it into the flour. Measure and record the size of the crater. Use the spoon to smooth the surface of the flour.
2. Repeat Step 1. This time, use a chair to increase your height and drop the same meteor into the tray. For your own safety, have someone hold the chair steady.
3. Repeat Steps 1 and 2 for each meteor. What's the relationship between the speed of the meteor and the size of the crater? Again, record your data in a table and create a graph. Discuss what you will put on the X-axis (*height of the meteor*) and the Y-axis (*size of the crater*).

Observations



The bigger the object and the faster it travels, the bigger the crater.

Explanation



Look carefully at the moon with a telescope, and you will see that its surface is covered with different sized holes known as impact craters. These have been caused by asteroids or comets smashing into the moon's surface.

Solid matter from space that enters the Earth's atmosphere is called a meteor. If it hits the Earth's surface, it is called a meteorite. Scientists can learn a lot about a meteor by studying the crater it left behind. They can find out what it was made of, how fast it was travelling, how big and heavy it was, and how long ago it happened.

In this activity, you can explore how the size and speed of a meteor influences the crater it makes upon impact.

Conclusion



The size and speed of a meteor determines the size of its impact crater. This is because bigger and faster meteors release more energy when they collide with another body, mostly in the form of kinetic (moving) energy. Other factors, such as the weight of the meteor, what it's made of, the angle of its landing and the type of surface it hits will also determine the shape and size of an impact crater.

Earth, like other solid planets, has its own impact craters. We have an atmosphere and geological events such as volcanoes and earthquakes, so most craters become hidden or disappear over time. The moon has no atmosphere or tectonic activity, which means that the craters remain unchanged over a longer time than on Earth.



Source: www.nasa.gov

5. Making an observation chart of the night sky

Objectives

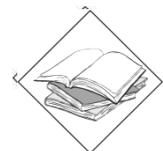
- Students can explain why we don't see the same stars and constellations throughout the year.
- Students can make and use a simple star chart.
- Students can identify some common constellations in the night sky.
- Students learn to appreciate the night sky.



Link with curriculum

Grade 10, chapter 4, lesson 3 (2010)

Grade 12, chapter 3, lesson 2 (2011)



Material needed

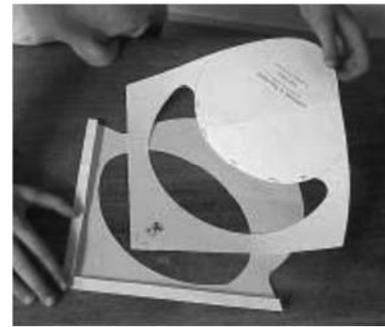
- A3 sized pocket and wheel worksheets
- Scotch tape
- Scissors
- Glue



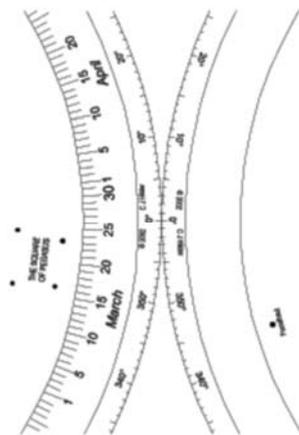
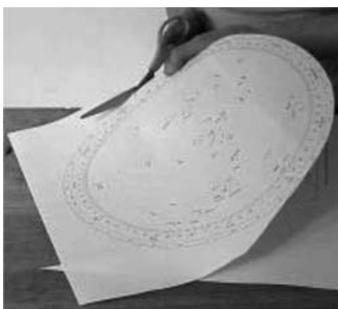
Procedure



- Provide students with photocopies of the pocket (2 copies) and the star charts (2 copies).
- Cut the pocket. Cut slowly and carefully, keeping to the lines.
- After you have cut around the edge, fold the paper without creasing and give it a single snip with the scissors to make a hole in the window. This lets you get your scissors into the window without crumpling the paper.
- Cut the window out.
- Fold the tabs on the pocket back accurately.
- Insert the back of the pocket under the tabs...
- Insert the back and tape it into place with scotch tape.



- Cut out both wheels. Cut slowly and carefully, keeping to the lines.
- Place the two wheels side by side, printed side up. Turn them so that the degree numbers around the edge match at the point where they touch.
- Pick up the two sides of the wheel like this keeping the numbers lined up and put them together, back to back. Now is the time to check that the degree numbers match from front to back. It is not necessary for them to match perfectly; a few degrees out will not make a noticeable difference.
- Peg the two sides together with paper clips, or something similar.



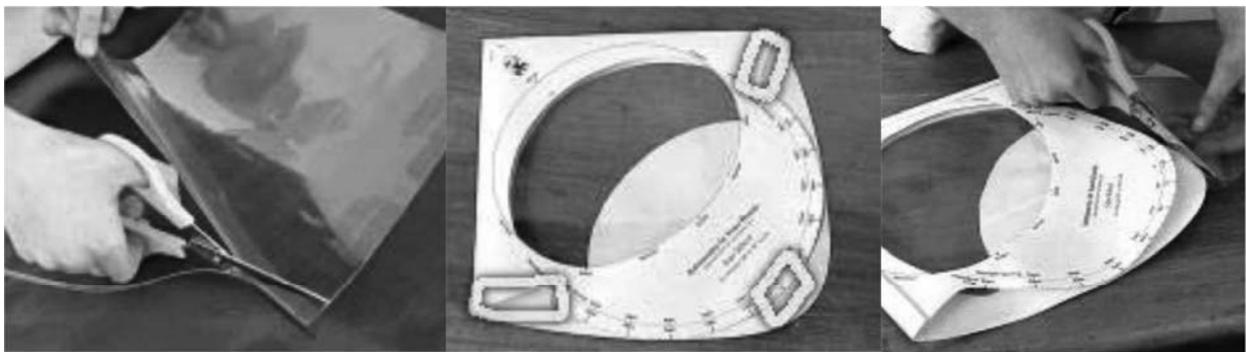
- Glue the two sides together. Apply the glue thinly and evenly.
- Remove the paper clips and gently smooth any wrinkles out of the wheel.
- Let the glue dry before you put it in the pocket, otherwise you will make the pocket sticky.

- Put the wheel in the pocket. Your Star Wheel is now ready to use!

Option: adding a pocket liner

Adding a pocket liner makes the Star Wheel a little easier to use, and makes it a little more durable.

- Examine your L-pocket letter file. There should be a folded edge down one edge, and a seam down the other. Cut the seam off as neatly as possible.
- Now your L-pocket file is open along three sides. Put it into the pocket. Make sure it sits right into the corner of the pocket. Make sure you have put it the right way round so that you can still get the wheel in and out of the pocket.
- Put scotch tape on to keep it in the pocket. The places where you should put tape are highlighted in the middle photo in yellow. You can put tape in more places if you wish.
- Turn the pocket over and put scotch tape on the back too in the same pattern.
- Trim off any excess plastic.



Observation



Following activities can be done as an introduction on how to use the wheel:

- Look at the dates around the edge of the wheel, and the times around the edge of the pocket.
- Put your wheel in its pocket and set your Star Wheel to 10pm. Check that all students can do this.
- Line up today's date with the time.
- Keeping the date lined up with the time, turn the window until the direction you are looking in is at the bottom.
- The bottom part of the window will show you the stars in that direction. Depending on the direction you're looking, you need to flip it to look at the back window.

Explanation



A star wheel is a circular map of the stars. At any given time it shows you what stars you can observe in the sky. Another word for a star wheel is planisphere. It is an ideal tool to teach student teachers to recognize stars and constellations.

Moreover, it not only points the way to the stars, but it helps you understand the mechanics of the night sky, like why we see different stars during the course of a year and why stars rise and set during the night.

1. What Shape is the Sky?

When you look at the blue sky during the day, what shape do you see? Our eyes cannot tell how far away the sky is, so our brains decide that it is all the same distance. This makes it look like the inside of a dome, ball or sphere. When you look at the sky on a clear night, what shape do you see?

Although the stars are all different distances away, our eyes cannot tell this. They all look the same distance to us. So the night sky looks like the inside of a dome, ball or sphere.

There are stars in all directions from the Earth, although we cannot see them all at once. So we think of the stars as forming a starry sphere, known as the celestial sphere. How much of this starry sphere can we see at any one time? We can only see half of it. The half that we can see is called the sky. In a Star Wheel, the wheel is a map of the entire celestial sphere, and the window shows us the part we can actually see at any one time; the sky.

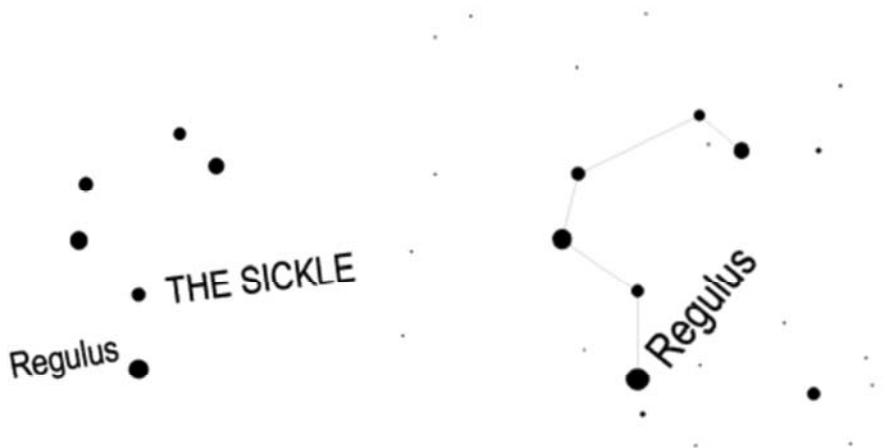
2. The Shape of a Double-sided Star Wheel

The wheel is a double-sided map showing the celestial sphere. When we take a sphere and make a flat map of it, we have to stretch it. The stretching is especially noticeable around the edges of the map. We cannot put the whole sphere on a single map, as it would be stretched beyond recognition at the edges. For this reason we use two maps, one on each side of the wheel. Each covers about three-quarters of the sphere. It is not possible to fit the whole sky into one window, so it is split into two. The two windows have a significant amount of overlap. Taken together the two windows represent the part of the sky that we can see at one time: half of a sphere. The horizon is a line running around the edge of the sky, so the horizon line runs around the edges of the windows. In reality the horizon is circular, but this is distorted by the stretching involved in making a flat map. This explains the unusual shapes of the windows, and why east and west are not exactly opposite each other on the windows' edges. When you put the wheel in the pocket, the windows show the stars visible in that part of the sky at that particular time.

4. Distortion at the Edges

The City Wheel has been stretched unevenly to preserve the shapes of individual constellations at the expense of the spaces between them. This is of great benefit to beginner stargazers as the constellations are shown in the correct part of the sky and the same shape as they appear in the sky. On the right is the actual shape of the Sickle of Leo as it appears on the City wheel. This is exactly as it appears in the sky.

This technique cannot be used for the Milky Way Wheel. The Milky Way wheel shows so many stars that there are not enough empty spaces to adjust in this way. Without adjustment the constellations furthest from the centre look squashed. The illustration on the right shows the Sickle of Leo when it is close to the centre of the Milky Way wheel. It is very little different from its actual appearance in the sky. However, when it is close to the edge of the wheel, as shown here, you can see that it looks quite a different shape to the actual shape in the sky. If you are looking for a constellation that can be seen in both the front and back windows, it is best to use the window in which it can be seen closer to the centre of the wheel.



Sickle of Leo in the sky

Sickle of Leo close to centre



Sickle of Leo far from centre

Conclusion



A star chart can help students learning to identify stars and constellations in the night sky at a given time in Cambodia.

Questions



1. Turn your star wheel so that you can see one complete day and night passing. Which stars and star groups never set? These are the circumpolar stars. List them here.
2. Set your star wheel to 10pm tonight. Name at least two stars or star groups that you can see at 10pm. Do not include the circumpolar stars.
3. Set your star wheel to 4am tomorrow morning. Name at least two stars or star groups that you can see at 4am. Do not include the circumpolar stars, or the night stars.
4. Set your star wheel to 12 noon. To do this, slide it part way out of the pocket to set it, then slide it back in. These are the lunchtime stars. List any lunchtime stars that you have not listed yet. During which month of the year will these stars be up at 10pm?

6. Analysing Light with Spectroscopes

Objectives

- Students can use a simple spectroscope.
- Students can interpret what they observe with a spectroscope.
- Students can explain how light is composed of different colours
- Students can explain how chemical elements absorb and emit at specific wavelengths.



Link with curriculum

Grade 7, chapter 1, lesson 1 (2008) & Grade 7, chapter 2, lesson 3 (2008)
Also suitable for Physics: Grade 12, chapter 5, lesson 2



Material needed

- Spectroscopes (the ones we use are produced by “EnVision Labs” in the USA, www.envisionlabs.com)
- Fluorescent light
- Bulb light
- Bright computer or television screen
- Blue sky, or even better: bright white wall illuminated by the Sun
- Salt and a Bunsen burner



Procedure



The spectroscopes have a triangular shape. The small end has a square viewing hole. The wider end has a small vertical slit (this has to be pointed to the light source) and a wide window with a numbered scale.

While looking through the square whole, point the slit to one of the selected light-sources. On one side, we'll see the brightly lit slit; on the other side, we'll see the colours of the spectrum.

Please try this with all kinds of light-sources, don't limit yourself to the ones described in “Material needed”. Street-lights can be a good choice, but also car-lights, or try to burn different kinds of salt, neon lights, or (carefully) observe a welders flame...



Observations

- When looking at a light bulb, we will see a continuous spectrum (all the colours of the rainbow)
- When looking at the fluorescent light, on top of a fainter continuous spectrum we will see at least three bright coloured lines (violet, green, orange), and maybe a few fainter ones. This is a typical **emission spectrum**.
- When looking at a bright computer screen or television screen, you will see three coloured bands: Red, Green, Blue. It's also an emission spectrum, but with broader bands instead of discrete lines. All the colours of your computer or television screen are made of these three colours!
- When looking at a bright white, sunlit wall (or sunlit clouds in the sky), the view through this simple spectroscope gets a bit more difficult. One will first see a bright, continuous spectrum, but when looking more careful it's possible to see a few dark lines. This is the **absorption spectrum** of the sunlight. The easiest visible lines are in red and between green and blue. Can you distinguish a fainter third line, in the green part of the spectrum?

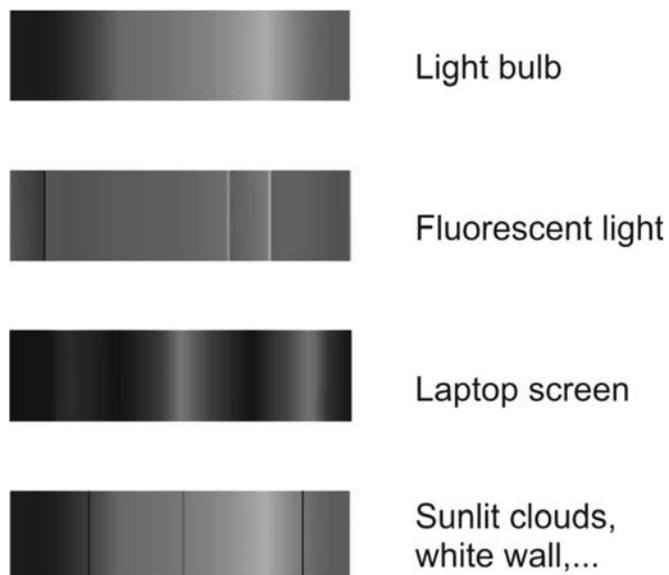




Explanation

All these light sources appear white to the human eye, but their colour-composition differs greatly. The light-bulb (incandescent lamp) is the easiest one: it emits light in all the colours of the rainbow, although not all colours have the same brightness. Some light-bulbs appear more orange: their peak emission lies somewhere in the yellow-orange part of the spectrum.

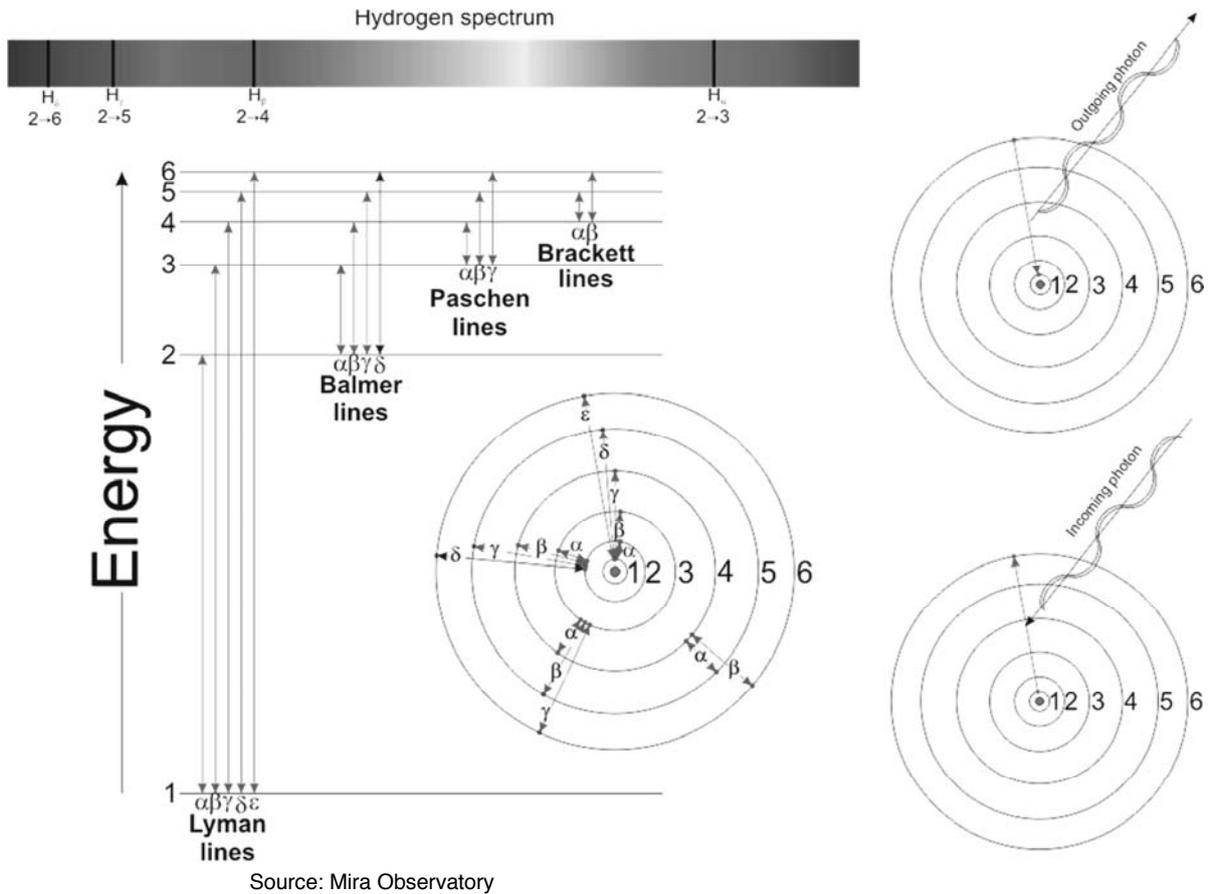
The light from a fluorescent light tube also appears white, but it is made up of only a few discrete colours. The human eye mixes these together and the result appears white.



