Natural Science for Social Impact

St. Stanislav's Institution

Erasmus+

Sint-Calasanzinstituut

This brochure is the result of an Erasmus+ project under KA2 (Cooperation for innovation and the exchange of good practices) entitled Natural Science for Social Impact (abbreviation: NaSSI). It is a two-year project running between September 2014 and September 2016 with the Diocesan Classical Gymnasium within St. Stanislav's Institution, Ljubljana, Slovenia (the applicant institution) and Sint-Calasanzinstituut from the town of Nijlen, Belgium (the partner school) as participating schools. Both schools have been cooperating with each other since 2006 and in 2014 we decided to apply for an Erasmus+ project to enhance our cooperation and work on a joint project. Natural science teachers from both schools have participated in the project along with Institute for Education Research and Development (InERD) that has helped carry out some activities and coordination tasks.

The project focuses on natural sciences, energy, raw materials, sustainable development, environment, and climate change. In the first project stage, the Slovenian and Belgian syllabi of natural science subjects and approaches to teaching these subjects were compared with each other. Following this, materials were gathered and natural science lessons were prepared as examples of good practice. The brochure consists of 62 biology, chemistry and physics lessons that were designed by natural science teachers of both schools. The aim of the lessons is to improve the quality of natural science classes, develop problem-oriented approach, encourage independent and research work of students, acquire long-lasting and useful knowledge, and raise the interest of students in natural sciences. In addition to cooperation between teachers and lab workers of both schools, student exchanges were an important part of the project. The first exchange was held in October 2014 when 14 Belgian students and 2 teachers came to Slovenia for 8 days. A group of Slovenian students returned their visit in March 2015. In October 2015 and March 2016, another two exchanges took place with different students involved. In addition to getting familiar with various natural science topics, the advantages of exchanges are socialising with peers from another country, obtaining new experience, practising English, becoming familiar with natural and cultural heritage of another European country.

The participating teachers who prepared the lessons for this brochure hope that it will be useful for teachers of both partner schools and also broader and that they will find new ideas and opportunities for designing their lessons as well as extra-curricular activities.

Nasta Zupančič and Lieve Snels, *project coordinators*

Ljubljana and Niljen, May 2016

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BIOLOGY

ST. STANISLAV'S INSTITUTION

At the Workshop »Evolution of Man« (Natural Science Museum Brussels, March 2015)

A PROPORTION BETWEEN THE SPEED OF DIFFUSION AND THE SIZE OF A CELL

Cells are the basic building blocks of all living organisms. They get all the substances they need for functioning and metabolism from the outside through their membrane. This membrane also enables that cell and waste products go out of the cell. The supply to the cell depends on the amount and speed of the substances that enters the cell and the cell's needs increase with the growth in its size.

Therefore, the proportion between the surface of the area where the substances pass through and its volume is important. Cells cannot grow beyond a certain size. After the end of interphase, cell division occurs resulting in two new smaller cells. Their volume divides in half, the proportion between the surface and the volume increases (becomes more favourable), and the new cells can continue to grow and divide.

The purpose of this exercise:

The original purpose was to get to know how the proportion between the surface and the volume affects the life of a cell, to understand cell absorption, excretion, growth, and reproduction and to become familiar with diffusion (a way for the exchange of substances between the cell and its environment).

With this experiment, we are going to examine the features of diffusion, the influences of external factors on its speed, and the course of diffusion in different mediums.

Material:

- 3% agar-phenolphthalein cubes and 10% agar-phenolphthalein cubes
- millimeter ruler
- 4% NaOH solution, 1% NaOH solution
- plastic spoon
- razor blade or sharp scalpel
- paper towel
- ceramic or glass board
- pin
- thread
- 2 skewers

PERFORMANCE:

Exercise 1:

- Cut out three cubes of agar-phenolphthalein with sides: a = 1 cm, 2 cm, and 3 cm. Put them in a pot and pour NaOH solution over them so that they will be completely covered. Mark the time. In the next ten minutes, turn them around several times.
- In between calculate the volume, the surface area, and the proportion between the surface area and the volume using formulas.
- After 10 minutes, take the cubes out of the solution. Place them on the board and dry them with a paper towel. Cut each cube in two halves with a razor blade. Use a ruler to measure the depth of the coloured area representing the area of diffusion and also the depth of the uncoloured area. Be accurate and do not round off the results obtained.

HYPOTHESIS: NaOH moves into each of the cubes with the same speed (at the same time the phenolphthalein moves out); however, the proportion between the coloured and the uncoloured part will differ from cube to cube due to their difference in size (in case of bigger cubes, the uncoloured part will be bigger, whereas in case of smaller cubes, the uncoloured part will be smaller or even non existing (depending on time), because the proportion between the surface area and the volume is bigger in case of smaller cubes meaning it is more favourable (the cube with a = 1 cm has a proportion of 6:1, the cube with a = 0,1 cm has a proportion of 60:1).

Exercise 2

Do exactly the same as you did in exercise 1 with one exception: do not turn the cubes around in this 10-minute period. They should lie at the bottom completely covered with NaOH.

HYPOTHESIS: The surface which touches the bottom of the pot is not in direct contact with the solution. Therefore, the contact surface will be less coloured. Diffusion will occur on the other five surfaces of the cube and on the contact surface an uncoloured square will occur. With this, we want to show that diffusion only occurs in direct contact with the solution.

Exercise 3

Repeat exercise 1, but do not cover the cubes with the solution. Put them in a pot in which there is a thin layer of the solution. Upon placing the cubes in the pot, measure the depth of the solution and write it down. After ten minutes, compare the height of the coloured area and the depth of the solution. The results should be read from the outside of the cubes, so do not cut them. With this exercise, we want to find out how diffusion occurs not only between the cell and the solution but also in agar itself.

*Instead of the cubes, you can also use a bigger piece of agar in the shape of the spike.
This enables us to accurately measure the height of the diffusion's influence.

HYPOTHESIS: After 10 minutes, the level of diffusion will be higher than the level of the solution because diffusion will somehow occur due to different concentrations of phenolphthalein and NaOH. We predict that diffusion would be faster and bigger if the experiment was conducted with a real cell which interior is more liquid comparing to agar which is solid.

Exercise 4

For this exercise, you need two cubes of the same size (recommended a = 1 cm). Take the first one and put it in the NaOH solution for about 20 to up to 30 minutes and turn it around several times to ensure that diffusion is steady. Do not touch the other cube. After 20 or 30 minutes, take the first cube out of the solution and put it next to the other. Be careful that the surfaces of the cubes are flat and close to each other, because a contact is what is necessary.

HYPOTHESIS: In principle, diffusion should occur due to the difference in concentrations. However, it is likely to be very slow and shallow because of agar's density. Slight colouring is expected. You should leave the cubes together for 24 hours to ensure enough time for all the processes.

Exercise 5

Do exactly the same as you did in exercise 1, but then give one cube in the fridge (write down the temperature), one cube should stay at room temperature and the third one should be placed in the incubator with the temperature of 37°C. Compare the results after ten minutes. The cubes must be of the same size.

HYPOTHESIS: Diffusion is a consequence of particles' movement. They collide with each other and over time fill up the place in which they have not been originally. The energy of the particles also depends on heat; therefore, we expect that diffusion will be slower in the fridge compared to room temperature (but the fastest in the incubator).

Exercise 6

For this exercise, you need two beakers with different concentrations of NaOH solution (4% and 1%). Put one cube in each of the beakers. The cubes must be of the same size. Follow the instructions from exercise 1. Compare the results after ten minutes.

A similar experiment can also be conducted in a different way by using different agars. One agar cube should have 3% concentration of phenolphthalein, the other 10%. Put one cube in each of the beakers with the 4% NaOH solution. Follow the instructions from exercise 1. After 10 minutes of turning around the cubes, study the results.

HYPOTHESIS: With a bigger/smaller concentration of one or the other substance, we would increase/decrease its amount and thus change the speed of diffusion. If the concentration of NaOH is higher, it will permeate faster. In addition, phenolphthalein will move out faster if its concentration in agar is bigger.

Exercise 7

Cells in living organisms are different in shape (from long tubular neurons, epithelial cells of skin to wrinkled catarrhal epithelial cells). In order to define the influence of the cell shape and consequently its membrane on diffusion, we should resemble its shape with agar. For a neuron cell, cut a very thin and long piece of agar. For epithelial cells of skin, cut out square pieces, whereas for a catarrhal epithelial cell, cut out a cube and (from the top) cut two notches at an angle, remove the excessive agar to get deep dents that are densely scattered. In doing so, we improve the proportion between the surface and the volume. Cut out some spherical cells from agar. If you want, we can try making other shapes as well. All of them should be immersed in the 4% NaOH solution for the same period of time and turned around several times. At the end, compare the results.

HYPOTHESIS: Elongated cells and cells with a twirled surface let in and out a greater amount of substances because diffusion occurs through the membrane. A thin neuron and a catarrhal epithelial cell are doing the best. In case of the catarrhal epithelial cell, its shape is logical because it absorbs nutrients from food. In case of the neuron, its long and thin structure enables fast transmission of messages over long distances.

DETERMINATION OF ORGANIC COMPOUNDS WITH COLOUR REACTIONS

Scientific question:

What organic molecules does each of the food items contain?

Introduction:

In food analysis, one can use different reagents that point to the presence of certain compounds with a characteristic colour change. In doing this exercise, you will become familiar with tests for starch, sugar, proteins, and fats (greases and oils).

Organic substance	**Reagent**	**Positive reaction**
Starch	iodine (I_2/KI water solution)	Black (blue, purple, brown)
Sugar	Benedict's reagent	Green → light brown → brick brown
Proteins	conc. HNO_3 (xanthoproteic reaction)	Yellow
Proteins	$CuSO_4$, NaOH (biuret reaction)	Purple
Fats	/	Stain on a paper

Material:

- iodine (I_2/KI water solution)
- Benedict's solution
- concentrated nitric acid (HNO_3)
- 2% sodium hydroxide (NaOH)
- 1% copper sulphate ($CuSO_4$)
- 5 test tubes in a rack
- mortar with pestle
- glass rods
- droppers
- beaker filled with water
- water bath
- marker

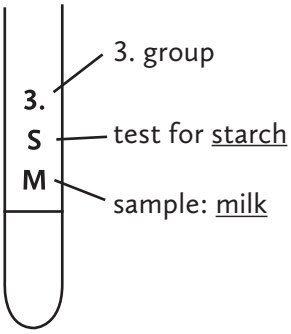
Food items:

- milk
- egg white
- bread slice
- apple
- peanuts
- wheat, corn grain
- beans
- grapes
- cheese
- potato

PERFORMANCE:

1. Prepare a food sample:

Add a food item and a bit of water to the mortar.
Use a pestle to get a liquid mixture
(approximately 20 mL).



2. Label each of the test tubes:

group, name of the test, sample

3. Do the testing:

Pour approximately 2 mL of the sample into each of the test tubes, add the needed amount of the reagent (see instructions for each of the tests), shake it and read the result. The result is positive if a typical colour occurs, otherwise it is negative (if there is another colour or if the colour is absent).

4. Writing down the results:

Draw up a table in which you are going to write down your results and the results of other groups.

1. Test for starch

Add some drops of iodine to the sample and read the colour.

2. Test for the determination of invert sugar

Put the same amount of the sample and Benedict's reagent in a test tube, cook everything for 5 minutes and read the temperature.

3. Test for proteins – biuret reaction

Pour the sample into a test tube, add some drops of $CuSO_4$, shake it and add NaOH (the same amount as the amount of the sample). Read the colour. With the biuret reaction, the presence of peptide bonds is determined.

4. Test for proteins – xanthoproteic reaction

Pour the sample into a test tube, add some drops of concentrated HNO_3.
Shake the test tube and read the colour. This test will be performed by your teacher.
With the xanthoproteic reaction, the presence of aromatic amino acids is determined (phenylalanine, tyrosine and tryptophan).

5. Test for fats

Add the sample to a paper towel or blotting paper and dry it with a hairdryer.
If there is a wet stain on the paper, the sample contains fats, otherwise not.