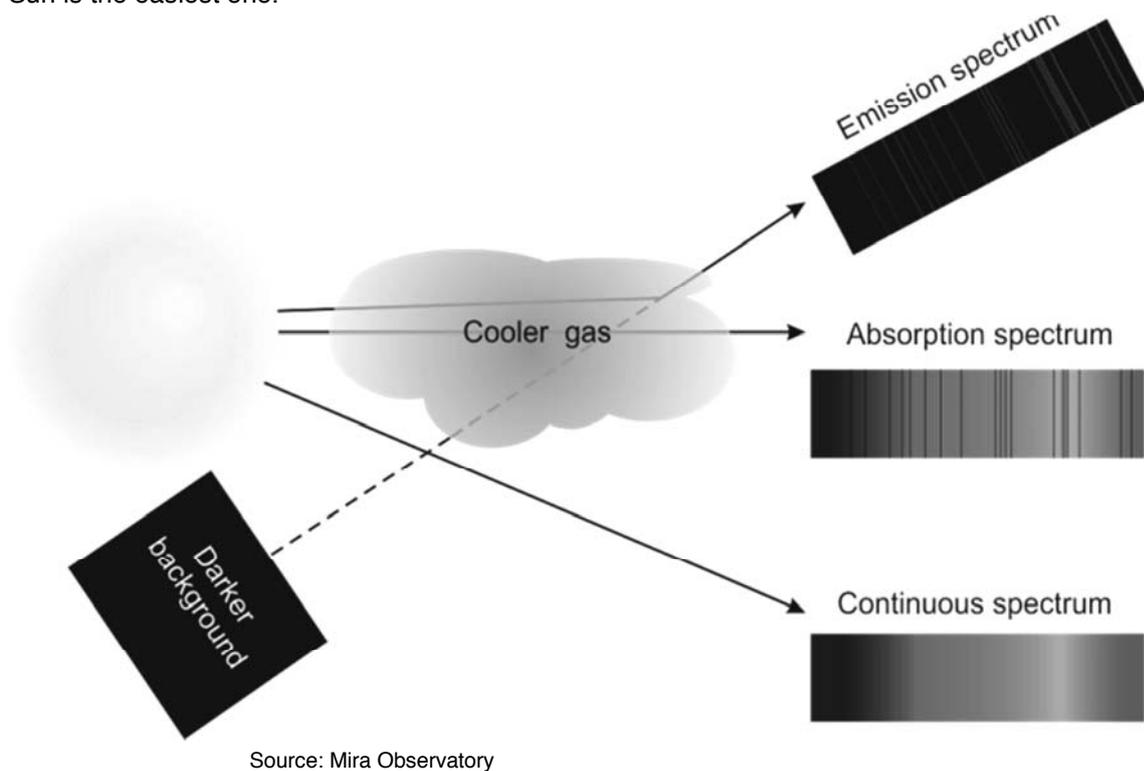
Source: Mira Observatory

Light can be viewed as a wave-phenomenon, different colours relate to different wavelengths (the red ones having longer wavelengths, the blue ones having shorter wavelengths). Inside an atom, electrons can only sit at certain energy-levels. When an electron moves to a higher energy level, it absorbs an exact amount of energy, corresponding with a certain wavelength (colour). So if there are many of these atoms, all light with that wavelength will be absorbed => we get a dark line in the spectrum.

On the contrary, if the electron falls down to a lower energy-level, it will emit a certain amount of energy, corresponding to a certain wavelength (colour). This time, we get a bright line in the spectrum.



When a continuous spectrum (like that coming from the inside of the Sun) passes through a colder gas (like the outside of the Sun), the atoms in that colder gas will absorb certain wavelengths: we will see an absorption spectrum. Those can be seen with every star, but of course the spectrum of the Sun is the easiest one.



Some nebulae in the universe are heated by one or more hot stars at the inside or close to the nebula. The atoms in the cloud (mostly hydrogen and helium) will emit certain wavelengths: an emission spectrum.

Conclusion



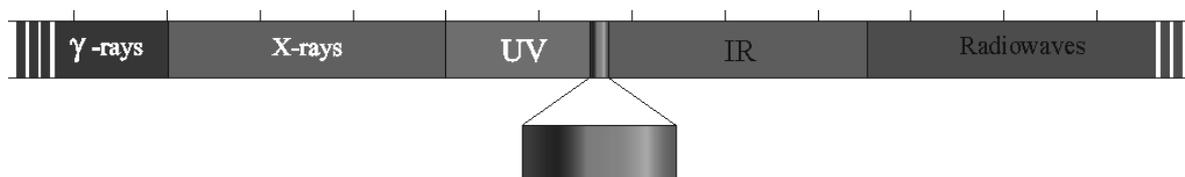
All light sources appear white to the human eye, but their colour-composition differs greatly. A spectroscope allows us to see the different wavelengths that make up white light. The characteristic spectrum of a light source gives us information about its source or about passing absorptive objects.

Questions & Answers



- Is the spectrum limited to the 7 colours of the rainbow?

No, this is only a very small (although important) part of the whole spectrum: the one visible with the human eye. But it extends beyond the red colour into infrared and radio-waves, and beyond violet into ultraviolet and even the very dangerous gamma-rays and X-rays.



Since the human eye can't see these, we need special equipment. Most of these wavelengths can't even be observed from Earth because they are blocked by the atmosphere (except for a few radio-waves and some infrared and "near ultraviolet"). That's why those instruments are placed on board of satellites in orbit around Earth.

- If the spectrum of the fluorescent lamp is an emission spectrum (the bright lines), why can I see a continuous spectrum in the background?

The bright lines show the spectrum of mercury (or better: the visible part of the spectrum), but the inside of the tube has a phosphor coating. Most of the mercury-spectrum lies in the ultraviolet, and cannot be seen with the human eye. The phosphor coating transform these ultraviolet spectral lines into a continuous spectrum in the visible wavelengths (this phenomenon is called "fluorescence"). The so-called "black lights" that are used in discotheques for special effects, are simply fluorescent tubes without this phosphor. They only emit a little light in the visual spectrum, but most in invisible ultraviolet.



7. Building a Comet

Objectives



- Students can explain the structure of a comet;
- Students know how to build a simple simulation of a comet;
- Students can explain why a comet develops a “tail” when it approaches the Sun.

Link with curriculum

Grade 7, chapter 1, lesson 5 (2009)



Material needed



- Dry ice (frozen CO₂), 2 cups

Never store the dry ice in a closed box!

- Water, 2 cups
- Sand, dust,... (2 spoons)
- Ammonia (liquid), a spoonful
- Some soot or other fine black material (fine grinded charcoal?)
- Wooden or rubber hammer
- Thick protective gloves, even protective eye-wear
- A large bowl
- Plastic bags
- Some organic material to explain about the possible links with starting life on Earth (Prahok)



Procedure

- First of all: be very careful! Dry ice has a temperature of -79° , so never touch it too long with bare hands and always use protective clothes, gloves and eyewear. Never do this in a closed room (make sure there is enough circulation, open all windows),
- Put the water, sand/dust in a plastic bag. Carefully add the ammonia and the prahok.
- Mix it all
- Wearing protective gloves, put the dry ice in a second plastic bag, and crush it with the hammer
- Add the content of the first bag, and mix both by squeezing it with your hands (gloves!)
- Tear away the plastic bag, and what you get is a perfect comet!



Observations

- A small spoonful of soot is enough to darken the whole comet. Indeed, comets as seen by space probes, proved to be very dark. That's why they react so much (evaporate!) when approaching the Sun
- The ice doesn't melt (frozen \Rightarrow liquid) but evaporates (frozen \Rightarrow gas), we can sometimes see real "jets" of gas coming out of our tiny comet.

Explanation



Comet orbits are typically highly elongated, so they spend most of their time far away from the Sun (aphelion). But when approaching the Sun (perihelion) they quickly start to heat (remember, they are very dark due to the carbon!), and their outer layers evaporate. Due to their own movement and the action of the Solar wind, all the material that comes free (gas and dust) tend to stay away from the main body, forming the famous “tails” of a comet. This is the archetypical image we all know of comets.



1882 Nov 7^d.

Great Comet of 1882 (Source: Wikipedia; PD licensed)

Older comets, having passed several times close do the Sun, can break apart into smaller ones (last time we witnessed this was with comet 73P/Schwassmann-Wachmann 3 in 2006).

Because comets contain pockets of gas, sometimes a “jet” of gas shoots away when the ice around it has molten (just like we could see during the workshop), pushing the comet in a slightly different orbit (just like the way a rocket works). Because these jets can occur on any part of the comet, and in any direction, it is impossible to exactly determine the orbit of a comet.

Conclusion



A comet can be described as a huge, dirty snowball, containing lots of ice, gases, dust and organic materials. When they approach the Sun, parts of the comet evaporate and form the tail of the comet. This increases their brightness, and makes some comets visible to the naked eye. Comets have orbits around the Sun.

Questions & Answers



Why is comet Halley so famous?

Comet Halley is the only comet that doesn't get his name from its discoverer. Instead, English astronomer Edmund Halley was the first one to realize that comets flew in an orbit around the sun. Before that, most astronomers thought that comets were phenomena in the atmosphere of the Earth, just like clouds, lightning and shooting stars.

Mr Halley noticed that a "great comet" had been seen in the past every 76 years or so, and he realized this must have been the same object.

Besides that, comet Halley is also a rather big comet, so most appearances are rather spectacular (except the one in 1986 ☹). And an orbit of 76 years means that some people can be lucky enough to see it twice, if they get old enough!



Source: NASA

What's the relation between comets and meteoroids/meteors/shooting stars?

Most smaller meteorites we see in the sky originate from comets (the bigger ones, those that don't burn up completely in the atmosphere, originate from the minor planets). It's the dust-sized and sand-sized material inside the comet, that come loose when the outer part of the comets evaporate and form the tail of the comet.

That's why on certain nights we can observe many shooting stars: when the Earth crosses the orbit of a comet.

- ⇒ 12-13 August, "Perseids", coming from comet **109P/Swift-Tuttle**
- ⇒ 13-14 December, "Geminids", coming from minor planet 3200 Phaethon
- ⇒ 3-4 January, "Quadrantids (Boötids)", origin not clear
- ⇒ 17-18 November; "Leonids", coming from comet 55P/Swift-Tuttle



Perseid 'shooting star' at the left of the Milky Way (Author: Brocken Inaglory, CC licensed)

8. Constructing & Demonstrating a Solar System Scale Model

Objectives



- Students realize that the relative distances between the inner planets are much smaller than those between the outer planets.
- Students are aware of the enormous scales of distances and diameters in the solar system.
- Students can use a simple model to explain the huge distances in the solar system to their pupils.

Link with curriculum



Grade 12, chapter 2, lesson 6 (2011)

Material needed



- A large campus, or along the road. The more place you got, the bigger the scale model can be build. One could even think of a scale model the size of Cambodia!
- Printed images of the different planets + the Sun
- If possible, little objects representing the planets (depending on the scale you are using, this can vary from the finest dust-particles to a big balloon - for the Sun)
- Some instrument to measure long distances: this can be a long tape measurer or simply use your own steps (every step is +/- one meter)

Procedure



- Put the photo or scale model of the Sun at the start location
- The start walking using the tables at the end of this experiment guide, and put each planet (photo or scale model) at the exact location
- Don't forget to put the Moon (very close to the Earth!)
- If possible, this could become a fixed exhibit on the school campus. This way, all students can become familiar with the names of the planets, their sequence, and of course the scale. Information like the diameter, number of satellites (Moons), visits by spacecraft?,... can be added

Observations



- At first (up to Mars or Jupiter), all planets are close to each other
- But once we get to the big gas planets, distances increase rapidly
- The contrast between the huge distances and the tiny diameters is striking!



Explanation



Planets may be huge objects, but they are dwarfed by the enormous size of the Solar System itself. In fact, the mean density of the Solar System is lower than the best vacuum we can achieve in laboratories on Earth!

The distances between the Sun and the planets increase exponentially, this was already noted in the 18th century by Johann Titius and Johann Bode. Independently from each other, they formulated the “**Titius-Bode Law**” (although it’s still not sure if it’s an actual physical law, or just a nice coincidence). We can summarize it as “ $a = 0.4 + 0.3 \times 2^m$ ” (a is the distance in Astronomical Units = the distance from the Sun to the Earth) and m is the number of the planet (Mercury = minus infinite, Venus = 0, Earth = 1, Mars = 3, Ceres = 4...). This formula works rather well up to Uranus...

Somewhat similar “logics” can be found in other systems: the major moons of Jupiter and Uranus, and even with some of the newly discovered planet-systems around other stars!

Conclusion



Planets may be huge objects, but they are dwarfed by the enormous size of the Solar System itself. A scale exercise clarifies the relative distances between the eight planets in the solar system.

Questions & Answers



Are all these planets always lined up?

Of course, a correct scale model of the Solar System should be seen in 2 dimensions, as all the planets travel around the Sun at a different speed. The possibility of all the planets lying more or less on one line is so infinitely small that it will never happen during the lifetime of our Solar System. And why not in three dimensions? Actually, most objects in our Solar System (except for some comets) move almost in the same plane: we call this plane the **ecliptic plane**. Sometimes 2 or 3 of the planets lie more or less in the same direction, this can be a beautiful sight in the sky (especially with the brighter ones: Venus, Jupiter, Mars,...)

What about the other objects in the Solar System (moons, minor planets, comets...). Would it be interesting to incorporate them in the scale model?

Most of them are so small that they would be totally invisible, even on the largest scale models. Only a few of the biggest small objects (Ceres, the 4 larger moons of Jupiter, Saturn-Moon Titan...) would be big enough to add to the scale-models.

Scale: 1/20 billion => school campus

	Sun	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
Real distance (km)	0	58000000	108000000	150000000	228000000	778000000	1427000000	2871000000	4497000000	5913000000
Scale distance (meter)	0	3	5	8	11	39	71	144	225	296
Real diameter	1400000	4878	12104	12756	6787	142796	120660	51118	48600	2274
Diameter on scale (mm)	70,0	0,2	0,6	0,6	0,3	7,1	6,0	2,6	2,4	0,1

At this scale, the Moon (0,2 mm) would be at 19mm from the Earth

Scale: 1/10 billion => larger school campus

	Sun	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
Real distance (km)	0	58000000	108000000	150000000	228000000	778000000	1427000000	2871000000	4497000000	5913000000
Scale distance (meter)	0	6	11	15	23	78	143	287	450	591
Real diameter	1400000	4878	12104	12756	6787	142796	120660	51118	48600	2274
Diameter on scale (mm)	140,0	0,5	1,2	1,3	0,7	14,3	12,1	5,1	4,9	0,2

At this scale, the Moon (0,3 mm) would be at 39mm from the Earth

Scale: 1/1 billion => village, city

	Sun	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
Real distance (km)	0	58000000	108000000	150000000	228000000	778000000	1427000000	2871000000	4497000000	5913000000
Scale distance (meter)	0	58	108	150	228	778	1427	2871	4497	5913
Real diameter	1400000	4878	12104	12756	6787	142796	120660	51118	48600	2274
Diameter on scale (mm)	1400	5	12	13	7	143	121	51	49	2

At this scale, the Moon (3 mm) would be at 385 mm from the Earth

Scale: 1/10 million => Cambodia !

	Sun	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
Real distance (km)	0	58000000	108000000	150000000	228000000	778000000	1427000000	2871000000	4497000000	5913000000
Scale distance (km)	0	6	11	15	23	78	143	287	450	591
Real diameter	1400000	4878	12104	12756	6787	142796	120660	51118	48600	2274
Diameter on scale (meter)	140,0	0,5	1,2	1,3	0,7	14,3	12,1	5,1	4,9	0,2

At this scale, the Moon (35 cm) would be at 385 meter from the Earth

Even if it's uncertain that this scale model would ever be constructed, it could be drawn on a map of Cambodia. The Sun could be placed at the Independence Monument in Phnom Penh, Mercury would be close to the airport, Venus would lie in Takhmau,... Jupiter would be close to Takeo, Saturn in Battambang Province,... and Pluto would not fit on the map of Cambodia!

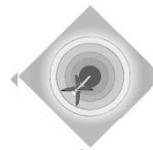
If you have access to planetarium software (such as the freeware "**Astronomy Lab for Windows**") or the website "**www.heavens_above.com**" one could do this activity this in two dimensions: not only the correct distances but also the correct orientations on the map.



9. Observing the Sun with Sunspotter telescopes

Objectives

- Students can explain what sunspots are;
- Students can observe and make a drawing of sunspots;
- Students are aware that looking directly at the Sun is very dangerous and should never be attempted without specialized equipment such as a Sunspotter telescope or a solar filter.



Link with curriculum

Grade 12, chapter 2, lesson 5 (2011)



Material

- Sunspotter telescopes
- white paper to draw the Sun and sunspots
- pen or pencil



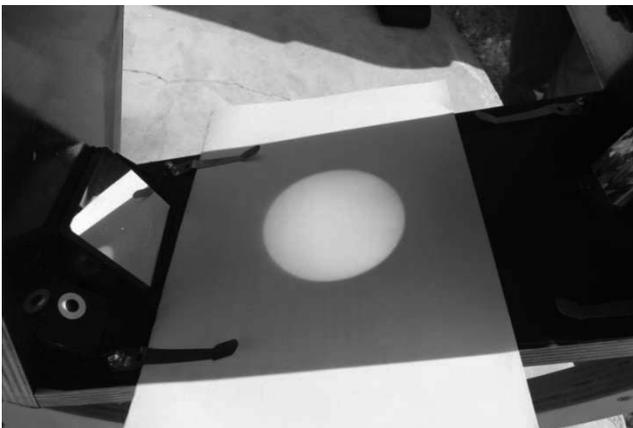
Procedure

- This activity requires clear sky.
- Put a piece of white paper on the bottom (inside) of the sunspotter, this will be used to project the Sun and make a drawing of the sunspots
- Point the front side of the Sunspotter (with the lens and the word "Sunspotter") at the Sun.





- Adjust the angle of the Sunspotter (left/right by moving the base, up/down by moving the sunspotter itself), the Sun has to shine perpendicular on the lens and front side. The Sunspotter has two special mechanisms to help you with this: one metal stick (the “gnomon”) that should point exactly at the Sun (then it has no shadow) and two small holes left and right of the lens (that project a small, bright spot of sunlight onto the two small white hollow circles on the back side (inside) of the Sunspotter).



- Then the projection image of the Sun should become visible on the sheet of white paper.

Observations



Most of the time (except during periods of Solar Minimum activity), you should be able to see little dark spots on the disc of the sun: the so called sunspots.

If you can observe the Sun day after day, you will see how the sunspots seem to be moving, and how they change in appearance and size. Some days you will see new spots, while other days some spots will have disappeared. And some sunspots will seem to disappear behind the disc of the Sun.

Explanation



Sunspots are locations on the Sun with a lower temperature. The mean temperature of the solar surface is 5700°C , the temperature of the sunspots can be 4200° (outer part, appears grey) to 3500° (inner part, dark black). They are caused by magnetic disturbances on the outside part of the Sun, they make it difficult for the heat coming from inside the Sun to get out (and therefore this part of the solar surface cools).

Small sunspots only last for a few days, the biggest can exist for several months.