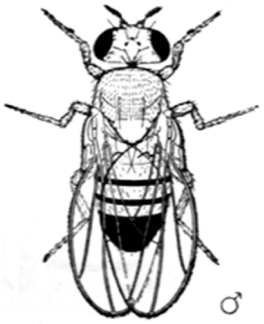
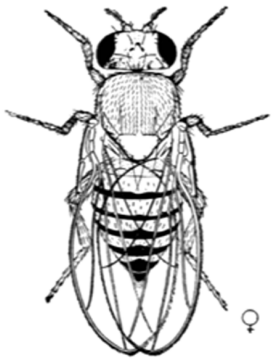
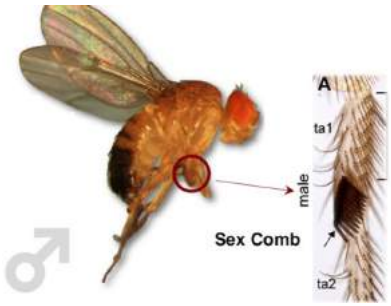
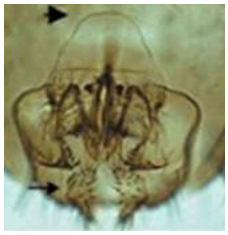
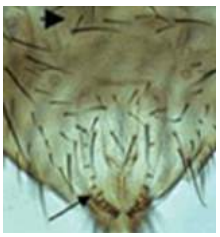
Questions:

1. What organic molecules does your sample contain?
2. Which foods contain starch? For which organisms is starch a typical molecule?
3. Is it possible to determine with Benedict's reagent which sugar is in milk?
4. What are the visible changes when concentrated nitric acid is added to an egg white? What is the conclusion based on these visible changes?
5. Which reaction should always signal the presence of proteins? Describe why.
6. How do you know that a drop on your clothing contains fats?
7. Draw a grain of corn cut in half, name its parts and colour it with appropriate colour pencils to show where individual organic molecules prevail.
8. Make a meal out of the tested foods. It should contain all kinds of organic molecules.
9. Is there another food you want to test? What organic molecules do you expect in this food?

FRUIT FLY SEX DETERMINATION

Fruit flies are common laboratory animals extensively used for genetic experiments. They have a very short life span, are easy to breed and have lots of offspring in a short period of time. Sexual dimorphism is their typical characteristic: the existence of physical differences between males and females.

In the table below, the morphological differences between male and female fruit flies are presented.

	Male	**Female**
		
Size	Smaller	Larger
Shape of the abdomen	Rounded	Pointed
Colour of the abdomen	Dark	Striped
Sex comb		
Sex chromosomes	 XY	 XX
Shape of the genitals	Bigger, more distinct 	Smaller, less distinct 

Material:

- fruit flies preserved in alcohol
- Petri dish
- setting needle or tweezer
- stereomicroscope

EXERCISE:

Carefully observe fruit flies in your Petri dish and find all of their morphological signs.
After that, divide the animals into two groups: a male and a female group. Take a picture of them.

Questions:

1. Decide whether the pictures below show male or female fruit flies and circle the visible signs that help you distinguish between males and females.



2. What was the easiest sign for distinguishing between males and females?
3. Which sex is more common among the fruit flies you observed?
4. What is sexual dimorphism? Find an explanation on the Internet.

GENETIC CODES AND ZOLES

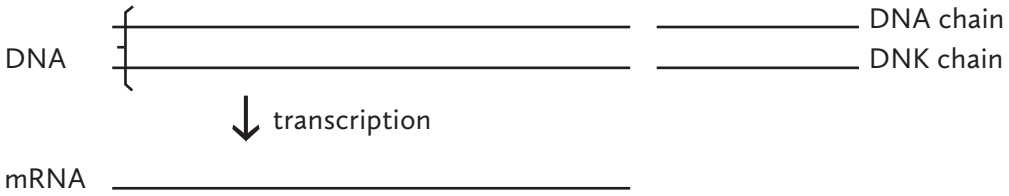
In this exercise, you will study the DNA sequences of imaginary organisms called Zols. You will define characteristics of a Zol, how they are expressed, and at the end draw a picture of it. In addition, you will get to know a chromosome, a gene, an allel, a codone, mutation, and how to decode a genetic code.

Zols have been discovered on a planet called De Zea in a remote galaxy. They have one chromosome containing 10 genes.

A gene is a part of a chromosome that carries a code for one protein which determines one characteristic of this organism (e.g. there is a gene which determines skin colour). Each gene can occur in two forms that are differently expressed (e.g. skin colour can be either red or blue).

1. **Draft Zol's chromosome – as a horizontal line – and its genes on it. Label the genes with numbers (Gene 1, Gene 2 etc.) from 1 to 10. In addition to numbers, write down a characteristic that is coded by each of these genes. Use Table 1 for help.**

Five Zols gave their DNA sample. Researches transcribed their DNA in a complementary mRNA chain. The process is shown in the following draft.



The sequences of the nucleotides in mRNA of these five Zols are presented in Appendix 1.

2. Write down the names of both chains on the right line. Which one is transcribed? Why is it said that in this process a complementary RNA chain is built?

Table 1: The table below represents genes or in other words characteristics that are coded by a particular gene, the sequences of amino acids in a protein that is coded by a particular gene, and a description of how a particular characteristic is expressed.

Genes – characteristics	Sequences of amino acids	How are these characteristics expressed
Gene 1 – hairiness	val - ser - leu val - ser - lys	Without hairs Hairy
Gene 2 – body shape	tyr - pro - glu - glu - lys val - pro - thr - glu - lys	Fat Thin
Gene 3 – number of legs	leu - leu - leu - pro leu - leu - ser - ala	3 legs 2 legs
Gene 4 – head shape	ala - val - val val - ala - ala	Rounded head Square head
Gene 5 – tail	his - ile his - his	With tail Without tail
Gene 6 – skin and hair colour	ser - pro - val val - phe - tyr	Blue hair and skin colour Red hair and skin colour
Gene 7 – eyes shape	asp - ile - leu - leu - pro - thre asp - ile - pro - pro - pro - thre	Small slanting eyes Big rounded eyes
Gene 8 – mouth shape	val - asp - asp - ala asp - asp - asp - ala	Rounded mouth Rectangular mouth
Gene 9 – ears shape	phe - ser - gly phe - phe - gly	Pointed protruding ears Rounded rolled ears
Gene 10 – arms shape	arg - tyr - cys - lys arg - arg - asp - thre	Long *spaghetti-like* arms Short stout arms

These genetic sequences are much simpler compared to the sequences of living organisms that exist in reality. Their genes are usually made up of several thousand or hundred thousand nucleotides and the proteins they code for can have from 100 to up to 100.000 amino acids.

Table 2: Genetic code, a collection of 64 triplets that mostly code for amino acids.

1st letter	Second Letter: U		Second Letter: C		Second Letter: A		Second Letter: G		3rd letter
U	UUU	Phe	UCU	Ser	UAU	Tyr	UGU	Cys	U
	UUC		UCC		UAC		UGC		C
	UUA	Leu	UCA		UAA	Stop	UGA	Stop	A
	UUG		UCG		UAG	Stop	UGG	Trp	G
C	CUU	Leu	CCU	Pro	CAU	His	CGU	Arg	U
	CUC		CCC		CAC		CGC		C
	CUA		CCA		CAA	Gln	CGA		A
	CUG		CCG		CAG		CGG		G
A	AUU	Ile	ACU	Thr	AAU	Asn	AGU	Ser	U
	AUC		ACC		AAC		AGC		C
	AUA		ACA		AAA	Lys	AGA	Arg	A
	AUG	Met	ACG		AAG		AGG		G
G	GUU	Val	GCU	Ala	GAU	Asp	GGU	Gly	U
	GUC		GCC		GAC		GGC		C
	GUA		GCA		GAA	Glu	GGA		A
	GUG		GCG		GAG		GGG		G

Names of amino acids:

Amino acid names			
Ala = alanine	Gin = glutamine	Leu = leucine	Ser = serine
Arg = arginine	Glu = glutamate	Lys = lysine	Thr = threonine
Asn = asparagine	Gly = glycine	Met = methionine	Trp = tryptophan
Asp = aspartate	His = histidine	Phe = phenylalanine	Tyr = tyrosine
Cys = cysteine	Ile = isolevcine	Pro = proline	Val = valine

Appendix 1: RNA SAMPLES of five Zols

A smiling Zol

GUC AGC AAA | UAC CCC GAA GAG AAA | CUC UUA AGU GCG | GCU GUU GUG | CAU CAU | GUU UUU UAC | GAU AUC UUA CUG CCC ACC | GAC GAC GAU GCC | UUU UCU GGG | AGA UAU UGU |

A snotty Zol

GUA UCU AAA | GUU CCU ACU GAA AAG | CUU CUC CUC CCC | GUU GCG GCU | CAU CAC | | GAU UUU UAU | GUA AUU CUU CUG CCC ACA | GUU GAC GAC GCA | UUC UCG GGU | AGA UAU UGU |

A lively Zol

GUC AGC CUU | GUU CCC ACA GAA AAA | CUC UUA AGU GCG | GUU GCG GCU | CAC AUU | UCU CCC GUA | GAU AUU CCC CCC CCC ACC | GAU GAC GAC GCA | UUC UUU GGG | CGC CGG GAC ACA ACA |

A curious Zol

GUA UCC CUC | UAC CCC GAG GAA AAA | UUA UUA CUG CUA CCC | GCU GUU GUA | CAU AUU | UCU CCC GUA | GAU AUU CUU CUG CCC ACA | GUU GAU GAU GCC | UUU UCU GGU | CGC CGU GAC ACG |

A surprised Zol

GUA UCG UUG | GUG CCG ACG GAG AAG | CUU CUC CUA CCU | GUG GCG GCG | CAU AUU | UCG CCG GUG
GAC AUA CCA CCG CCA ACG | GUG GAC GAC GCA | UUU UUC GGG | AGG CGU GAU ACA I

Analysis sheet

Name of the analysed Zol:

Genes	**Number of amino acids that this gene codes for**	**Expressed characteristic**
Gene 1		
Gene 2		
Gene 3		
Gene 4		
Gene 5		
Gene 6		
Gene 7		
Gene 8		
Gene 9		
Gene 10		

3. Analyse one Zol.

a) Cut paper into two strips (width: 10 cm, length: between 50 and 100 cm).
Take one strip and write three parallel lines on it. This strip is mRNA.

b) On the middle line, copy the sequences of RNA nucleotides of your Zol (see Appendix 1).
Before and after each of the genes leave a free space to write down three nucleotides.
Demarcate the genes by upright lines.

c) With the help of Table 2, translate the sequences of nucleotides into the sequences of amino acids and write them on the upper line (each of the amino acids above each of the nucleotides' triplets).

d) With the help of Table 2, determine Zol's phenotype (observable characteristics) and write them down on the lower line.

e) Draw your Zol with colouring pens on an A4 sheet of paper.

f) On the second strip, draw two parallel lines and the sequences of nucleotides in DNA on them.

g) Fill out the analysis sheet and answer the questions.

Questions:

1. Are all genes of the same length? Justify your answer.
2. Do all Zols have the same number of genes? How many?
3. What does it mean to analyse RNA sample?
4. With which triplet does each gene start? What does this triplet code for?
   Write it down on the strip.
5. With which triplet does each gene end? How many of such triplets exist?
   Do they code for amino acids? Write them down on the strip.
6. Does an individual amino acid always have the same triplet? Justify your answer.
7. Technical name for RNA triplet:
8. There is a mistake in one of the genes. In which one? What kind of a mistake is it?
   Mark it on the strip.
9. Is it possible that a mistake occurs while transcribing?

MOSSES

Mosses (*Bryophyta*) are small soft plants that typically grow up to 10 cm; however, some species are taller. They usually grow in dense clumps or mats, often in damp or shady locations. They do not have blossoms and seeds and their leaves are attached to thin thread-like stems. Their cuticle is thin; therefore, it is difficult for them to prevent water from evaporating. In dry periods, they can desiccate, but if it is raining, they soon make for the evaporated water. Mosses have a great ability of water absorption, above all different species of peat moss (*Sphagnum*). One kilogram of desiccated moss can absorb up to seven litres of water.