The apparent movement of the sunspots is in fact the rotation of the Sun itself. One rotation of the Sun takes approximately 25-30 days (some parts turn slower than others), so day after day we'll see another part of the surface. Very big sunspots can last for a few months as they can be seen during several revolutions of the Sun. They will disappear behind the west border of the Sun and reappear two weeks later at the east side.

Conclusion



With a Sunspotter telescope we can safely observe the surface (photosphere) of the Sun, identifying the sunspots. These are cooler regions on the Sun, giving them their darker colour.

Questions & Answers



Why are sunspots dark?

Sunspots are locations on the surface of the Sun with lower temperature compared to the rest of the solar surface. Lower temperature means less energy, and less energy means less light emitted.

But it's only relative: if you were flying (In a rocket) just in front of a sunspot, it would still be too bright to look at without a filter. It's only when compared to the rest of the solar surface that it appears to be darker.

10. How does a telescope work?

Objectives

- Students can describe how to use a telescope correctly.
- Students can explain how a telescope collects light and projects an image.
- Students strengthen their observation and calibration skills.



Link with Curriculum

Earth and environmental science:
Grade 12, chapter 3, lesson 1 (2011)

Physics:
Grade 9, chapter 5, lesson 1-4 (2011)

Material needed

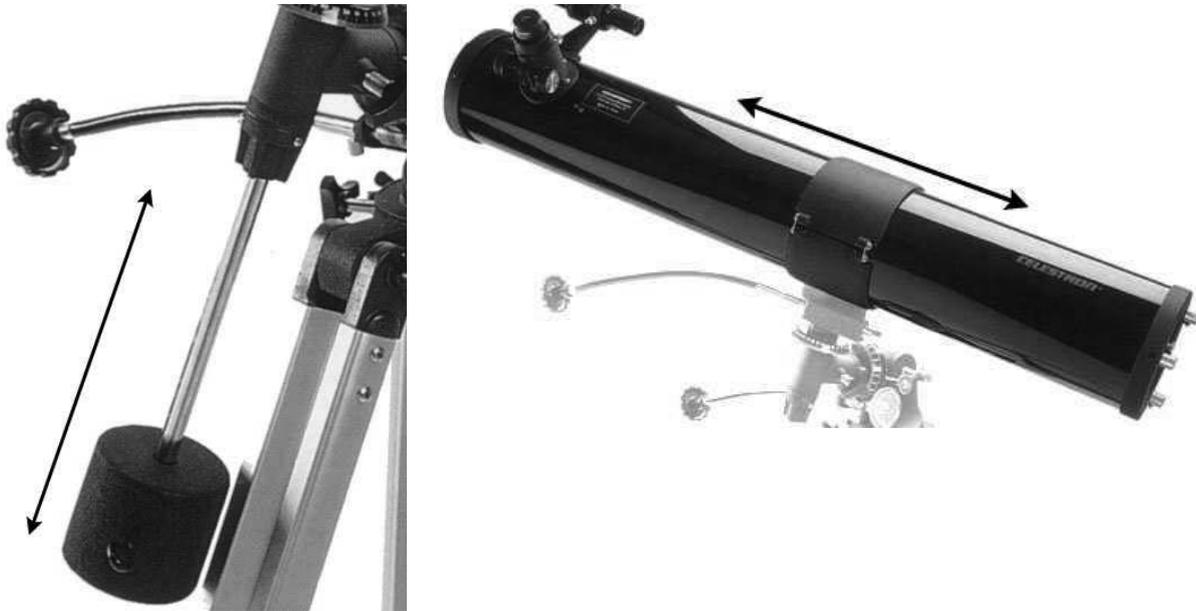
A telescope (or binoculars) with its accessories (tripod, eyepieces, finder scope, counter weights,...)
Clear sky (no clouds), at evening or night

Procedure

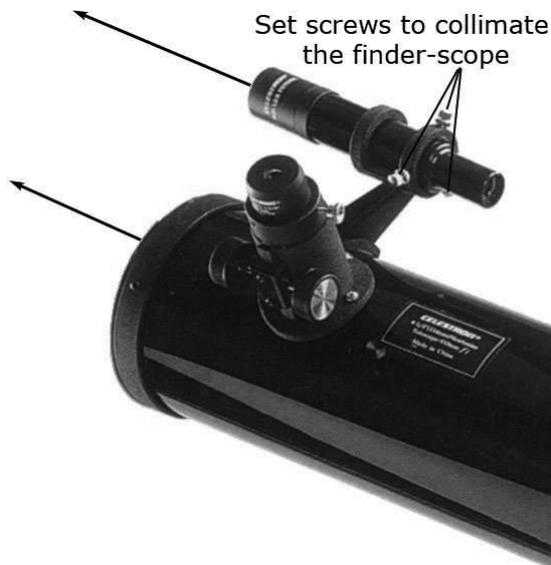
Start by explaining and showing a few easy constellations, depending on the season. For example: Cassiopeia or Orion in December -February, the Scorpion and Sagittarius in summer, Gemini or the Big Dipper in March - May, the so called Summer Triangle (Deneb-Altair and Vega, the brightest stars of the Swan, the Eagle and the Lyre) in September – October. Refer to the experiment on “Constructing and using a Star Chart”.



Prepare the telescope during the day. Make sure that everything is well balanced: the counterweight(s) can be moved along the axis (balance between left/right), and most of the time the telescope tube can be moved forwards/backwards in its rings. The easiest way to do this is by loosening the two screws that tighten the two axes of the mount.



Source: MIRA (used with permission)



Source: MIRA (used with permission)

Then set the small telescope (finder scope) parallel to the main instrument. The easiest way to do this is by using the smallest magnification for the main telescope (using the eyepiece with the largest focal length, most often 20mm or 24 mm). During daylight, try to point the main telescope to an easy to distinguish object far away (at least 500m): the top of a tree, a Wat... Then firmly block the two axes of the mount, and look through the smaller telescope (finder scope). If it's not exactly looking at the same object, correct this by loosening and tightening the three (or 6) small set screws.

Having done this, your telescope is ready to be used!

Depending on what's visible in the sky, you can observe the Moon, different planets, star clusters, galaxies, nebulae, double stars, sometimes even comets,... The most difficult part of observing with a telescope is learning to know the sky: you need to know where a certain object is located in the sky, especially the fainter objects. And learning how to manipulate the telescope when it's dark!

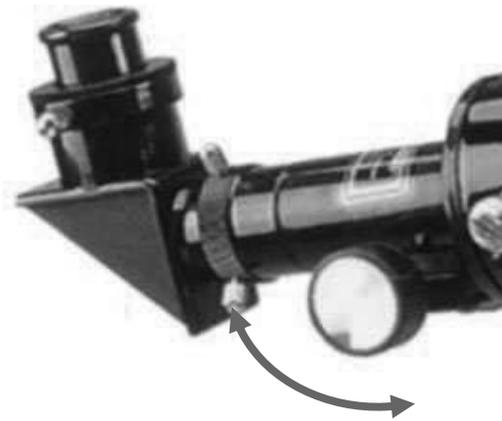
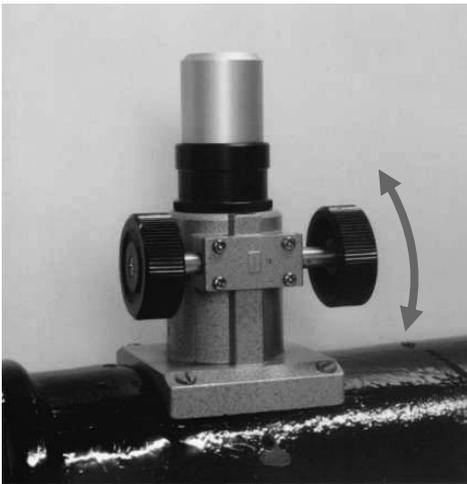


Source: MIRA (used with permission)

If the mount is an “equatorial mount” (like the one on the image above, where the two axes are not simply moving horizontal/vertical) then it can be interesting to point the “polar axis” more or less to the north star. It means that this axis is oriented towards the North, and pointing 10-15° high (for the latitude of Cambodia).

By doing this, the axis will be parallel to the rotation axis of the Earth and it will be easier to observe celestial objects for a longer time. The apparent motion of the sky is actually caused by the rotation of the Earth, so once we set the rotation axis of the telescope-mount parallel to the axis of the Earth, we only have to adjust the telescope in one axis (called “Right Ascension” or “RA”) to keep the object centred. More expensive telescopes even have a motor to do this.

Pointing the telescope is rather easy, once we have some knowledge of the sky and are accustomed to the mechanics of the telescope. Slightly loose the two rotation axes of the telescope mount (so that they can “slip” without damaging the axes), and use the smaller telescope (finder scope) to point an object. Having done this, we should be able to see the object in the main telescope (using the lowest magnification). Don't forget to adjust the focus; just like we do with a microscope (every human eye is different!).



Different focusing mechanisms: left: Newtonian telescope, right: lens telescope

Source: MIRA (used with permission)

Observations



- ☒ The **Moon**: it's the most spectacular object as seen through a telescope: full of craters, mountains, large dark patches (the so called "seas", no water but large darker lava flows), and easy to view.
- ☒ **Jupiter**: when the giant planet is visible, observe its four biggest moons (the so called "Galilean Moons", because they were discovered by Galileo Galilei). When observing them evening after evening, you will notice they move around the planet (just like our own Moon does around the Earth)
- ☒ **Saturn**: when visible (the next few years it will be visible in spring and summer) we can easily observe its rings. When observing them year after year we will notice how their inclination will change.
- ☒ **Venus**: when visible (can be any time of the year, but only at morning or evening) it's the brightest object in the sky. When observing the planet through a telescope, it's easy to see its phases (like the phases of our Moon)
- ☒ For more experienced observers: try to observe the Pleiades (M45) and the Orion-nebula (M42) during winter, or the Andromeda-galaxy (M31) during autumn. And try to find the Small and Large Magellan Clouds during autumn/winter, or the double star-cluster in Perseus (NGC 884 and NGC 869) (see star chars in annex).

Explanation



A telescope not only magnifies the image, but (more important) functions as a **giant eye**. The human eye has a pupil-diameter (at night, in the dark) of 7 mm. With those 7 mm we can see a few thousands stars. A telescope (mirror or lens) is much bigger, and captures more light. That's why we can see much fainter stars and other objects.

A telescope is a giant eye

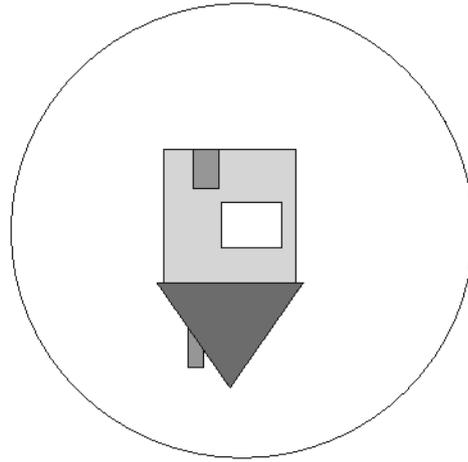
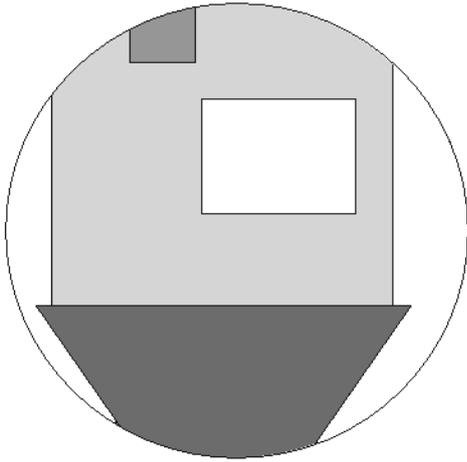


Source: MIRA (used with permission)

The magnification of a telescope is less important: it is mostly limited by external factors (turbulence in the atmosphere of the Earth,...). Most basic telescopes are provided with a set of 2-3 eyepieces, for different magnifications. It's best to use only the lowest magnification (eyepiece with the highest focal length, mostly 20 or 24 mm).

It's easy to calculate the magnification of the telescope: simply divide the focal length of the telescope itself by the focal length of the eyepiece. A typical basic telescope will have 700-900 mm of focal length (it's mostly written on the tube: $f=900$ mm or so). When using a 20mm eyepiece on a 900mm focal length scope, the magnification will be $900/20 = 45$ times.

If we magnify more, the field of view becomes very narrow and it will be more difficult to locate an object.



The two most common types of telescopes for beginners: a refractor (“lens telescope”) –mostly with a lens of 60 to 90 mm diameter and a Newtonian mirror telescope (mostly with a mirror of 114 to 150 mm). (Source: MIRA (used with permission))

Conclusion



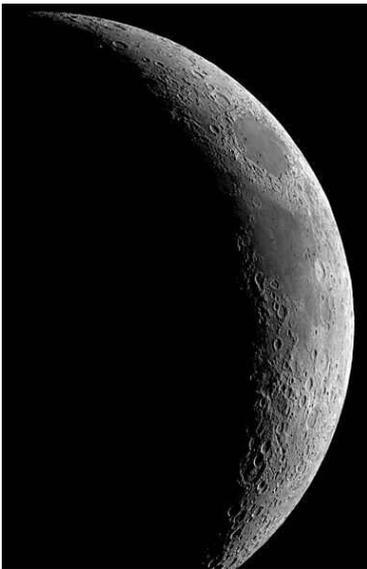
A telescope not only magnifies the image, but (more important) functions as a **giant eye**. The magnification of a telescope is less important than the diameter of the lens which determines how much light the telescope can collect.

Questions & Answers



Try to find and view the thin crescent of the Moon the first 3-4 days after New Moon: what do you see?

The “dark side” of the Moon is not completely dark, it’s illuminated by sunlight reflecting of the surface of the Earth. We can only see this a few days before or after New Moon, when we see a thin crescent Moon. A larger crescent of the Moon will be too bright to observe this faint light.



Crescent moon (source: ESO)

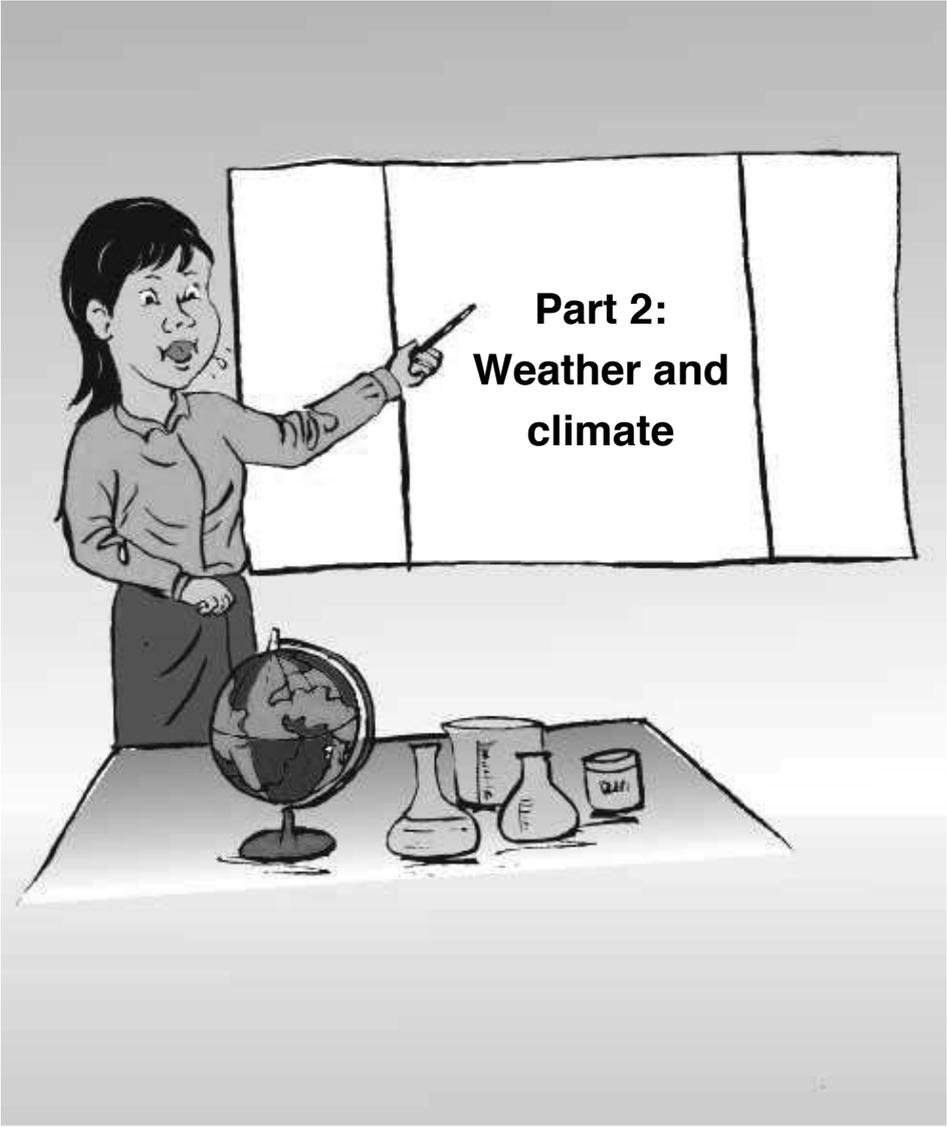


How powerful is your telescope?

We need to compare the light-grasp of the telescope with that of our eye (7mm pupil-diameter). Typical (good) basic-telescopes have primary lenses (objective lenses) of 60mm (sometimes 80 or 90 mm), or mirrors of 114mm (sometimes 150mm). All we have to do is compare the surface of that objective with that of the human eye. A 60mm-lens will gather almost 75 more light, so with this instrument we can observe stars that are 75 times too faint for the human eye. A 114mm mirror will gather 260 times more light. The (professional) Spanish GTC- telescope has a mirror of 10.4 meter! It’s more than 2 million times more powerful as the human eye!

*Most people (especially children) draw a star like this “ * ”, but when we look through the telescope we only see them as a tiny point, even at the highest magnification. How come?*

Stars may be gigantic, but they are so unbelievably far away that even the biggest professional telescopes are just able to see a few of the biggest stars as a disc. The “star-like” appearance of stars (with 5 or 6 spikes mostly) in drawings and comics, is probably caused by bad eye-sight: light that is scattered by the eyelashes of our eyes.



Introduction



This experiment guide presents a set of easy-to-do and low-cost experiments to help teacher trainers and teachers to teach weather and climate. The experiments cover main concepts of weather and climate such as temperature, pressure, density, convection, differential heating and condensation. The experiments also show how these elements combine to create the dynamics of wind and clouds. Some experiments can be done as discrepant events; others are suitable for inquiry based exploration by students.

This experiment guide was compiled with the greatest care. However, errors may happen and we apologize for any mistakes in this text. Please provide us your comments and suggestions so we can improve this text. We wish you inspiring earth science lessons with this manual!

Main Concepts



Convection's role in creating wind

- The sun's energy is the driving force that causes weather.
- The surface of Earth heats unevenly because of its tilt to the sun.
- Uneven heating of Earth's surface by the sun creates air temperature differences, which result in air density differences from location to location.
- The sun provides the energy to create convection currents on our planet.
- Warming makes molecules move faster, bump into one another, and spread apart. Therefore there are fewer surrounding air molecules within a given space, resulting in lower density. · Air that is less dense (lighter) than surrounding air will rise and air that is more dense (heavy) will sink.
- Air is a fluid (similar to water) and moves because of the differences in temperature and density. The continual cycling of air is called convection current.
- Winds are the horizontal movements of air masses as the atmosphere acts to equalize density differences in adjacent air masses caused by unequal heating. Convection cells occur in the atmosphere at different scales.
- Large scale convection cells occur in the atmosphere causing the prevailing winds.

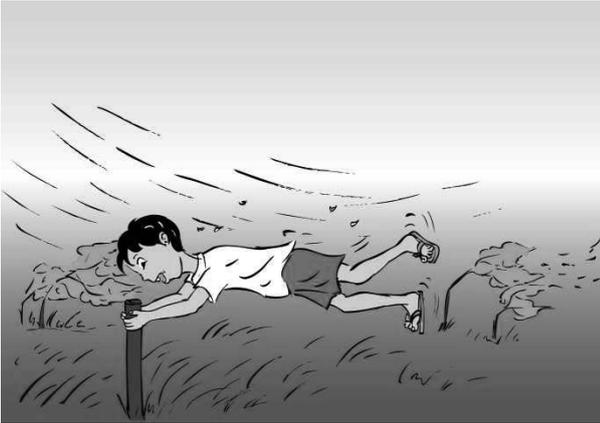
The role of **pressure and differential heating** in creating wind

- There is a direct correlation between density and pressure. As density increases, pressure increases.
- Density differences create areas of high and low pressure. Areas with high density (more molecules) have higher pressure. Winds blow from high to low pressure and create air mass characteristics and boundaries (fronts)
- Winds are the horizontal movement of air as the atmosphere acts to equalize pressure differences in adjacent air masses caused by unequal heating.

Local wind systems

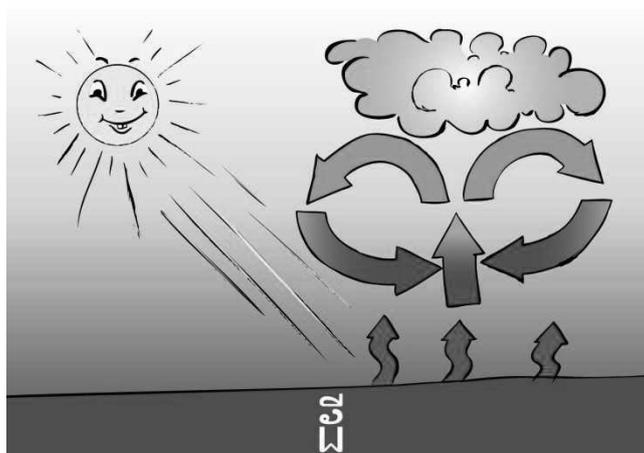
Land gains and loses heat more quickly than water. · Land and sea breezes develop in response to differential heating of the land and sea surface.

- During the day, the land heats up more quickly than the sea causing a low pressure over the land with warm air rising, while at sea cool air sinks creating higher pressure. This convection system results in a breeze at the surface from the sea to the land (sea breeze).
- In the evening, the land cools off more quickly than the sea with the cool air sinking over the land causing high pressure, while at sea a low pressure area develops. This convection system results in a breeze at the surface from the land to the sea (land breeze).



Global Wind Patterns and Convection

There is an indirect correlation between latitude and receiving the Sun's energy – Over a year, the tropical latitudes 0-30° receive most of the Sun's energy, the polar latitudes (60°-90°) the least. As a result the poles are colder than the equator. Air moves from areas of higher pressure to lower pressure (often resulting from unequal heating). The simplest case is convection current.



On Earth, convection currents occur on many different scales due to relative differences in temperature in adjacent air masses. In areas of vertical air motion – at 0°, 30°, 60°, and 90° latitudes – there is very little wind at the Earth surface.

In the Northern Hemisphere, winds move clockwise, outward, and downward around a high pressure system. Winds move counterclockwise, inward, and upward around a low pressure system. Air movement is influenced by Earth's rotation (Coriolis Effect). The boundaries between air masses of different characteristics (Highs and Lows) are known as fronts.

How do clouds form?

Air cools as it rises.

- Rising air occurs with low pressure and leads to cloud development. Clouds are often present with low pressure systems (e.g. cold front).
- Sinking air is associated with high pressure, and leads to dissipating clouds or no cloud development.

Clouds form when:

- 1) there is enough water vapour (water in gas form) to change to liquid droplets or ice;
- 2) the air is cooled enough as a result of vertical lifting;
- 3) there are particles (sand, dust, salt) onto which water vapour can condense.



Precipitation occurs when cloud droplets grow large and heavy enough to overcome the rising air creating the cloud.

Activities on Heat Energy and Greenhouse Effect

1. How does the Greenhouse Effect work?

Objectives

- Students can explain the mechanism of the greenhouse effect
- Students can perform an experiments to illustrate the greenhouse effect.
- Students can discuss the reasons of global warming.
- Students can compare the heating of the Earth and the heating of a car under the sun.



Link with curriculum

Grade 12, chapter 4, lesson 5 (2011)

Grade 9, chapter 3, lesson 3 (2011)

Materials

- glass pot (such as empty coffee pot)
- two thermometers



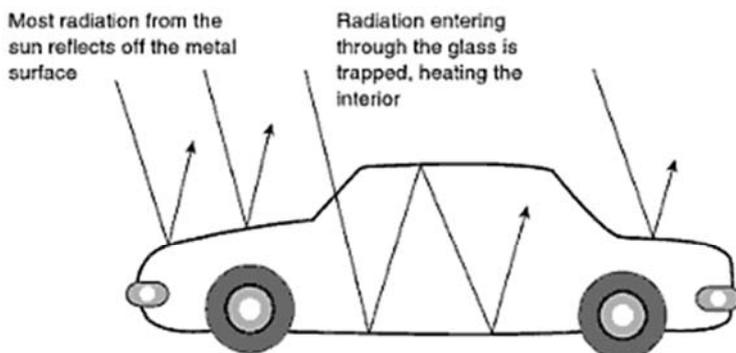


Procedure

1. Put a thermometer into the glass pot. Make sure the thermometer fits completely in the pot.
2. Close the pot and place it outside in the sun. Don't put the thermometers on a conducting surface like a metal table. A wooden block is fine.
3. Place the second thermometer on the same place with similar characteristics (sunshine, surface)
4. After 10 minutes, read both thermometers
5. Supplementary: Look every 5 minutes and note down the measurements. Plot the temperatures on two graphs with time as the "x" (horizontal) axis and temperature as the "y," (vertical) axis.



A situation like the inside of a car is created, causing the air inside (and the thermometer) to heat faster.

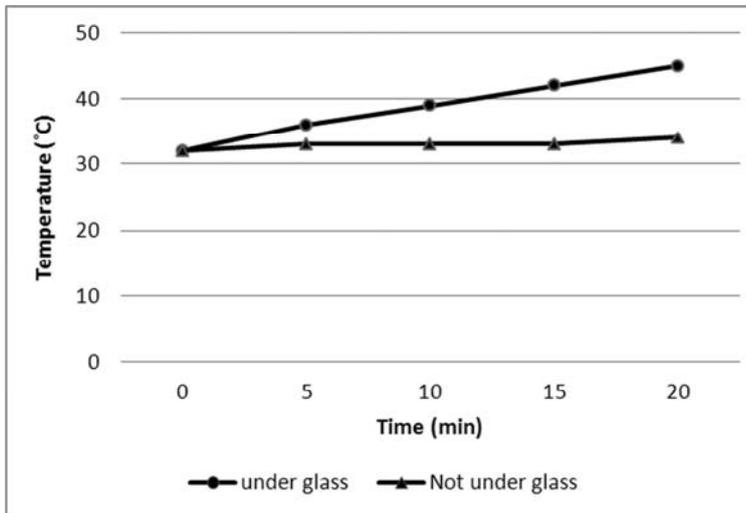


Source: Ernst, 2010.



Observations

What differences do you see in the temperatures observed with the two thermometers?
Predict how the temperatures will evolve if you would keep both thermometers in the Sun longer.



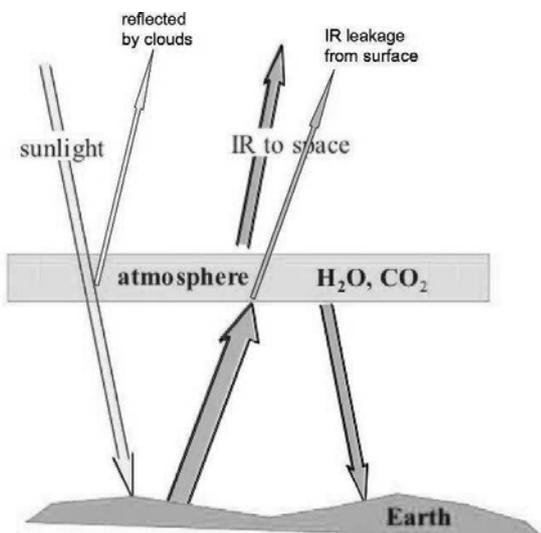
Graph showing possible temperature evolution under/ outside glass



Explanation

The Sun's visible rays pass through the glass bottle easily. Once inside, they are partly absorbed by the surfaces and objects inside the bottle and converted into heat radiation. Glass is transparent for visible light but not for heat radiation, which is partly reflected. Because of this reflection the air inside the bottle heats up and the temperature rises.

In the atmosphere the Sun's visible light rays pass through in the same way. Part of this radiation is absorbed by the surface of the Earth and re-emitted as heat (infrared) radiation. Molecules such as CO_2 , H_2O and CH_4 reflect part of this infrared radiation instead of letting it through, thereby heating up the atmosphere and the Earth's surface.



Source: Muller, 2010 (All rights reserved)

The last 50 years has seen a global rise in average temperature which many researchers attribute at least partly to human activities. The higher carbon dioxide (CO₂) concentration in the atmosphere, resulting from the burning of fossil fuels such as oil, natural gas and coal, has enhanced the greenhouse effect. Also the presence of other (even more potent) greenhouse gases such as methane (CH₄) has increased. Many feedback mechanisms and the unsure role of clouds make exact temperature predictions impossible.

The greenhouse effect is not related with the ozone layer, which is an increased concentration of ozone at about 25 km, which protects us against harmful UV-radiation from the Sun.

Conclusion



The earth is warmed by the greenhouse effect. The greenhouse effect is caused by certain gases in the atmosphere that absorb and reflect infrared radiation from the Earth.

Questions



- 1) *Predict what would happen if you would put a black object in the bottle. What kind of graph would you obtain?*

The black object results in a stronger heating effect.

- 2) *Why is the greenhouse effect important for humans?*

Without the greenhouse effect (so only the heating of the Earth's surface by the sunlight and from the interior of the Earth) the temperature would be much lower.

- 3) *Is global warming a problem that should be solved by the developed countries? Give arguments for your opinion.*

This is a complex discussion with arguments that stretch beyond the realm of science. However, it is an interesting discussion and students may start the discussion spontaneously. Some examples of arguments that can be used:

- Yes, because the rich countries are responsible for the majority of the extra CO₂ in the atmosphere.
- No. It's a problem of every person on the world. If everybody changes his/her life a little bit, this can decrease the CO₂ pollution enormously. We have to work together, and start with changing yourself.
- No, developing countries such as China and India are rapidly catching up. A decrease in carbon emissions by the developed countries would be neutralized quickly by developing countries.
- No, developing countries will be affected more badly by global warming as they lack the resources to protect themselves.

2. Why is it hotter at the equator than at the poles?

Objectives

- Describe the procedure of an experiment that proves equator receives more light than polar regions
- Point out reasons why direct sun rays produce more heat than slanted rays
- Enjoy observing natural phenomena



Link with curriculum

Grade 10, chapter 3, lesson 4

Material

- flashlight
- balloon
- marker

Procedure

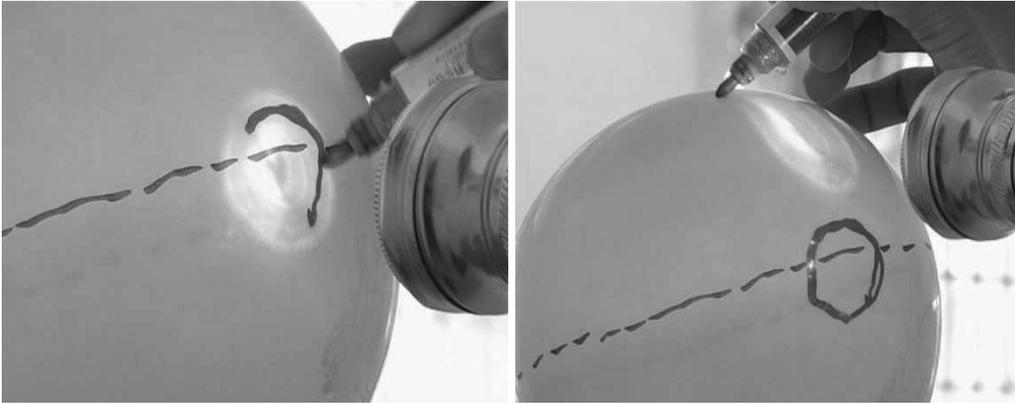
- Mark a north and south pole on the balloon, which will represent the Earth. The flashlight represents the Sun.
- Shine the sunlight on the “equator” of your balloon and then move the light so it shines near one of the two poles. Keep the flashlight horizontal!



Observations



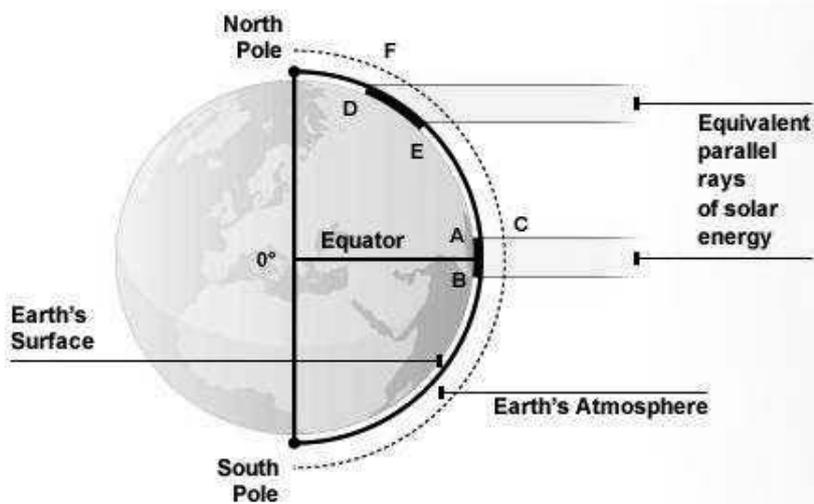
- Notice how concentrated the light beam is at these two different positions.
- Is the heat equal at both angles? Why?
- Is the intensity of the sunlight that falls on the poles the same as on the equator?



Explanation



In shining the flashlight on the balloon, you have noticed that the light beam spreads out over a larger area when it hits the poles of the Earth than when it hits the equator. This means that a square meter at the poles receives less sunlight (and thus energy) than a square meter at the equator.



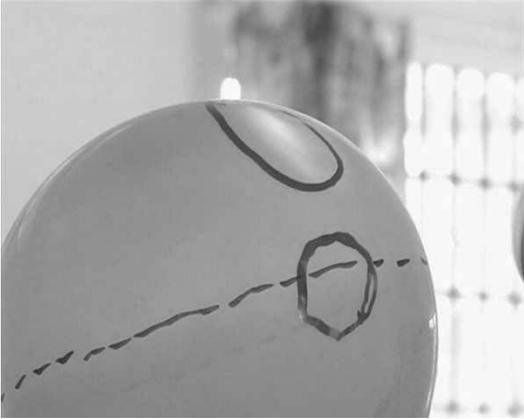
Source: Wikipedia (CC licensed)

This leads to an important conclusion that helps us understand much of Earth's weather. The equator receives more solar energy than the poles, heating the equator more than the poles. This would have the consequence that the equator gets warmer and warmer and the poles colder and colder. This doesn't happen because energy transfer redistributes heat between the equator and the poles. Heat is constantly exchanged between equator and poles.

Conclusion



Direct rays of the Sun are hotter than slanted rays. With slanted rays the same amount of energy is distributed over a larger surface.



3. Diffusion of heat energy

Objectives

- Students can describe the relation between temperature and the speed of molecules.
- Students can illustrate this relation with a simple experiment.
- Be cautious when doing experiment with material at high temperature.



Position in curriculum

Grade 11, Chapter 3, lesson 9



Material needed

- hot water
- cold water
- two identical glasses
- liquid food colouring



Procedure

- Fill one glass with cold water and the other glass with hot water.
- Pick a colour of food colouring and put three drops of it in each glass.



Observations

- What do you observe in the two glasses?
- In which glass does the food colouring spread out faster? Can you find an explanation?

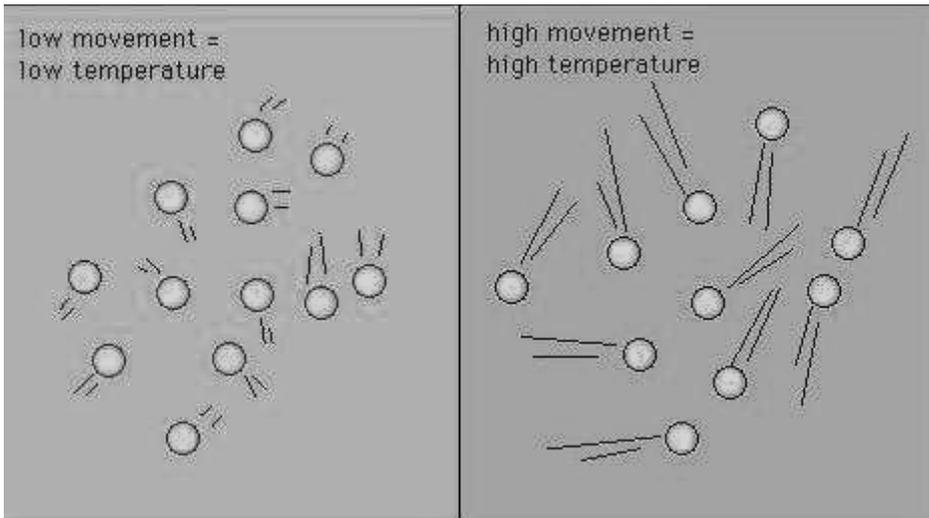




Explanation

In hot water, the food colouring spreads out faster than in cold water. Water molecules in hot water are moving around faster than those in cold water. This faster movement causes the food colouring to spread out faster as it gets jostled around by the water molecules. So, we might expect that temperature has a lot to do with the speed of the molecules. Higher average speeds mean higher temperature and lower average speeds mean lower temperatures. This process we call diffusion.

This situation is similar to gases such as air. The average speed of air molecules is higher for hot air than for cool air.

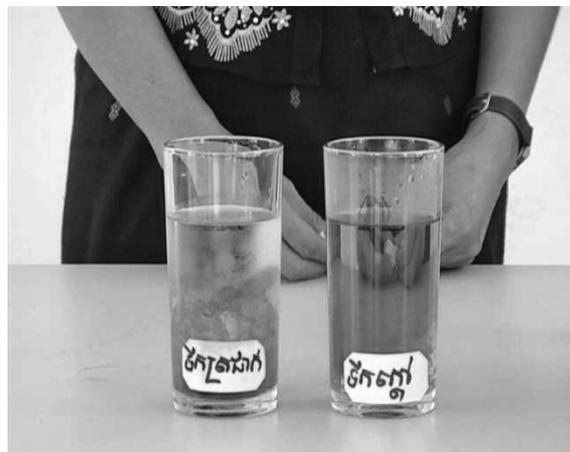


Source: Wikipedia (Public Domain)



Conclusion

Temperature is related to the speed of the molecules. The average speed of air molecules is higher in hot air than in cool air. These differences lie at the basis of many weather phenomena.