Material:

- three different species of desiccated mosses
- three 200-mL beakers
- three strainers
- tap water
- scales
- pencil for writing on glass

PERFORMANCE:

- Pick different moss species and desiccate them (either in an desiccator, in a thermostatic chamber, in an oven heated at 40°C, in the air (it lasts several months) or on a radiator).
- Weigh each of the desiccated mosses.
- Dip each moss into a beaker of water. Be sure it is covered with water and leave it there for 30 minutes. Each beaker should be appropriately labelled.
- Take them out of the beakers carefully, leave them on a strainer for a minute so that the water runs off and then weigh them. Write the results in the table.

Glass number	Name of the moss	Mass of the dry moss (g)	Mass after 30 min in water (g)	Difference in grams	Difference in %
1.					
2.					
3.					

Questions:

1. Which moss absorbed the most water? For how much did its mass change?
2. What is the scale of the mass increase of all the tested mosses?
3. Could they absorb more water if left more time in water?
4. Plan an experiment to find out what the influence of salt water is on mosses.

OBSERVING SEGMENTED ANIMALS

1. Observing a water flea

Place a drop of water containing a water flea in the slide, cover it with a coverslip, and examine it under the microscope. Be careful not to have it too long under the microscope, otherwise the preparation can overheat and the animal can die.

a) Draw the water flea. What are the special features that you notice?
Estimate the size of the animal.

Sketch of the water flea:

Approx. size of the animal:
Special features:

b) Classify the animal into the system.

c) What does the water flea, in your opinion, use for moving around?

d) Describe water flea's reproduction.

2. Observing an isopod

Take a close look at the animal under the magnifying glass.

a) Draw the isopod and estimate its size.
Sketch of the isopod:

Approx. size of the animal:

b) Classify the animal into the system according to its morphological characteristics.

c) Slightly shake the Petri dish containing the observed animal so that it curls up into a ball.
What is the purpose of this mechanism?

d) Try to conclude, on the basis of their classification, what the isopods use for breathing.
In what kind of environment are they commonly found?

3. Observing a spider

Take a close look at the animal under the magnifying glass.

a) Draw the animal and identify its parts.
Sketch of the spider with indicated body parts:

b) Classify the animal into the system according to its morphological characteristics.

c) What do the spiders use for breathing?

d) Spiders are predators. How do they catch their prey; how do they perceive and identify it? What is the name of the structures that enable this kind of predation?

e) Describe their digestion in detail.

4. Observing a scorpion

Carefully observe the animal; if it is too small, use a magnifying glass.

a) Draw the animal and identify its parts.
Sketch of the scorpion with indicated body parts:

b) Classify the animal into the system.

c) Describe the two-part abdomen in detail. Where is the venom gland situated?

d) Describe scorpion's chelicerae. What is their purpose in your opinion?

e) Are any types of scorpions that live in our country dangerous to humans?

5. Observing a tick

Observe the tick under the microscope.

a) Draw the animal and estimate its size.

Approx. size of the animal:

b) Classify the animal into the system.

c) Does the tick have jack-knife or scissor chelicerae? What are they used for?

d) The castor bean tick (*Ixodes ricinus*) transmits dangerous viruses and bacteria. It waits for its main host (large mammals) in high herbs and bushes. Which diseases can be caused by viruses and bacteria transmitted by the tick?

e) List at least three ways to protect yourself from the tick.

6. Observing a millipede

Carefully observe the animal in the Petri dish.

a) Draw the millipede and estimate its size.
Sketch of the millipede:

Approx. size of the animal:

b) Classify the animal into the system according to its morphological characteristics.
Does the millipede remind you of any other animal belonging to the same phylum? Which one?

c) How many pairs of legs grow from a single segment?

d) Does it move fast or slowly? What does this tell you about the millipede's diet?

e) Millipedes are often found in soil. Do they play any useful role there?

7. Observing a beetle

Carefully observe the beetle. You can use a magnifying glass.

a) Draw the beetle and identify its parts.
Sketch of the beetle with indicated body parts:

b) Classify the animal into the system.

c) The beetles are insects that undergo complete metamorphosis. What does this mean?

d) What kind of eyes are typical of insects? Draw the beetle's eye.
Sketch of the beetle's eye:

e) What are the elytra? From what have they developed?
Describe them in detail by observing the animal.

OPERATION OF THE SENSES

Skin, eyes, ears, and nose are the senses that react to the stimuli from the environment. The skin is sensitive to different conditions and changes in the environment. It perceives heat, cold, pain and touch, as well as the difference between smooth and rough surfaces and between sharp and blunt objects. We will conduct a few experiments that will contribute to your knowledge of certain sensory aspects of the skin. The eyes perceive light and adjust to its intensity. This process is called accommodation; we will learn about its features through an experiment. The ears respond to mechanical stimuli and are sensitive to sound intensity, height, colour, etc. Humans can only hear a limited range of frequencies. We will verify how extensive this range is.

During the laboratory exercise, we will:

- **Find that the receptors are only stimulated by relevant stimuli;**
- **Find that the density of sensory cells varies between different parts of the skin;**
- **Realise that the skin contains different receptors (pain, heat, cold, etc.);**
- **Realize that the receptors are sensitive to different stimuli;**
- **Learn about the range of human perception of sound frequency;**
- **Learn about adaptation of the eye to light intensity.**

A. HOW SENSITIVE IS OUR SENSE ORGAN TO TEMPERATURE?

Material:

- large container with hot water (45°C)
- large container with lukewarm water (32–35°C)
- large container with ice-cold water (5–10°C)
- stopwatch
- waterproof thermometer

* Water temperature in all three water baths MUST be constantly controlled and preserved during the experiment.

PROCEDURE:

- The testees dip one arm into the hot water bath up to the mid-forearm.
- At the same time, they dip the other arm into the ice-cold water bath.
- They hold both arms in the water for 1 minute (timed using the stopwatch).
- After a minute, the testees take both arms out of the water and simultaneously immerse them in the lukewarm water bath.
- The testees indicate in the table how they felt when they had both arms immersed in lukewarm water. They should memorise which arm was immersed in the ice-cold water bath and which one in the hot water bath.