Activities on Air Pressure, Density and Differential Heating

4. Effect of colour on temperature

Objectives

- Students can describe the relationship between colour and temperature
- Students can explain a graph showing the change of water temperature in cans with different colours
- Students can apply knowledge on differential heating, for example when selecting coloured materials to use in the Sun.



Link with curriculum

Grade 10, chapter 2, lesson 1 (1999)



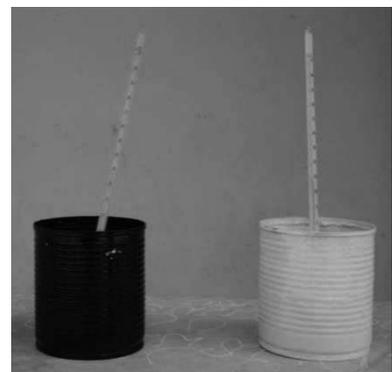
Material

- 3 clean, empty tin cans
- white and black paint
- warm water
- cold water
- thermometer
- paper
- pencil
- index cards
- tray



Procedure

- Paint a drinking can white, another one black. Leave the third can shiny (if it is a coloured can, remove its colour).
- Fill the cans with very hot water of equal temperature. Record the temperature.
- Cover each can with an index card, and place all three in a shadowy place
- Record temperatures of the water in each can every 5 minutes, during 20 minutes as accurately as possible.
- Now empty the cans, dry them and fill each one with very cold water. Record temperatures of each can.
- Cover each can with an index card and place them in a sunny spot.
- Record the temperature of the water in each can at 5 minute intervals for 20 minutes.



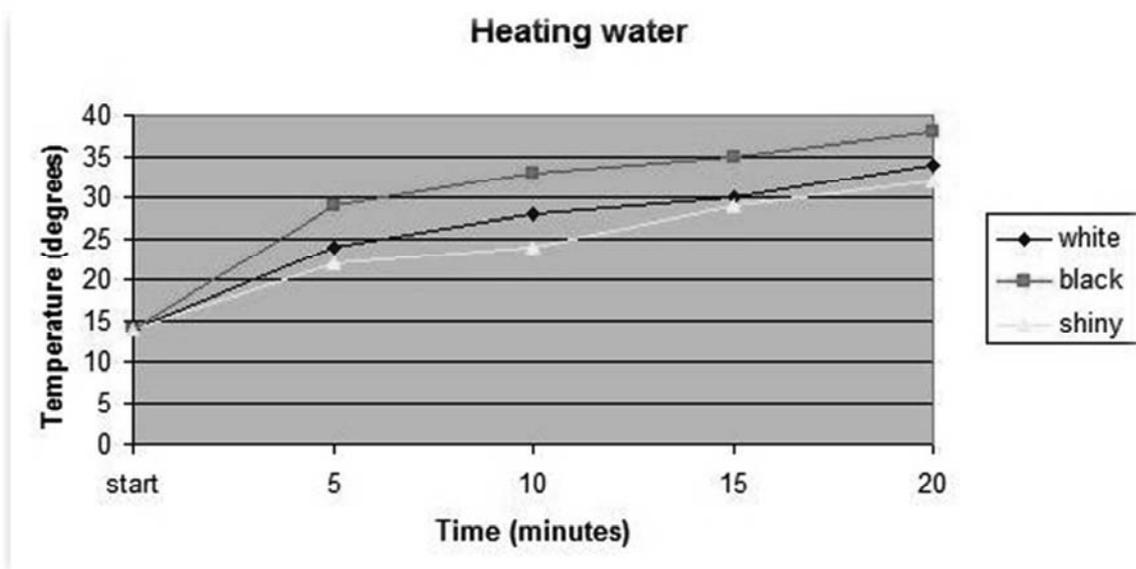


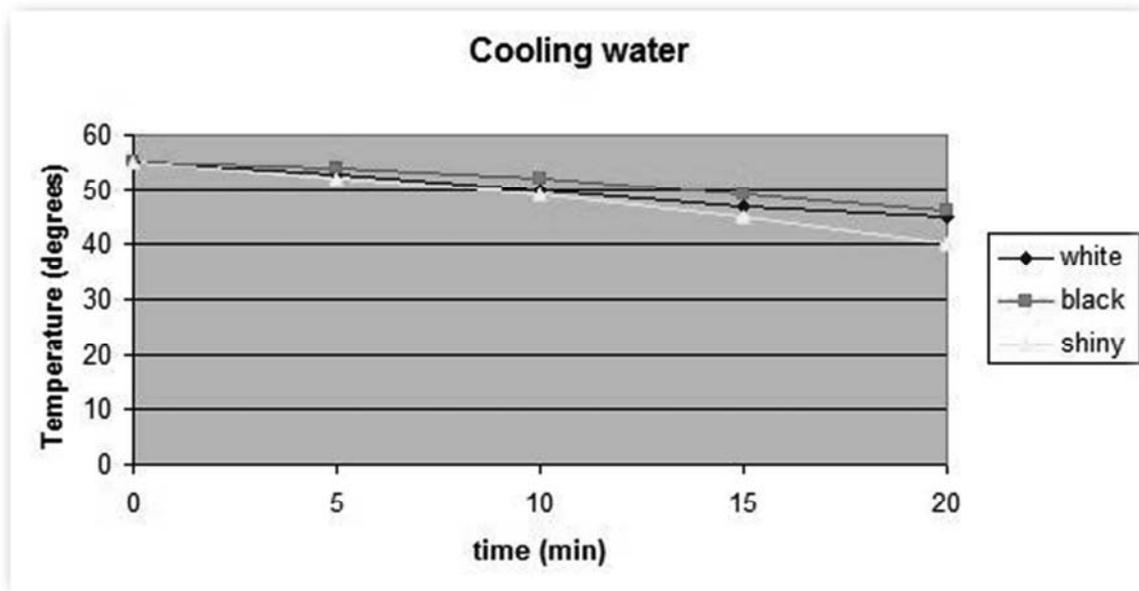
Observations

- Record your observations in a table.
- Make two graphs: one for the cooling process and one for the heating process (see graph below)
- How do temperatures evolve in the three cans?
- Which box stays hot the longest? Why, do you think?
- Which box cools down the fastest? Why, do you think?

Cooling water				
		white	black	shiny
	start	55	55	55
	5	53	54	52
	10	50	52	49
	15	47	49	45
	20	45	46	40

Heating water				
		white	black	shiny
	start	14	14	14
	5	24	29	22
	10	28	33	24
	15	30	35	29
	20	34	38	32





Explanation



In both cases, the water in the black can has the highest temperature whereas the water in the shiny can is the coolest. The dark can absorbs more light, which is then turned into heat. The white and shiny cans reflect a larger part of the light back, before it can turn into heat.

Conclusion



Differential heating is caused by different reflection and absorption characteristics of colours. A dark surface absorbs more light, whereas a light surface will reflect more. As a consequence, a dark surface will heat up more than a light surface with an equal amount of energy.

Questions



- *How would the temperature evolve if you would measure for a longer time? Indicate on your graph.*
The temperature would go up/go down until the water in the cans reach the surrounding temperature.
The shiny can will always reach the surrounding temperature as first; the black one the last.
- *What would be the result if you'd do the experiment with a red painted can? Indicate the results you'd expect on your graphs.*
Red absorbs more radiation than white (in fact, it absorbs all wavelengths except for the red, which it reflects) and less than black.



Recording increasing temperature of cool water

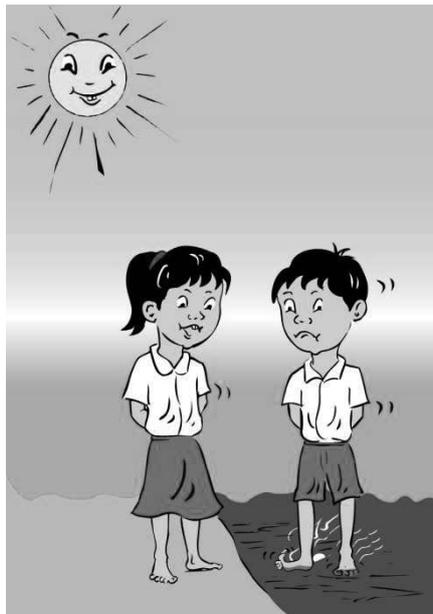


Decreasing temperature of hot water

5. Effect of material on temperature

Objectives

- Students can explain the difference in rate of heating and cooling between water and soil.
- Students strengthen their observation and graph making skills.
- Students develop interest in observing natural science phenomena.



Link with curriculum

Grade 10, chapter 2, lesson 3 (1999)

Material needed

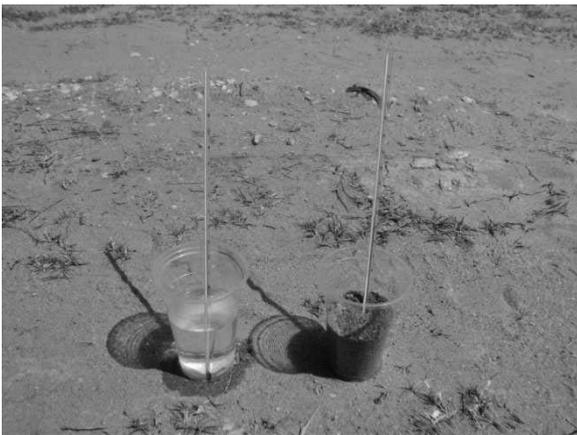
- 2 plastic cups
- $\frac{1}{2}$ cup of water
- $\frac{1}{2}$ cup of soil (or two cups with light and dark soil)
- 2 (identical) thermometers



Procedure



- Ask students to think about their own experiences involving the temperature of sand and water. Prompt them to think about walking on sand with bare feet. How did it feel (cold, warm, hot)? Now imagine walking into some water nearby. How would that feel? (warmer or cooler than the sand)?
- Give each group of students two beakers, one filled with sand and one filled with an equal volume of water. Ask them to make a prediction which they think will heat up faster, sand or water, and why they think that.
- Write students' ideas on the board. Suggest that they can gather some data to find out if their ideas are correct.
- Fill two plastic cups with respectively water and soil and place both cups in a cool or shadowy place (as cool as possible) and measure the temperature.
- Tell students to place each beaker in the sun. Put one thermometer in each beaker, holding the thermometer so it is in the middle of the sand or water, not resting on the bottom of the beaker. Tell the students to record the temperature of the sand and the water on the data sheet every two minutes for 15 minutes. After 15 minutes, they will put the beakers back in the shadow (or a cool place) and again record the temperature of the sand and water every two minutes for 15 minutes.
- Have students graph their data on graph paper, with time on the x-axis and temperature on the y-axis. They need to draw two lines, one for sand and one for water.



Observations



- Have the students examine their graphs. Point out that graphs can help us see patterns in our data. Which heated up faster, sand or water? Which cooled down faster? Ask students why they think this happened.
- Their responses might be something like this:
 - o Sand heated up faster than water because sand has a colour and water is clear.
 - o Sand heated up faster than water because sand is darker than water; dark colour materials will absorb more light.
 - o Sand heated up faster than water because sand is a solid and water is a liquid.

Questions



- Students can now use these ideas to make and test hypotheses about heating. Based upon what they have already observed, ask students to make a hypothesis about the rate at which different materials will heat up and cool down. Remind students that a hypothesis should involve an explanation.
- To help students to write a good hypothesis, you might ask them to complete this sentence: "Sand heats up more quickly than water because _____." This can give them ideas about what factors might cause different rates of heating and cooling. Students will likely need guidance on this. If you would prefer, the whole class could brainstorm together to come up with factors that might explain what they have observed. They might consider:
 - o Colour: students might think that darker coloured materials will heat up more quickly than lighter coloured materials. Darker colours absorb more light (and heat), and lighter colours reflect more light (and heat).
 - o Weight or Density: students might think that heavier or denser materials heat up more slowly than lighter or less-dense materials.
 - o Liquid versus solid: students might think that liquids will heat up more quickly than solids, or vice versa.
- Of course, students probably won't come up with the explanation for specific heat capacity; the important point is that they come up with some explanation that could help answer the question of *why* some materials heat/cool faster than others.
- Each student group should come up with (or choose) a hypothesis to test. Ask students if their hypothesis is testable and ask them to think about what they could do to test it.

Extension



- Let students collect materials that can be used to test their hypothesis. Examples are:
 - o Sand and water mixed together
 - o Salt water
 - o Tea (room temperature)
 - o Dirt (or potting soil)
 - o Mud (try several types of mud of different thicknesses, with different amounts of water)
 - o Gravel
 - o Rocks
 - o Leaves
- Point out that they will do an experiment exactly the same way that scientists do experiments. Show the students the other materials. They will be comparing the heating and cooling of this material to sand and water. Ask the students to write down their hypothesis (explanation) and, based on this hypothesis, what they expect to happen (their prediction): will their material heat up and cool down faster or slower than sand or water?
- Tell students to take the temperature of the new material in the Sun for 15 minutes and in the shadow for 15 minutes.
- Meanwhile make a summary table on the whiteboard to show the relative heating and cooling rates of all of the materials.
- Have each group graph their results and discuss what happened within their groups. Did their results support or contradict their hypothesis?
- In order to share class results, have one student from each group come to the front of the classroom and present their findings to the class.
- After each group has presented their results, ask the class if they see any patterns in the results. Ask students if they have changed their minds about which hypothesis is the best one. Can they come up with any new explanations after doing this experiment? How might they test those explanations? There

may not be any real pattern in the heating and cooling rates of different materials — the main point is that different materials heat up and cool down at different rates.



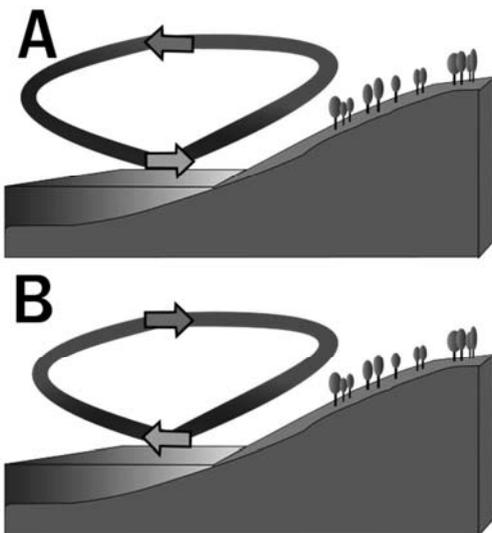
Explanation

The core physical principle at work is the **specific heat capacity** of different materials. If this is an introductory activity, then it is not important that students understand the details of specific heat capacity at this point. It is just important that students understand that different materials heat up and cool down at different rates; this has important implications for life on Earth.

A material's specific heat capacity is the amount of heat (or energy) required to increase the temperature of one kilogram of the material by 1°C. You can think about heat capacity as "thermal inertia." Similarly, for objects with a lot of physical inertia, you have to put in a lot of energy to get them to move. For objects with a lot of thermal inertia, you have to put in a lot of energy to get them to heat up. Every material has its own specific heat capacity. The **specific heat capacity** of water is higher than soil. This means it takes more heat to raise the temperature of water than the same amount of soil. It takes a lot of energy to heat up water. Large bodies of water, like the ocean, don't change temperature very much throughout the year. That is partly why, in coastal areas, the temperature doesn't change much throughout the year, or between day and night. The ocean keeps the temperature on land relatively stable.

In addition, land is darker than water so it absorbs better the heat. In water, the heat can go farther down and spread out. Soil keeps the heat on the surface. If you dig down on a hot beach, you find that sand underneath is cool. Sunlight can't pass through it. The surface, therefore, becomes very hot.

Near the sea there is often a breeze blowing from the ocean toward the land during the day and a breeze blowing from the land toward the ocean at night. These breezes are due to the different heating and cooling speed of land and water. During daytime, the land gets much warmer than the water. The air above the warmer land heats up, rises and air pressure decreases. The air above the sea heats up more slowly, resulting in a pressure difference. A pressure difference causes a wind, with the wind blowing from the area with the higher pressure to the area with lower pressure. During the day, there is a wind blowing from the ocean toward the land. When the Sun sets, the reverse process takes place. The land cools down much faster than the ocean and we end up with the land being cooler than the ocean. Once again, the air above the land and the ocean changes temperature accordingly. There is a breeze from the land toward the ocean.



Sea breeze (A) and Land breeze (B) (Source: Wikipedia, CC licensed)

Conclusion



The specific heat capacity of water is higher than soil. This means it takes more heat to raise the temperature of water than the same amount of soil. This is the cause of temperature differences between land and sea and of sea and land breezes.

Important tips



Don't be troubled if there is no clear pattern; you can use this to point out to students that this is often how science works. We did not find a definitive answer to the question "why do some materials heat up and cool down at different rates?" but we know a whole lot more than we did when we started! And we have lots of ideas about other tests we could do to learn more. This is how the process of science works — often, scientists can't answer a question with a single experiment. It can take many experiments, over many years, to slowly learn more about it.

6. Atmospheric Pressure (1)

Objectives

- Students can do an experiment to prove the presence of air.
- Students can correctly draw conclusion about presence of air from their observations.
- Students develop interest in climate phenomena linked to their daily life.



Link with curriculum

Grade 11, Chapter 3, lesson 2 (2011)



Material needed

- clear drinking glass
- paper towel/napkin or a piece of newspaper
- bowl (deeper than the height of the glass)
- water



Procedure

- Fill the bowl with water. (The bowl should hold enough water in order to submerge the glass). Crumple the paper and push it tightly into the bottom of the glass. (If the paper is packed tightly enough, it will stay inside the glass when the glass is turned upside down.) You may use some tape to stick the paper towel at the bottom of the glass)
- Hold the glass upside down and submerge it without tilting in the bowl with water. Hold it for a few seconds.
- Pull the glass slowly out of the water. Pull the glass straight up out of the water and allow the water to run off.
- Take the paper towel carefully out of the glass and observe it.



Observations



Before the experiment:

- Is there air in the glass?

During the experiment:

- Is there still air in the glass?

After the experiment:

- What did you observe?
- What happened with the paper?
- Was there any change in the water level of the bowl during the experiment?
- Where was the air during the experiment?

Explanation



Air occupies space. Beside the paper, the glass was full of air. It takes up space and prevents the water from entering. The air inside the glass is trapped between the paper towel and the water.

If you put the glass in the water in an slanted way, the air can escape and the paper will get wet.

Slightly tip the glass to allow a bubble of air to escape and float to the surface of the water. The air bubbles show there is air inside the glass. As the air moves out of the glass, it is replaced by the water.

Conclusion



Air is not nothing, but is matter that takes up space and exerts pressure.