Left arm	Right arm
Warm/cold feeling	Warm/cold feeling

B. HOW FAR APART ARE THE TACTILE AREAS AT OUR FINGERTIPS AND ON THE BACK SIDE OF OUR ARMS?

Material:

- paper (cardboard) circles with different diameters (5 to 2 cm and 10 to 2 mm)
- pins

PROCEDURE:

- Stick two pins into the circumference of paper (cardboard) circles (at the opposite ends of a circle).
- The testees close their eyes and turn their head to the side.
- Take a circle with a diameter of 10 mm and slightly touch it with index fingertips and lips (be extra careful in the latter case).
- If the testees feel two tips in the first attempt, take a 1 mm-smaller circle and touch it.
- Reduce the circle diameter until the testees feel only one stab.
- Repeat points 2, 3, 4, and 5 on the back side of your arm and on your back. Use the circles with larger diameters.

C. WHICH PART OF YOUR BODY HAS THE HIGHEST DENSITY OF RECEPTORS?

Material:

- pins
- marker

PROCEDURE:

- Using ink, draw a square with a side of a = 1cm on the index fingertip. The testees should have their eyes shut or covered with a scarf or should look away.
- The second member of the group should touch the skin by pricking individual squares with the pin (25–30×). The procedure should be carried out in five sequences of 5 to 6 touches.
- When they feel the touch, the testees should give a sign. The third member of the group writes down all the touches felt by the testee and their number.
- Repeat the experiment on the back side of your arm, on the bottom side of your forearm, on the outer side of your upper arm, on your knuckles, foot, instep, etc.
- Finally, use the acquired data to calculate the ratio: Number of touches perceived ÷ number of touches = X Compare your ratios.

D. IS THE SKIN SENSITIVE TO COLD AND HEAT ON THE SAME SPOTS?

Material:

- hot water bath (80°C)
- freezer
- several large nails (put some of them in the freezer the previous day)
- 2 markers of different colours (red, blue)

PROCEDURE:

- Put the nails in hot water for at least 2 minutes.
- Using ink, draw a square with a side of 2,5 cm on the back side of the testee's arm.
- Take the nail out of the hot water, wipe it, make sure that it is hot, and be careful not to get burned.
- The testees should close their eyes. Continuously pull the nail along the square sides on the back of the testee's arm. The head of the nail should steadily glide over your skin. The movement should be slow and continuous.
- When the testees feel the heat of the nail with the highest intensity, they should say "here". The third member of the group should draw a red dot on that spot. The testees should have their eyes closed throughout the experiment. Repeat the procedure several times and immerse the nail in the hot water bath after outlining each square to heat it up. There should be a certain time lag between individual experiments with the same testee. In the meantime, heat the nail.
- Repeat the procedure by using the nail taken from the freezer. In this case, mark the areas where the testee says "here" with a blue marker.

E. WHAT IS THE HIGHEST FREQUENCY HUMANS CAN PERCEIVE?

Material:

- sound frequency meter
- source of different sound frequencies

PROCEDURE:

- Place three testees in the quietest environment possible.
- The testees are given a table to indicate whether they perceive a certain frequency or not.
- The frequency will be changed throughout the experiment (frequencies are written in the table). The tone of each frequency lasts 5 seconds and is followed by a 5-second pause.

Experiment	**Perception (Yes/No)**
1. (10 Hz)	
2. (12 Hz)	
3. (20 Hz)	
4. (100 Hz)	
5. (700 Hz)	
6. (5.000 Hz)	
7. (12.000 Hz)	
8. (17.000 Hz)	
9. (20.000 Hz)	
10. (20.050 Hz)	

F. HOW DOES THE PUPIL CHANGE DEPENDING ON LIGHT INTENSITY?

Material:

- ruler
- lux meter
- (blindfold, if necessary)

PROCEDURE:

- First, measure the diameter of the testee's pupil in a normally lit classroom (with daylight and lights turned on).
- Then darken the classroom (turn off the lights and cover the windows) and put on a blindfold. Measure the diameter of the pupil immediately after untying the blindfold.
- In both cases, you should also measure light intensity using the lux meter.

HYPOTHESES:

Part A:

- In the case of the arm that was previously immersed in hot water, lukewarm water feels cold.
- On the contrary, in the case of the arm that was taken from the ice-cold bath, lukewarm water feels warm.

Part B:

- Sensory cells are situated closer together at the index fingertip than on the back side of the arm. The circle radius that allows you to feel more than one stimulus is therefore smaller in the first case.

Part C:

- Density of sensory cells varies throughout the body. The parts that are more often used for touching and sensing (fingers and lips) are more densely packed with sensory cells.

Part D:

- The skin is sensitive to heat and cold on different spots. The spots where it is sensitive to cold are more common.

Part E:

- The lowest frequency perceived is 20 Hz (in case of normal hearing).
- The highest frequency perceived is 20.000 Hz (in case of normal hearing).

Part F:

- The pupil is relatively small in a bright room.
- In a dark room, the pupil is larger.
- (The difference in diameter is a few millimetres.)

PHOTOSYNTHESIS

Specialised plant cells contain special organelles – chloroplasts. Their main role is to conduct photosynthesis – a process by which sunlight is used to produce carbohydrates from water and carbon dioxide and to release oxygen.

Photosynthesis occurs in two stages, i.e. the stages of light-dependent (primary) and light-independent (secondary) reactions. In the light-dependent stage, oxygen is separated from water, while energy-rich ATP molecules and $NADPH/H^+$ molecules are synthesised. As the name implies, light is not required in the light-independent phase. Nevertheless, light-independent reactions can only occur after the light-dependent phase. During light-dependent reactions, sugars are released from carbon dioxide using ATP in $NADPH/H^+$.

Equation for photosynthesis: $6\ CO_2 + 12\ H_2O \rightarrow C_6H_{12}O_6 + 6\ H_2O + 6\ O_2$

Bromothymol blue indicator turns yellow in acidic solutions and blue in basic solutions.

Purpose of the exercise:

- **To plan and conduct the experiments properly**
- **To demonstrate that plants consume CO_2 and release O_2 during photosynthesis**
- **To demonstrate that plants breathe**

HYPOTHESES:

- Photosynthesis only occurs when plants are exposed to light
- Plants need CO_2 to conduct photosynthesis
- Plants breathe all the time, even when photosynthesis does not take place
- CO_2 is released during plant respiration
- Plants produce oxygen during photosynthesis
- The presence of chlorophyll is necessary to conduct photosynthesis

Experiment 1

Material:

- bromothymol blue
- american waterweed
- test tubes
- soda water
- aluminium foil

METHOD:

Prepare two sets of 4 test tubes. Place 4 test tubes in the light and wrap the remaining 4 in foil in order to carry out the experiment in the dark.

Contents of the test tubes:

In the light	**In the dark**
Test tube 1: bromothymol blue	Test tube 5: bromothymol blue
Test tube 2: soda water and bromothymol blue	Test tube 6: soda water and bromothymol blue
Test tube 3: plant and bromothymol blue	Test tube 7: plant and bromothymol blue
Test tube 4: soda water, plant and bromothymol blue	Test tube 8: soda water, plant and bromothymol blue

HYPOTHESES:

Test tubes in the light:

Test tube 1	No change (only a control experiment)
Test tube 2	Soda water emits CO_2 that binds with water to form carbonic acid. Bromothymol blue should turn yellow.
Test tube 3	If photosynthesis and cellular respiration occurred with equal intensity, the plant would use all the released CO_2 for photosynthesis and there would be no change. If cellular respiration was more intense, the indicator would turn yellow.
Test tube 4	Due to the soda water, bromothymol blue should first turn yellow. However, if the plant was left in the test tube long enough, it would consume all the CO_2 from the water. The indicator would again turn blue.

Test tubes in the dark:

Test tube 5	No change (only a control experiment)
Test tube 6	As the reaction is independent of light, the result should be equal to test tube 2.
Test tube 7	If the indicator turns yellow, the plant only conducted cellular respiration and not photosynthesis. The produced CO_2 was therefore not consumed.
Test tube 8	Just as in test tube 7, the indicator should turn yellow, which results from the release of CO_2 and consequent medium acidification.

Experiment 2

Material:

- aquarium water beaker
- sodium bicarbonate
- funnel
- shoots of American waterweed
- test tube
- test tube clamp
- chip of wood and matches

PROCESS:

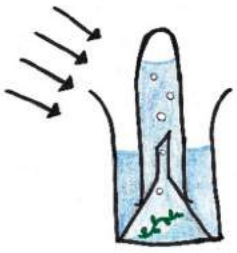
In order to determine whether oxygen is released in the plant conducting photosynthesis, we would carry out the following experiment:

We would put the plant in the beaker with aquarium water and sodium bicarbonate. We would immerse the funnel in the beaker in such a way that its wider part, which contains the plant, is at the bottom.

We would fix the test tube to the funnel with its neck facing downwards. We would leave the experiment in the medium bright light for a few days. If everything was correct, gas would be accumulated in the test tube. We would prove the presence of the gas using a smouldering chip of wood.

Expected results:

The chip of wood would ignite.



Additional Experiment I

Is the chlorophyll necessary for photosynthesis?

Material:

- green leaf (e.g. spinach, lettuce, etc.)
- multi-coloured leaf (e.g. aucuba, variegated maple, variegated ivy, etc.)
- water
- ethanol
- iodine solution

PROCESS:

Take the leaves of both plants and boil them for 5–10 minutes. This will cause damage to the membrane cells and facilitate the colouring of the leaves. Then put the leaves in a bowl containing ethanol. As the chlorophyll dissolves in ethanol, this will result in leaf discoloration. When the leaves are entirely discoloured, take them out of the ethanol bowl, put them on a flat surface, and level them. Pour iodine solution over the leaves. Iodine solution reacts with starch, turning it blue, brown or black.

Expected results:

Starch is one of the products of photosynthesis. This means that photosynthesis occurred in all parts of the leaves that contain starch. It is assumed that the green leaf would be coloured in its entirety, while only the green parts would be coloured in the case of the multi-coloured leaf.

Additional Experiment II

Production of gases in photosynthesis

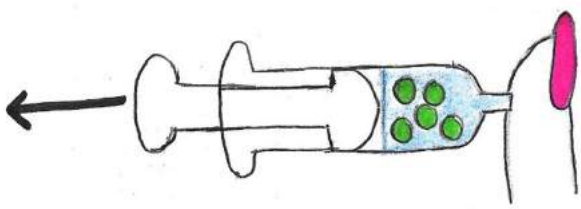
The production of gases can be verified by the following experiment.

Material:

- green leaf
- hole punch
- syringe
- beaker
- distilled water
- soda water
- UV lamp

METHOD:

Cut out approx. 20 pieces of the leaf using the hole punch. Prepare a solution of distilled water and soda water by adding some soda water to distilled water. CO_2 is thus added to the water. Put all leaf pieces into the syringe and squeeze out as much gas as possible. Then use the syringe to absorb some of the solution. Create a vacuum by closing the syringe with your finger on one side and pulling the plunger on the other. This part of the experiment enables you to suck all the gas from the leaf pieces. This occurs when the leaves are fully immersed. Then place the syringe on a stand under a UV lamp.



Expected results:

After some time, the leaf pieces should rise to the surface.

DISCUSSION

Experiment 1:

In the test tubes where the plants were constantly exposed to light, photosynthesis should be seamless.

Since test tube 1 only served as a control experiment, the colour of bromothymol blue should remain unchanged. In our experiment, bromothymol blue serves as an indicator for the presence of CO_2. It turns yellow in acidic solutions and blue in basic ones.

Test tube 2 contains both bromothymol blue and soda water. Soda water is a substance that emits CO_2. The latter binds with water to form carbonic acid. Bromothymol blue thus turns yellow in test tube 2.

As test tube 3 only contains the plant and bromothymol blue, there is a chance that the indicator will not change its colour. The plant produces CO_2 due to cellular respiration, but consumes it during the photosynthesis process.

Test tube 4 includes bromothymol blue, the plant, and some soda water. The indicator first turns yellow due to the soda water. As the plant eventually consumes all the CO_2 from the soda water, the indicator again turns blue. The experiment confirms the hypothesis that plants need CO_2 for photosynthesis.

Photosynthesis does not occur in the test tubes that are constantly in the dark.