Questions



1. Why is it important to submerge the glass under a right angle? *If you don't submerge the glass under a right angle, air will be able to escape out of the glass.*

7. Atmospheric Pressure (2)

Objectives

- Students can do an experiment to prove that air exerts pressure
- Students can explain the result of experiment in their own words
- Students develop an interest in science as a result of discrepant events



Link with curriculum

Grade 11, chapter 3, lesson 2 (2011)

Material needed

- a glass, filled with water
- an index card, if possible with a shiny side (laminated card, photo)
- bucket

Procedure

- Fill the glass full with water. Use preferably a glass with a smooth rim.
- Put the card on the glass with its shiny side down.
- Turn around the glass cautiously. Do this above a bucket.

Observation

- What do you observe?
- Try to formulate an explanation for the experiment. Make a drawing.





Explanation

Air is everywhere and pushes in any direction. If the glass is upside down, air pushes from the bottom against the card. From the top the water presses because of its weight. Still, the water doesn't fall out of the glass, because the air pushes harder against the card than the water.

Air presses with an equivalent of one kilogram per square centimetre ($10\text{N}/\text{cm}^2$) in all directions, so also against the card. A litre of water weighs about one kilo. With every square centimetre surface, it can support a litre of water. The opening of a glass has a surface of approx. 15 square centimetres. So you can easily hold the glass upside down with a card. This implies that the shape and size of the glass don't matter.

Besides the air pressure, the surface tension of the water and the adhesion between the water and the card help holding the card in place.



Conclusion



Air is not nothing, but is matter that exerts atmospheric pressure. This pressure can be greater than the pressure exerted by a liquid.

Questions



1. Does it matter whether the glass is full with water or half full?

Yes, the glass needs to be full or almost full. If the glass is only half full, the air in the glass pushes the paper downwards.

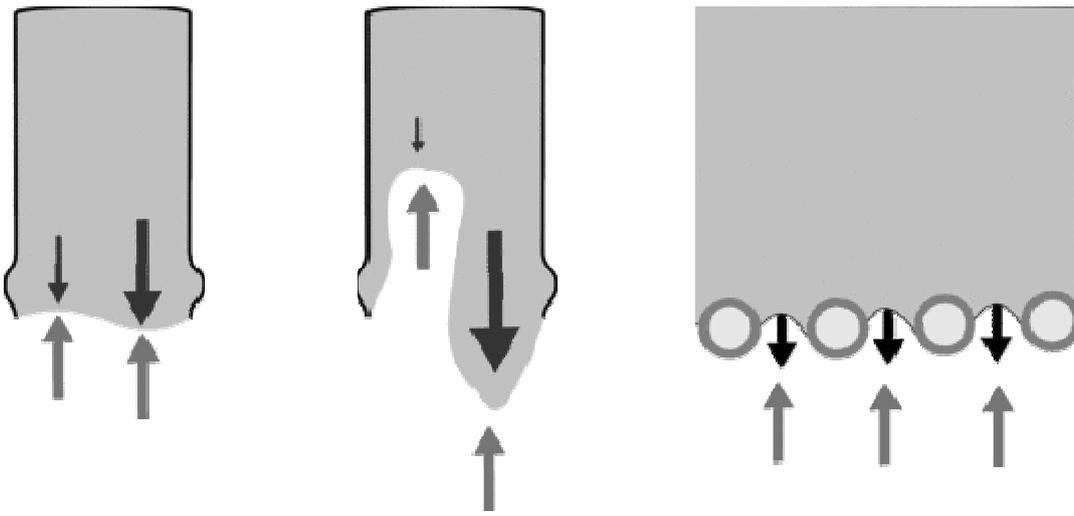
2. What happens when the glass is filled with sand instead of water? Why?

The sand will fall. It's not only air pressure but also the surface tension of the water and the adhesion between the water and the card that keeps the water in the glass. To illustrate the importance of surface tension, rub soap around the rim of the glass before you do the experiment. That significantly reduces the surface tension of the water.

3. Why do you need a smooth index card and doesn't the experiment work with, for example a towel?

The explanation given above is the basic principle. In fact, an important condition for keeping the card in place is that there is not too much *pressure difference* between different contact surface point of the card and the water.

In the case of a towel, small texture differences in the towel create slightly different water column depths, and, as a consequence, different pressures building up. The initial small difference get bigger and bigger until the towel or card falls. There is nothing stopping the slight unevenness in the base of the water growing (see figure below). The surface tension of the water helps keeping the card in place because it reduces pressure differences between contact surfaces.



Source: Wikipedia (CC licensed)

8. Atmospheric Pressure: Falling Parachutes.

Objectives

- Students can do the experiment correctly.
- Students can draw conclusions about the presence of air through the experiment.
- Students can explain why some things fall faster than others (in the presence of air).



Link with curriculum

Grade 11, Chapter 2, lesson 2

Material needed

- 2 lightweight plastic bags
- scissors
- tape
- 3 identical light weights (stationary, small stones)
- meter stick
- strings





Procedure

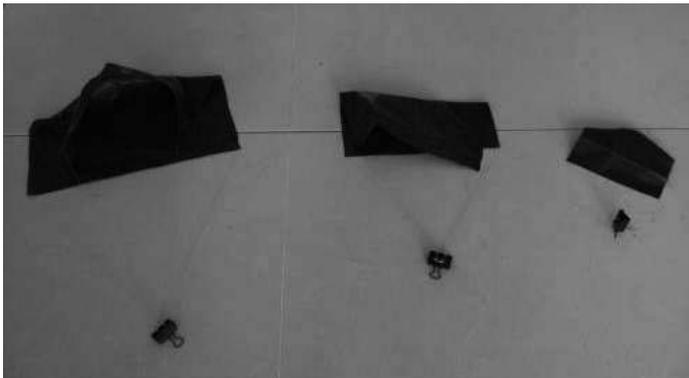
- Cut out a square from one of your plastic bags. The square should be about 25cm x 25cm.
- Cut 4 pieces of string so that each piece goes from one corner of the square to about 5cm past the centre of the square. Tape each piece down at the corner.
- Bring the free ends of the strings together and use a piece of tape to attach a light weight to the four strings. Your piece of bag, strings, and weight should look like a little parachute.
- Use the rest of your first bag and another bag to make two more parachutes. Make one about 15cm x 15cm. Make the other about 35cm x 35cm. Use one weight on each, as you did with your first parachute.
- Let students hold the parachutes and drop them from as high as possible.



Observations

- Which parachute do you think will fall fastest? Why?
- Why doesn't it fall as fast as a stone?
- What would happen to the parachutes if the air really was empty?

The small parachute will reach the ground the first, after that the medium parachute will land and finally the biggest parachute.



Explanation

Air is not empty (vacuum), but is a mixture of various gases.

The contact between the parachutes and the air causes friction. So the bigger the surface of the parachutes, the more friction the parachute encounters with the air and the slower it will fall down.

If the air were empty all parachutes would reach the ground at the same time.



Conclusion

Air is not empty (vacuum), but is a mixture of various gases.

9. Effect of Heating and Cooling Air on Air Pressure (1)

Objectives

- Students can describe the relation between air temperature and pressure.
- Students can perform a simple experiment to illustrate the effect of the changing temperature of air on air pressure.
- Students understand how changes in the temperature of air affect climate phenomena.



Link with curriculum

Grade 10, chapter 3, lesson 2 (2010)



Material

- Plastic bag
- Ice (or cold water)
- Plastic bottle with cap (small or large)



Procedure

- put the ice cubes in the plastic bag
- crush the ice
- put the ice in the bottle
- put the cap on the bottle
- shake the bottle



Observations

- What happens in the bottle?
- What effect does the ice have on the air in the bottle?
- What happens with matter (air) when it cools?
- What has happened with the air pressure in the bottle?
- Is the air pressure in the bottle higher or lower than the surrounding air pressure?
- What do you notice inside the bottle?



Explanation



The melting of the ice causes the air to get colder. As a consequence the air pressure will decrease (ideal gas law). The air molecules exert less pressure on the sides of the bottle causing it to crunch (pressure inside the bottle is lower than outside the bottle). Water vapour condensates within the bottle. When you open the cap, air flows in (from high to low pressure) until air pressure inside and outside is equal. The bottle will retake its original shape.

Conclusion



According to the Ideal Gas Law cold air exerts a lower pressure than warm air, resulting in the bottle getting squeezed.



10. Effect of Heating and Cooling Air on Air Pressure (2)

Objectives



- Students can describe the relationship between air temperature and pressure
- Students can draw conclusions based on experimental observations.
- Students understand the relationship between a number of factors affecting weather and climate.

Link with curriculum



Grade 10, chapter 3, lesson 2 (2010)

Material



- glass bottle
- balloon
- cold and hot water

Procedure



- Pull the balloon over the end of the bottle
- Let hot water flow over the bottle
- Let cold water flow over the bottle

Observations



- What happens with the air in the bottle when hot water is poured over it?
- Describe what happens with the balloon. How can you explain this?
- What happens with matter when it is heated?
- What happens with the air in the bottle when cold water is poured over it?
- Describe what happens with the balloon. How can you explain this?
- What happens with matter when it is cooled?

Explanation



When you put the balloon over the bottle, the air pressure inside the bottle is equal to the air pressure outside the bottle. When you place the bottle over a heat source, the temperature inside the bottle rises and there and the air pressure increases. The higher pressure inside the bottle causes the balloon to be blown. When you cool down the balloon, the reverse process takes place.



Heating the water and the air inside the bottle increases air pressure inside the bottle and inflates the balloon.



Cooling the bottle reduces pressure inside the bottle and the balloon deflates.

Conclusion



Heating the air inside the bottle increases the air pressure. This higher pressure causes the balloon to be blown up. When you cool down the bottle, the reverse process happens.

11. Effect of Heating and Cooling Air on Air Pressure (3)

Objectives



- Students can describe the relation between air temperature and pressure.
- Students can perform a simple experiment to illustrate the effect of the changing temperature of air on air pressure.
- Students understand how changes in the temperature of air affect climate phenomena.

Link with curriculum



Grade 10, chapter 3, lesson 2 (2010)

Material



- an empty plastic bottle (soft plastic!)
- hot water

Procedure



- Fill the bottle with hot water almost to the top.
- Pour the bottle out after a few seconds and put the cap on the bottle immediately.

Observations



- What happens with the bottle during the experiment?
- Where is air pressure the highest?
- What is the consequence for the bottle?



Explanation



We fill the bottle nearly full with water. The hot water heats the bottle. When you pour the water out, warm air takes its place. We put the cap immediately back on the bottle, trapping the hot air inside. When the air cools down, the pressure decreases. The higher pressure outside crushes the bottle.

Conclusion



Molecules in hot air moves faster than in cold air, creating more air pressure.

12. Effect of Heating and Cooling Air on Air Pressure (4)

Objectives

- Students can explain their observations applying their understanding about pressure and temperature.
- Students can illustrate the relation between temperature and pressure with a simple experiment.
- Students take necessary precautions when doing the experiment.



Link with curriculum

Grade 10, chapter 3, lesson 2 (2010)



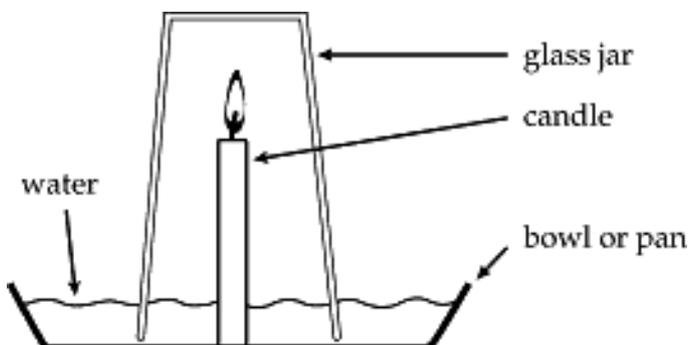
Material needed

- Glass or small thin jar
- (thick) cork
- candle
- large bowl
- water
- food colouring (optional)



Procedure

- Fill a bowl nearly to the rim with water. You may add a few drops of food colouring to make it easier to observe.
- Take a tall glass or thin jar. Measure its total height and mark on the glass how high the water is coming.
- Mount a candle on a cork. Both must fit inside the glass.
- Light the candle.
- Place the glass or tall jar over the burning candle and cork. Push the glass straight down into the water until the top touches the bowl.
- Wait until the candle goes out and mark on the glass how high the water is coming.



Experimental setup (Source: Wikipedia, PD)



Observations

Repeat the experiment several times if necessary. Ask students following questions:

- What is inside the glass when we put it on the candle?
- What happens when the candle goes out?
- Is the change in water level gradually or suddenly?
- After burning, we have low or high pressure in the glass? How do you know?



Explanation

The candle flame heats the air inside the bottle and this hot air expands. Some of the expanding air escapes out from under the bottle — you might see some bubbles. When the flame goes out, the air in the jar cools down. The cooler air contracts and creates a vacuum. This imperfect vacuum is created due to the low pressure inside the bottle and the high pressure outside of the bottle. Gases exerting pressure from an area of high pressure to an area of low pressure cause the water level to rise.

You can redo the experiment with more candles. More candles lead to more heat, a higher temperature before they are extinguished and therefore a higher water level upon cooling.

The fact that there is a disparity in water depth between one candle and more candles shows us that the absence of oxygen cannot be the key factor, because the same amount of oxygen is consumed in each case.

This happens also in real life and it causes wind. With low pressure air is rising and the air of the high pressure moves to the low pressure area and fills up the space.

An often cited alternative wrong explanation for this experiment is that the rising water level is due to the candle burning oxygen with the resulting carbon dioxide being dissolved in the water. How could you test whether this explanation is correct? *Do the experiment with different candles or with a larger candle (see explanation). Also, careful observation shows that the water level doesn't rise gradually but suddenly, after the candle goes out. This explanation is not correct.*



Variation

This experiment allows for further investigation. You can let your students hypothesize and investigate the effect of candle size and the shape of the bottle. Possible questions include:

- What effect does the size of the candle have on how high the water rises?
- What effect does the size of the bottle or jar have on how high the water rises?
- What effect does the shape of the bottle or jar have on how high the water rises?

For each of these observations, write down what you think will happen.

- Can you think of ways to test your ideas? (it's okay to have more than one for each observation)
- Do all your observations support your explanation? If not, why?
- Do you think you could prove your explanation?



Conclusion

Gases exerting pressure from an area of high pressure to an area of low pressure cause the water level to rise.

13. Effect of Heating and Cooling Air on Air Pressure (5)

Objectives

- Students can describe the relationship between air temperature and pressure
- Students can draw conclusions based on their observations
- Students understand the relationship between factors affecting weather and climate



Material

- Glass bottle with broad neck
- Hard-boiled egg, peeled
- Towel (or gloves)
- Hot and cold water



Procedure

- First, rinse the bottle with hot water. Protect your hands with a towel or gloves. An alternative is to set a piece of paper on fire and drop it into the bottle.
- Then, put the egg on the neck of the bottle.
- Put the bottle (with the egg) in a bath with icy cold water.



Observations

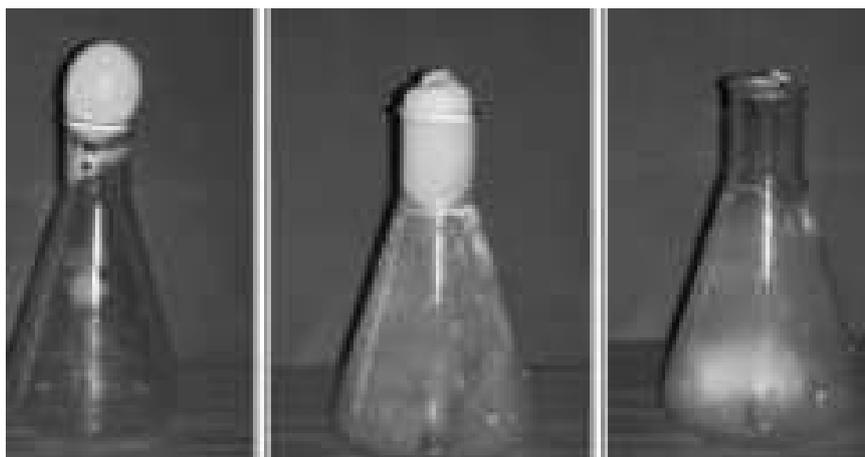


Before the experiment:

- Which diameter is the biggest? The bottle top or the egg?
- How can you get the egg inside the bottle without touching the egg?

During the experiment:

- What do you observe during the experiment?
- What happens with the air in the bottle?
- What happens with the air pressure in the bottle?
- Why does the egg fall in the bottle?



After the experiment:

- Would this experiment still work if you leave the egg in its shell?
- How can we get the egg out of the bottle again?

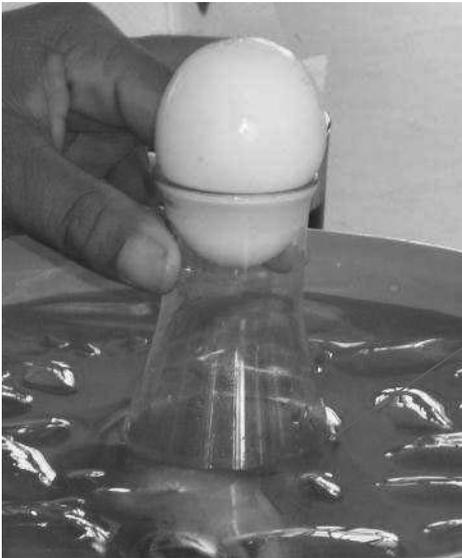
Explanation



If you just put the egg on the bottle, its diameter is too large to slip inside. The pressure of the air inside and outside of the bottle is the same, so the only force that would cause the egg to enter the bottle is gravity. Gravity isn't sufficiently strong to pull the egg inside the bottle.

When you change the temperature of the air inside the bottle, you also change the pressure of the air inside the bottle. If you have a constant volume of air and heat it, the pressure of the air increases. If you cool the air, the pressure decreases. If you can lower the pressure inside the bottle enough, the air pressure outside the bottle will push the egg into the container.

It's easy to see how the pressure changes when you cool the bottle, but why is the egg pushed into the bottle when heat is applied. When you heat, the bottle and the air are heated. Air molecules escape from the bottle until the pressure both inside and outside the bottle is the same. As the bottle and air inside continue to cool, a pressure gradient builds, so the egg is pushed into the bottle.



Cooling the bottle in ice water makes the air inside the bottle contract, reducing air pressure. The pressure gradient pulls the egg into the bottle.

Conclusion



A difference in air pressure, created by a difference in temperature causes the egg to move inside the bottle.

Questions



1. *How to get the egg back out the bottle?*

You can get the egg out by increasing the pressure inside the bottle so that it is higher than the pressure of the air outside the bottle. Roll the egg around so it is situated with the narrow end resting in the mouth of the bottle. Tilt the bottle just enough so you can blow air inside the bottle. Roll the egg over the opening before you take your mouth away. Hold the bottle upside down and watch the egg 'fall' out of the bottle.

2. *Would this experiment still work if you leave the egg in its shell?*

The experiment won't work if the egg is in its hard shell. The shell is not flexible and will never be able to go through the little diameter of the bottle top.

14. Functioning of a Barometer

Objectives

- Students can explain how a barometer works
- Students can make their own low-cost barometer
- Students develop interest in developing simple teaching material



Link with curriculum

Grade 11, chapter 3, lesson 2 (2011)



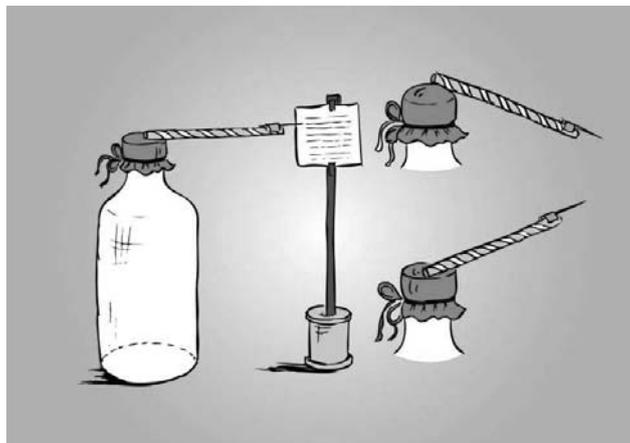
Material needed

- balloon
- narrow mouth jar
- rubber band
- drinking straw
- glue
- paper
- straight pin



Procedure

- Stretch the balloon over the top of the jar.
- Fasten it with the rubber band or string.
- Glue the straw horizontally, starting from the centre of the rubber, so extends beyond the edge of the top of the jar.
- Attach the pin to the free end of the straw.
- Prop up a marked index card so that you can follow the movement of the straw.
- Make a horizontal line on the paper at about the height of the jar. Make four lines above and below the line at 0,5 cm intervals. Write the words HIGH and LOW on the paper.
- On the paper, mark and date the position of the straw for at least five days.





Explanation

The unattached end of the straw (the pointer) sometimes moves up and sometimes down. The pressure inside the bottle is constant.

When air pressure increases, the pressure inside the bottle is lower than that of the air outside. Therefore the balloon rubber is pushed down, and the pointer end of the straw moves up. The pencil will point at the 'high pressure' part of the paper. When the air pressure goes down, the air inside the bottle presses harder than the outside air. The rubber pushes up and tightens, and the pointer moves down. The pencil will point at the 'low pressure' part of the paper.

Your balloon barometer functions like an **aneroid barometer**. A flexible top pushes in and out as air pressure changes, and moves the pointer around a scale on the face of the instrument.



Aneroid barometer (Source: Wikipedia, David R. Ingham, CC licensed)

In Cambodia air pressure determines the seasons. The monsoon cycle is driven by cyclic air pressure changes over central Asia. As pressure drops from June to October, moist air is drawn landward from the ocean bringing the southwest monsoon rains to Cambodia. During the winter months the weather is determined by a high pressure area over North Central Asia that brings a cool wind over Cambodia. From February onwards air pressure rises again, bringing on a largely rainless dry season.



Conclusion

A barometer is based on the principle that cold air exerts less pressure than warm air.

Activities on Air Pressure, Local and Global Wind Systems

15. Rotating mobile

Objectives

- Students can describe the phenomenon of rising and falling air masses.
- Students can explain the origin of wind as a temperature difference between air masses.
- Students develop interest in doing experiments using simple and low-cost materials.



Link to curriculum

Grade 10, chapter 3, lesson 2 (2010)



Material

- Paper spiral (made from a sheet of paper – see photo below)
- Candle



Procedure

- Keep the spiral paper in front of you. What do you observe?
- Keep the spiral paper above a heat source. What do you observe?



Observations

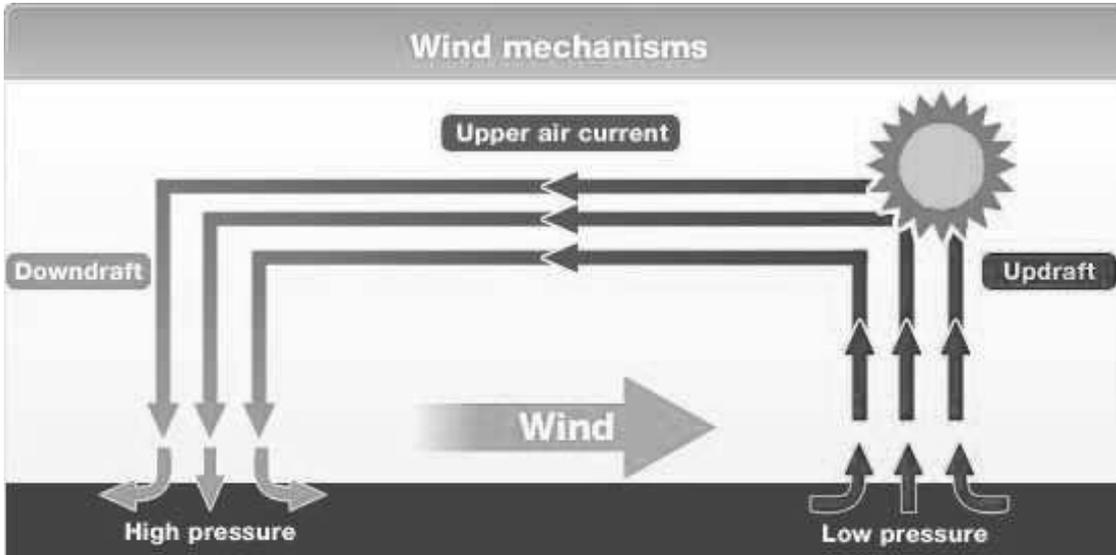
What is the effect of the heat source?





Explanation

The air above the candle heats up and expands. The density of the air decreases and the air rises. The flow of air comes into contact with the parts of the spiral, making it rotate. The surrounding cooler air flows in to take the place of the rising hot air. The candle heats up the cold air, which becomes hot and rises. In this way the mobile keeps rotating.



Source: HITACHI Environment

Conclusion



Hot air rises and cool air drops. This principle lies at the base of wind systems.



16. Wind model

Objectives

- Students can describe the procedure of rising and falling air masses.
- Students can explain the origin of wind as a temperature difference between air masses.
- Students develop an interest in doing experiments using simple and low-cost materials.



Link with curriculum

Grade 10, chapter 3, lesson 2 (2010)



Material

- One big plastic bottle
- small candle
- something that gives off smoke (incense, cigarette, ...)



Procedure

- cut the bottom off the 2-liter bottle
- cut a rectangular opening in the side
- set the bottle on a table with the cap off
- place the candle inside the bottle and light it
- hold your smoking object near the rectangular opening



Observation



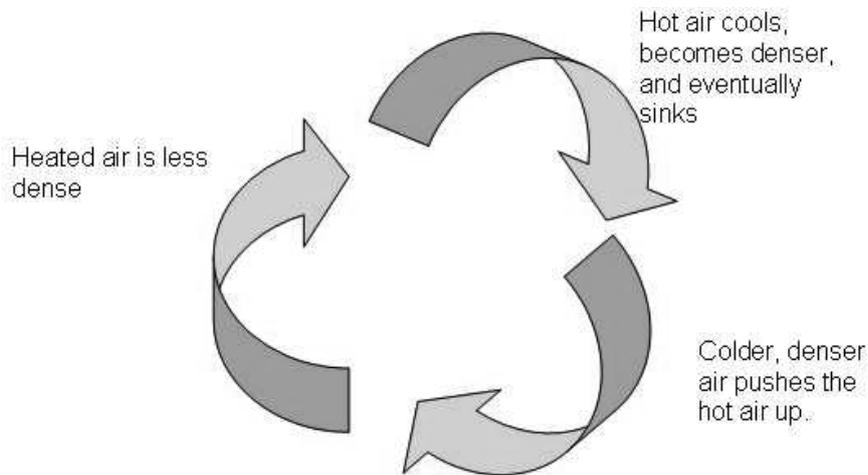
- Observe the movement of the smoke.
- Can you find an explanation?

The smoke moves from outside the bottle, through the opening, up inside the bottle, and then back down the outside of the bottle.

Explanation



This pattern of circulation of air is known as a convection cell. The hot air right above the candle is less dense than the cooler air outside the bottle. Cooler air takes its place and gets in turn heated by the candle and pushed upwards.



Source: Wikipedia (PD licensed)

Conclusion



Hot air rises and cool air drops, creating convection cells. Convection cells distribute heat energy in the Earth's atmosphere.

17. The Coriolis Effect

Objectives

- Students can describe the process that causes the Coriolis Effect
- Students can explain the influence of the Coriolis Effect on large scale wind and weather patterns.
- Students can illustrate the Coriolis Effect with a simple and low-cost experiment.



Link with curriculum

Grade 11, chapter 3, lesson 5 (2011)



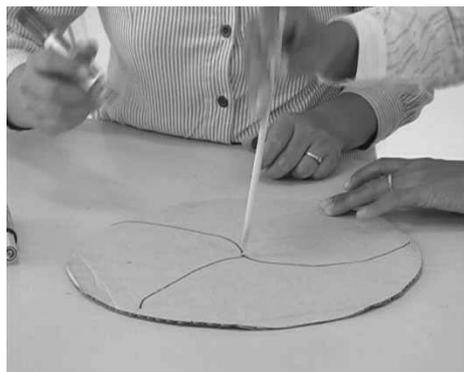
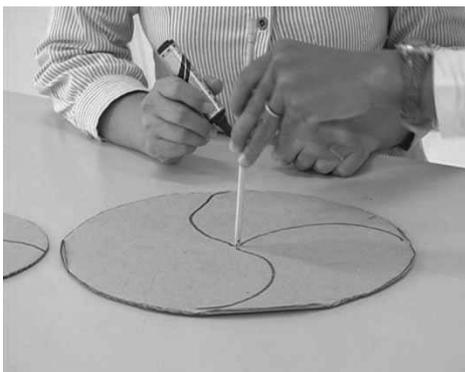
Material needed

- Paper (circle cut out)
- Small wooden stick
- Pencil or marker pen



Procedure

- place the sheet flat on a smooth surface
- ask a student to rotate the paper counterclockwise
- while this is going on, take your pen and try to draw a straight line from the paper rim toward the centre
- Now turn the paper upside down
- have the student rotate the paper clockwise
- try drawing lines from the outside to the centre

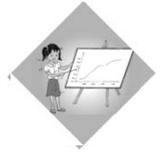


Observation

- Why can't you draw a straight line?
- Explain the difference between the two lines.
- What do the lines tell us about the rotation of the Earth?
 - What part corresponds with the poles and what part with the equator?
 - How are the lines deflected?

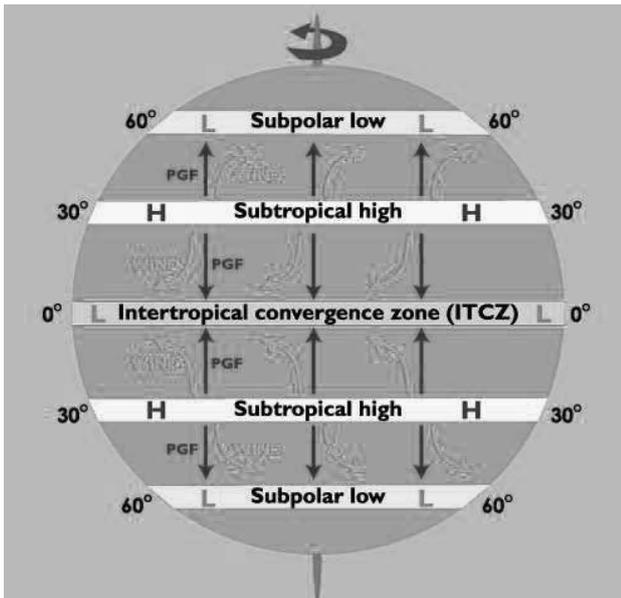


Explanation



On a rotating sphere, objects' linear speed varies depending on their distance to the rotation axis. This differential speed affects the direction in which winds blow. The Earth is a rotating object. If you'd look down on the Earth from above the North Pole, you would see that the Earth rotates counterclockwise.

The Coriolis Effect is caused by the different speed that objects rotate at various latitudes. An object at the equator moves at approx. 1700 km/h whereas an object at the poles moves at 0 km/h. You may use a globe to illustrate this.



Source: www.nasa.gov (PD licensed)

Spinning of the earth on its axis makes winds deflect from a straight line. This creates regular patterns of winds, blowing in the same direction most of time. Much of world's weather depends on this system of winds. The rotating pattern of winds around the centre of a hurricane is also an illustration of the Coriolis effect.



Source: www.nasa.gov (PD licensed)

The term “Coriolis force” is sometimes used. Since there is no external force involved, the term “Coriolis effect” is more correct.

If you have a plastic sphere or ball available and a marker pen, you can use these to illustrate the effect. Try to draw a straight line from the equator to the poles while someone rotates the globe.

Conclusion



The Coriolis Effect is caused by the rotation of the Earth. Because of this objects experience different speeds at various latitudes. The result is that movements of air and water are deflected from a straight line.

Activities on Convection and Currents

18. Experiment on Air Inversion

Objectives

- Illustrates the weather phenomenon of air inversions
- Points out the impact of air inversion
- Being cautious towards the health related impact of air inversion



Link with curriculum

Grade 11, chapter 3, lesson 3 (2011)



Material needed

- 2 glass jars
- hot water
- cold water
- index card
- match or lighter
- piece of twine, small stick or a cigarette



Procedure



Part 1

- Rinse one jar with very cold water and the other with hot water. Dry them thoroughly
- With the index card between them, place the jars mouth to mouth with the warm jar on the bottom
- Light the end of the twine so it smokes
- Direct the smoke into the bottom jar, as you lift the index card
- When smoke fills the bottom jar, pull out the card.

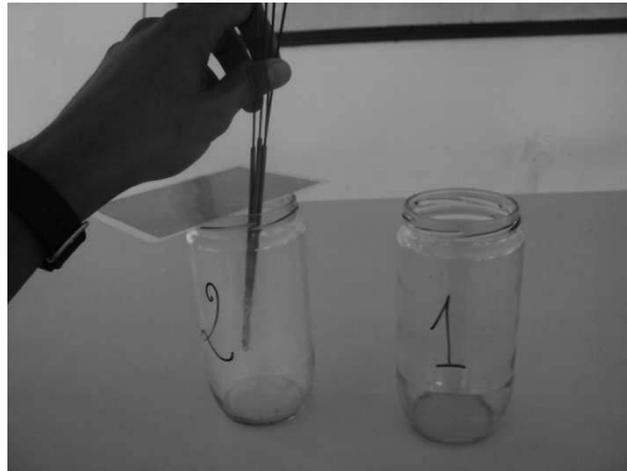


Figure 1.1



Figure 1.2



Figure 1.3

Part 2

- Do the same experiment with the cold jar on the bottom and the warm one on top.

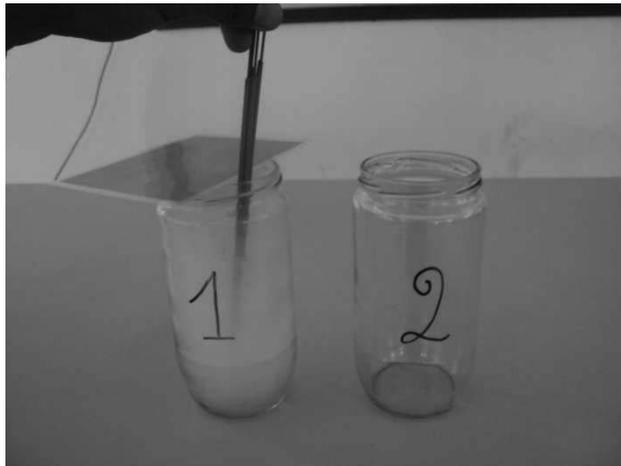


Figure 2.1



Figure 2.2

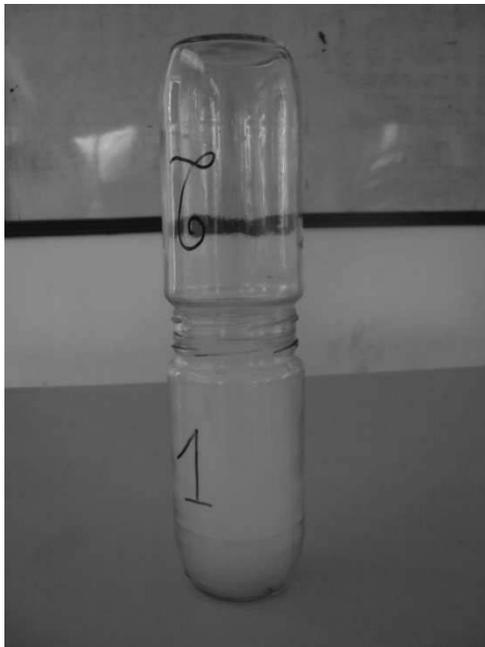


Figure 2.3

Observation

- What happens with the smoke? Explain the different observations in the two experiments.

Explanation

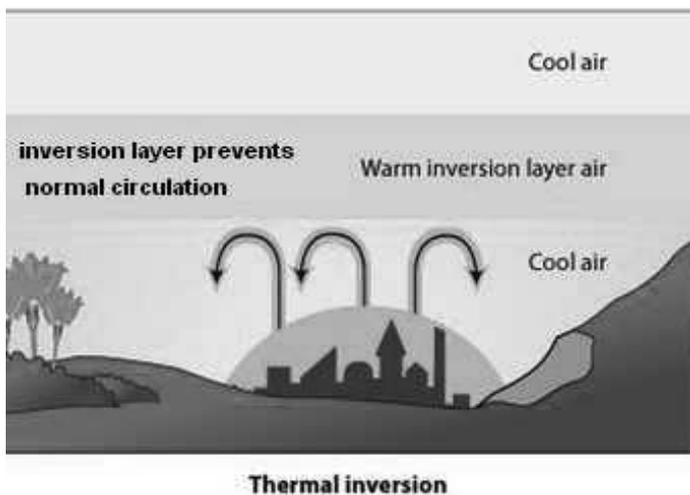
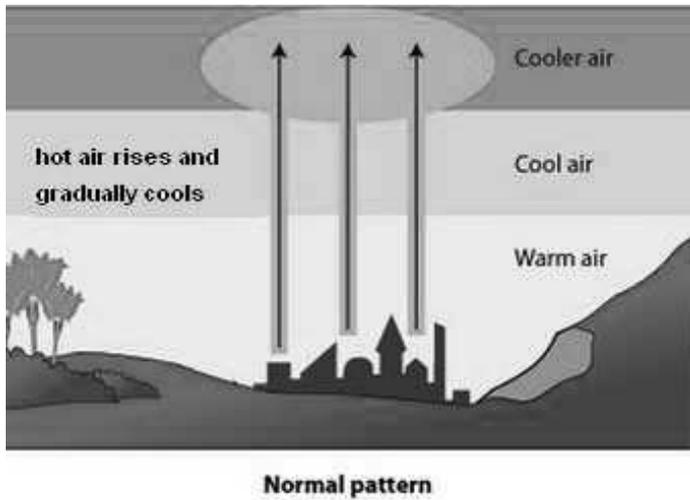
When the warm jar is on the bottom, the smoke rises from the lower to the upper jar. When the cold air is at the bottom, the smoke is trapped and cannot rise. The smoke rises as the warm, lighter, air rises and the cold, denser, air sinks. But when the cold air is trapped below the warm air, the smoke cannot escape. Usually, in the troposphere the air near the surface of the Earth is warmer than the air above it. This is because the atmosphere is heated from below as solar radiation warms the Earth's surface, which in turn warms the atmosphere directly above it.



Sometimes this situation is inverted such that the air is colder near the surface of the Earth. The warmer, less dense air mass moves than over the cooler, denser air mass.

Then, a layer of warm air holds down the dust particles in the cold surface layer. This is called an 'air inversion'. An inversion can lead to pollution such as smog being trapped close to the ground, with possible negative effects on health, such as coughing and breathing difficulties.

Smog is a kind of air pollution. The word is a combination from 'smoke' and 'fog'. The main sources of smog are emissions from cars and the burning of coal.



Source: minnesota.publicradio.org (PD licensed)

Conclusion



Air inversion means that warmer layers are above colder layers. This is the opposite of the normal situation in the Earth's troposphere where the temperature decreases with height.

Activities on Humidity and Clouds

19. Evaporation and Condensation

Objectives

- Students can distinguish and describe the processes of evaporation and condensation
- Students understand the role of water vapour in weather
- students develop an interest in doing scientific experiments



Link with curriculum

Grade 9, chapter 1, lesson 1 (2011)



Material needed

- big glass
- cold glass bowl with a round bottom that fits on the glass
- cold water



Procedure

- Put some cold water in the glass. A layer of ca. 5 cm is enough.
- Put the glass bowl on top so that it covers the opening of the glass completely
- Put everything on a warm spot and wait five minutes.



Observation

- What do you observe between the cold water and the glass bowl?
- What do you observe at the bottom of the bowl?
- How do you explain these phenomena?



Explanation

Between the cold water and the glass bowl, you can see water vapour condensing into small droplets of water. Condensation occurs when the air is saturated with water vapour. Cold air can contain less water vapour than hot air. Water vapour can be produced from the evaporation or boiling of liquid water or from the sublimation of ice.

Under normal atmospheric conditions, water vapour is continuously generated by evaporation and removed by condensation.



Conclusion



Air can contain a certain amount of water vapour. Warm air can contain more water vapour than cold air. As air cools, dissolved water vapour will condense and form water droplets.

Questions



Try to find examples of evaporation and condensation in daily life.

1. When we are boiling water, water molecules evaporate and condensate (what you see is not water vapour but condensed water droplets).
2. Water droplets appear on a cold glass. Breathing out on glasses, causes water vapour to condense on its surface.

20. Measuring Relative Humidity

Objectives

- Students are familiar with the function of a hygrometer.
- Students can make a simple hygrometer and use it correctly.
- Students can use a temperature table to determine relative humidity
- Students can link relative humidity with weather phenomena.
- Students develop interest in weather and climate.



Link with curriculum

Grade 11, chapter 3, lesson 8 (2011)



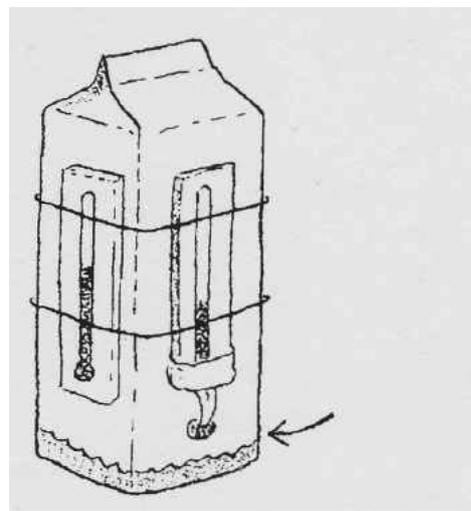
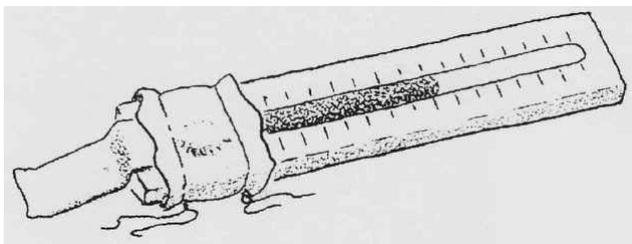
Material needed

- Carton box or plastic bottle (something to attach thermometers to)
- Two regular bulb thermometers
- A small piece of cloth
- Some thread or tape to attach the two thermometers to the box



Procedure

- Check the two thermometers to make sure that they register the same temperature
- Cover one of the thermometers with 5 cm piece of cloth. Tie it on with thread and leave a "tail" on one end, as in the illustration below.



Source: Churchill, E. R. et al., 1997 (All rights reserved)

- Use rubber bands to attach the two thermometers to two sides of the box.
- Cut a small hole in the box just below the thermometer with the covered bulb.
- Push the tail of cloth through the hole.
- Fill the box with water up to the level of the hole so the cloth can be kept wet.
- Read the dry bulb and wet bulb thermometers



Observations

The thermometers indicate a different temperature. The covered thermometer indicates a lower temperature.



Explanation

Water evaporating from the thermometer with moist cloth absorbs heat. Therefore, the temperature drops. The water in the cloth around the wet-bulb thermometer will keep on evaporating as long as the air can hold more water vapour. Dry air can take on more water vapour than air that is already filled with moisture. The drier the air (the lower the humidity) the further apart the two temperature readings will be. When the two temperatures are exactly the same, the humidity is 100 per cent. The higher the temperature, the more water vapour the air can hold at a particular temperature.

Check the readings of the two thermometers and use the table below to determine the relative humidity.

Dry-bulb temperature (°C)	Difference between dry-bulb and wet-bulb temperatures														
	0.5	1	1.5	2	2.5	3.0	3.5	4.0	4.5	5.0	7.5	10.0	12.5	15.0	
15	95	90	85	80	75	70	66	61	57	52	31	12			
20	95	91	87	82	78	74	70	66	62	58	40	24	8		
22.5	96	92	87	83	80	76	72	68	64	61	44	28	14	1	
25	96	92	88	84	81	77	73	70	66	63	47	32	19	7	
27.5	96	92	89	85	82	78	75	71	68	65	50	36	23	12	
30	96	93	89	86	82	79	76	73	70	67	52	39	27	16	
32.5	97	93	90	86	83	80	77	74	71	68	54	42	30	20	
35	97	93	90	87	84	81	78	75	72	69	56	44	33	23	
37.5	97	94	91	87	85	82	79	76	73	70	58	46	36	26	
40	97	94	91	88	85	82	79	77	74	72	59	48	38	29	
42.5	97	94	91	88	86	83	80	78	75	72	61	50	40	31	

Conclusion



A hygrometer uses the maximum amount of water vapour that air can contain to measure the relative humidity of the air. The larger the difference in temperature between thermometers, the lower the relative humidity is, or the drier the air is.



21. Constructing a Hygrometer

Objectives

- Students can make a simple hygrometer
- Students can observe changes in atmospheric pressure
- Students develop an interest in experiments which are linked to daily life



Link with curriculum

Grade 11, chapter 3, lesson 8 (2011)



Material needed

- Paper roll
- a pair of pushpins
- an emery board
- a long strand of human hair



Procedure

- Use a pushpin to poke holes in each end of the emery board.
- Put the two pushpins into the toilet-paper tube as shown in the picture.
- The emery board should be between the pushpin and the tube at the bottom.
- Tie one end of the hair to the pushpin at the bottom, place it up and around the top pushpin, and tie it through the free hole in the end of the emery board.
- Before you tie the last knot, adjust the length of the hair to obtain a result like in the figure.
- You may attach a toothpick to the emery board to act as a pointer and use a second toilet roll as a grading device to measure differences in humidity.
- Move it between a dry place (e.g. a freezer or a bottle filled with some ice) and a humid place to test if it works.



Strands of human hair are used to construct a basic hygrometer

Observations



Do you notice a change if you put the hygrometer in a more humid place?

In dry air, the emery board moves up. In humid air, the emery board moves down.

Explanation



Human hair absorbs and releases water as the humidity changes. As the humidity increases, the hair absorbs more water and, as a result, increases in length. The changes in length of the hair cause the emery board to move up and down. Now, the fact that human hair absorbs and releases water explains why you are more likely to have a bad hair day when the humidity is high.

The hair hygrometer works on the principle that organic fibre like hair absorbs water from the atmosphere. The more water a hair absorbs, the longer it gets. The drier the air is, the shorter the hair will grow. If the hair is affixed at one end and attached to a pointer at the other end, the hair will make the pointer move when the relative humidity changes.

Questions



1. Why do we experience high humidity as uncomfortable? Can you explain why a fan feels comfortable?

People sweat in order to cool off. When sweat evaporates, it takes heat from your body and cools you off. If the relative humidity is high, though, that means the air around you is already close to its saturation point. Therefore, for every bit of water that evaporates from your skin, almost as much water vapour from the air condenses on your skin, thereby warming your body again. Overall, there is very little cooling and you feel uncomfortable.

Conclusion



Strands of hair can relax and lengthen when the humidity increases, and then contract again when the humidity decreases. In fact, the rate of change in the length of hair strands is so dependable that they can actually be used as the basis for a hygrometer, a device that measures the humidity level in the air.

22. Formation of Clouds (1)

Objectives

- Students can explain how clouds form.
- Students can do a simple experiment to illustrate how clouds form.
- Students take necessary precautions when doing experiment that involve working with fire or hot water.



Link with curriculum

Grade 11, chapter 3, lesson 8 (2011)



Material needed

- big bowl with a broad neck
- tape
- matches
- hot water
- black paper or cardboard (to increase visibility)
- plastic bag with ice



Procedure



- Stick the black paper or cardboard to the back side of the pot, in order to have a dark background.
- Fill the pot with hot water.
- Light a match and blow it out. Wait a few seconds before you throw it into the pot.
- Put the bag with ice on top of the pot, so it forms a cold cover.
- Lift the bag after a while.

Observation



Record your observations:

- What happens with the hot water?
- What happens when it reaches the top of the pot?
- Can you observe a downward movement of white fog?
- How do you explain the observations?

Explanation



Rising water vapour condensates at the smoke particles and forms a cloud of small water droplets. When you lift the bag the cloud is released.

Clouds form because the warm, humid air rises, pushed upward by surrounding cooler air. As that warm, humid air cools, it gets cold enough for the water vapour in the air to condense into tiny water droplets, which make up clouds.

Conclusion



Clouds form when warm, humid air rises. As it cools, water vapour in the air condenses around condensation nuclei into tiny water droplets, which make up clouds.

Questions



1. *Without the smoke of the match, would you get clouds?*

Smoke particles give the molecules of water vapours something to hold onto, resulting in the water vapour condensing into water droplets, and a cloud. Small particles such as the particles of smoke are known as condensation nuclei. In general, water vapour needs condensation nuclei in order for clouds to form. In real life, these condensation nuclei can be smoke, salt in the air (near the ocean), dust, or even pollution.

2. *Why do you need to use hot water?*

In order to get clouds, you need humid air and a temperature gradient. Hot air can contain more water than cool air. When the hot air rises and cools, the air gets saturated and condensation occurs. Hot water is not strictly necessary, as long as you have humid air and a temperature gradient.

23. Formation of Clouds (2)

Objective



- Students can explain how clouds form.
- Students can do a simple experiment to illustrate how clouds form.
- Students take necessary precautions when doing experiment that involve working with fire or hot water.

Link with curriculum



Grade 11, chapter 3, lesson 8 (2011)

Material



- bottle with cap (use a plastic bottle that you can squeeze)
- matches
- (hot) water

Procedure



- Pour some hot water into the bottle.
- Light a match, blow it out and throw it into the bottle.
- Close the bottle.
- Squeeze the bottle.



Observations



What happens when you close the bottle? A white fog appears.
What happens when you squeeze the bottle? The white cloud disappears.

Explanation



When you close and squeeze the bottle, you decrease the volume and thereby increase the internal air pressure (since the temperature can be considered as constant). High pressure raises the condensation point and clouds disappear. When you stop squeezing the bottle, pressure is decreased and the condensation point is lowered. A white fog reappears.

This is similar to the real world situation. Areas of high pressure are associated with air moving downwards. This means this air doesn't encounter cooler temperatures nor a decreasing pressure, two causes of cloud formation. High pressure areas are generally associated with clear skies, whereas low pressure areas often cause cloudy skies.

Conclusion



Clouds form when air gets saturated with water vapour. This can happen when air cools, but also when the air pressure decreases. Increasing pressure raises the condensation point and clouds disappear.



Activities on other Weather Phenomena

24. Scattering of light and the blue sky

Objectives

- Students can explain why the sky is blue.
- Students can do a simple experiment to illustrate light scattering.
- Students develop an interest in doing simple experiments that are linked to daily life.



Link with curriculum

Grade 8, chapter 1, lesson 2 (2010)



Material needed

- a lemonade bottle or large glass
- a funnel
- water
- a little milk or milk powder
- a torch
- a darkened room



Procedure

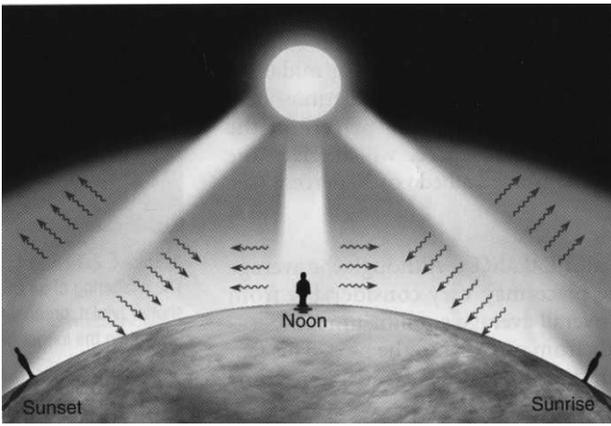
Part 1

- Fill the glass with water
- Add the milk or milk powder (do this very slowly as you only need a tiny amount)
- Turn the lights off
- Shine the torch up through the bottom of the bottle
- Look at the light coming straight through

Part 2

- add some more milk powder
- if nothing happens to the colour, you need to add more milk powder.
- if the light doesn't get through the bottle, you have added too much milk.





Source: Ahrens, 2007 (All rights reserved)

Observations

- Look at the light coming straight through the bottle.
- Look at the light coming out of the side.
- What happens to the colour?



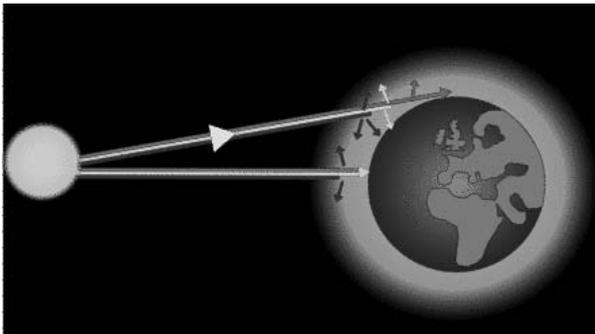


Explanation

Milk consists of tiny droplets of fat in the water. The white light coming from your torch is composed of all the colours of the rainbow. When the light hits the tiny fat droplets some of them are scattered.

The blue colours are scattered more quickly than the red colours (with green somewhere in between) this means that if you shine the light through a mixture all that gets through is the red light.

Right at the bottom there is lots of blue light scattering out of the sides so it has a blue tinge, as you go through more milk the blue light runs out so there is just red and green scattering so it looks yellow and then orange.

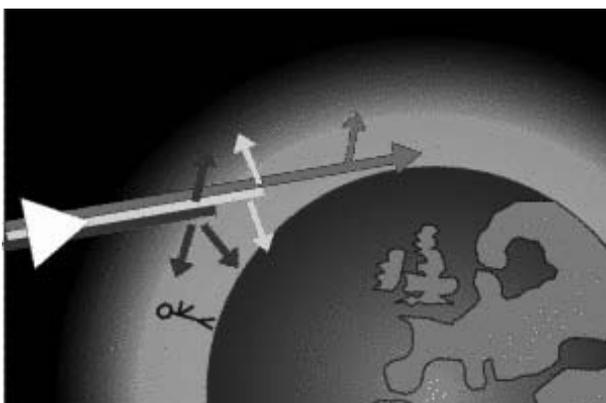


Source: www.sciencetheater.org (PD licensed)

The air molecules and any dust in the atmosphere act in the same way as the fat globules in the milk scattering more blue light than red. The sun actually looks white from space but if the light goes through some atmosphere some of the blue scatters out leaving yellow, which is why the sun looks yellow.

At sunset or sunrise the light grazes through the atmosphere at a low angle and so travels through much more atmosphere, so the only light that gets through is red, hence sunsets are red.

If there is lots of dust in the atmosphere, because of fires or volcanic eruptions then there are more particles in the atmosphere to scatter the light so the sunset is even more intense.



Source: www.sciencetheater.org (PD licensed)

If you look up in any direction other than up at the sun the only light you can see is the light that has been scattered, this is mostly blue, and so the sky is blue.

Conclusion



Water and dust particles scatter blue wavelengths more readily than red wavelengths. This explains the blue colour of the sky and the red colour of a rising and setting Sun.

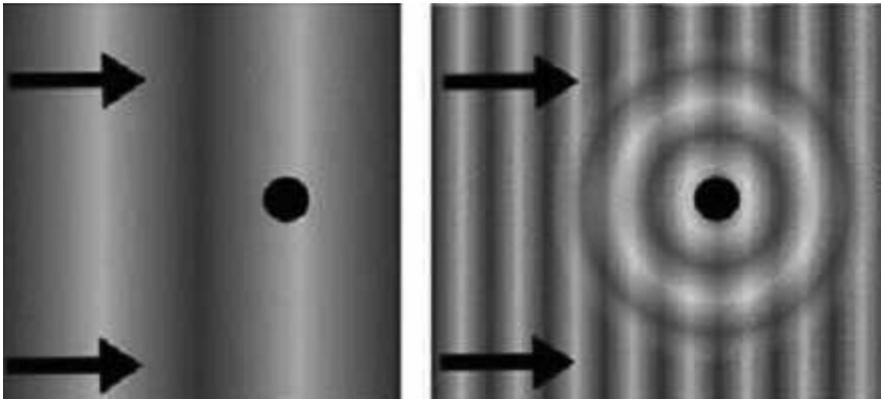
Questions



1. *Why does blue scatter more than other colours?*

Light is a wave, it is part of the electromagnetic spectrum which includes radio waves, microwaves, X-ray, gamma rays etc. Like any other wave, light waves have a wavelength (400nm-700nm). Light with different wavelengths has different colours. The long wavelength is equivalent to red and the short, blue (with green in between).

Red light's wavelength is significantly longer than the size of the particles. If you imagine a post in a harbour and a long wavelength ocean swell coming in, the post will just be too small to make much of a reflection (the difference in wave height between the two sides of the post is tiny so there is nothing to reflect).



However if there is a much shorter wave coming in (bluer) that is more similar to the size of the post, you will get much more of a reflection.

References

- Ahrens, C.D. (2007) *Meteorology Today: An Introduction to Weather, Climate and the Environment*, 8th ed. Brooks Cole.
- Arny, T. (2008) *Explorations: An Introduction to Astronomy, Volume 1 (Solar System)*, 5th ed. McGraw-Hill Science/Engineering/Math.
- Bohren, C.F. (2001) *Clouds in a Glass of Beer: Simple Experiments in Atmospheric Physics*, Dover Publications.
- Churchill, E.R., Loeschig, L.V. and Mandell, M. (1997) *365 Simple Science Experiments with Everyday Materials*, Unk. Black Dog & Leventhal Publishers.
- Strahler, A.H. and Strahler, A. (2002) *Introducing Physical Geography*, 3rd ed. Wiley.





**With the support of
THE BELGIAN
DEVELOPMENT COOPERATION .be**

With the support of
the government of Flanders

The logo of the Government of Flanders, featuring a stylized lion rampant on the left and three horizontal lines on the right.