Just as test tube 1, test tube 5 only contains bromothymol blue, which does not change its colour.

The reaction occurred in test tube 6 is identical to the one in test tube 2, as it is independent of light.

As photosynthesis is only carried out in the light, it is expected that the indicator in test tube 7 will eventually turn yellow. The plant cannot consume CO_2 in the dark, so it binds with water to form carbonic acid. The experiment confirms that CO_2 is released during respiration, that photosynthesis cannot be performed in the dark, and that cellular respiration takes place all the time.

Test tube 8 contains the plant, bromothymol blue, and some soda water. In the dark, the plant only carries out cellular respiration and adds CO_2 to the already acidic solution. The indicator turns yellow.

Experiment 2:

The easiest way to prove that oxygen is released during photosynthesis is by using a smouldering chip of wood. It is known that oxygen is required for ignition. Logically, the smouldering chip of wood will ignite if more oxygen is supplied. If CO_2 was released, the chip of wood would extinguish.

Additional Experiment I: Is the chlorophyll necessary for photosynthesis?

The aim of this experiment is to determine how important the function of chlorophyll is for photosynthesis. The previous exercise seems insufficient, as it only concerns the gases consumed and released during photosynthesis and does not include photosynthetic pigments. All the green parts of leaves contain chlorophyll. Since starch, one of the products of photosynthesis, is only created in these leaf parts, it can be concluded that chlorophyll is necessary for photosynthesis.

Additional Experiment II: Production of gases in photosynthesis

This experiment is conducted to prove the production of gases in a much shorter time. The experiment is also easy to prepare and more dynamic. The leaves rise to the surface because of the gas that has been produced in them. It is clear from the experiments carried out within the original laboratory exercise that the gas produced is oxygen.

SOLIDIFICATION OF OIL

Oils are esters between glycerol and three higher fatty acids (HFA) from which at least one is unsaturated fat. There are many different kinds of both saturated and unsaturated higher fatty acids. At room temperature, oils are liquid. Do they ever become solid and under what conditions? Which oils solidify after a short amount of time and which oils need more time to solidify? What does the speed of solidification depend on? Why are oils liquid and fats solid at room temperature?

Material:

- plastic glasses
- different oils
- marker
- camera
- freezer
- thermometer
- measuring cylinder or shot glass

PERFORMANCE:

- Label each of the plastic glasses with the name of the oil you put in it.
- Pour 0,3 dL of oil (or one shot glass of oil) into each of them.
- Put the plastic glasses filled with oil into a freezer. Write down the temperature of the freezer.
- Check every 10 minutes if the oil is already solid. It is solid when it does not move if you tip a glass or turn it upside down. Write down the time needed for solidification.
- Take pictures of product labels (there are information about the oil type, a producer, ingredients and its energy value).
- Fill in the table with the information obtained from the experiment and the product labels. If there was a bottle of oil without a product label, mark it.
- Attach the pictures of the product labels.
- Answer the questions.

Povprečna hranilna vrednost	na 100 g	na porcijo (15 g)	% PV *
Energijska vrednost	3700 kJ/ 900 kcal	555 kJ/ 135 kcal	7%
Maščobe	100 g	15 g	21%
od tega			
-nasičene maščobe	16 g	2,4 g	12%
-enkrat nenasičene maščobe	76 g	11,4 g	
-večkrat nenasičene maščobe	8 g	1,2 g	
Ogljikovi hidrati	0 g	0 g	0%
- od tega sladkorji	0 g	0 g	0%
Beljakovine	0 g	0 g	0%
Sol	0 g	0 g	0%
Vitamin E	26 mg – 217% PDV**	3,9 mg – 32,5 %PDV**	

*Priporočeni vnosi za povprečno odraslo osebo (8 400 kJ/2 000kcal)

** Priporočeni dnevni vnos

Source: www.gea.si/izdelki

Student				
Oil				
Producer				
Mass fraction (grams or %) – saturated HFA				
– 1× unsaturated HFA				
– polyunsaturated HFA				
Energy value of 100 g – kJ				
– kcal				
Temperature (°C)				
Time needed for solidification (min)				

THE FEATURES OF PLASMA MEMBRANE

Plasma membrane is a biological membrane that surrounds the protoplast of a plant cell. Lipid bilayer is a thin membrane (between 7 and 10 nm) made of phospholipids and proteins. Plasma membrane is selectively permeable to substances that move in and out of the cell (it also contains protein channels and other transport systems).

With this experiment, we will investigate the role and abilities of the cell membrane in preserving chemical balance in the cell and at the same time prove the movement of molecules in and out of the cell. The purpose of this experiment is to better understand plasmolysis and deplasmolysis in plant cells, the concept of selectively permeable plasma membrane, and the meaning of osmosis.

Basic concepts:

HYPOTONIC SOLUTION: the solution outside the cell is less concentrated than the solution inside the cell. In this case, there is a greater concentration of water outside the cell; therefore, water enters the cell.

HYPERTONIC SOLUTION: is a particular type of solution that has a greater concentration of solutes on the outside of the cell when compared with the inside of the cell. In this case, the cell loses water by osmotic processes.

ISOTONIC ENVIRONMENT: is an environment in which the number of osmotic active particles outside the cell is the same to the number of osmotic active particles in the cytoplasm of the cell.

DIFFUSION: is the movement of particles down a concentration gradient. It stops when the particles of the solute and solvent are equally distributed in the area.

Material and methods:

1. The influence of different concentrations of aqueous solutions on the cells of the leaf of red onion bulb

Material:

- leaf of red onion bulb
- cells of waterweed
- cells of sea algae
- 3%, 10% and 20% solution of table salt
- dropper
- distilled water
- slides
- coverslips
- microscope
- filter paper

PERFORMANCE:

- Add a drop of water to the slide.
- Cut into the onion, remove the layer of the epidermis on the inner side of the leaf of red onion bulb, and put it in the water on the slide. Cover the preparation with the coverslip.
- First you should take a look at the cells of the leaf of red onion bulb under 100× magnification in tap water (which is not totally clean).

- Then put a piece of filter paper next to the edge of the coverslip so that the water will be drawn from under the coverslip and add the 10% solution of NaCl next to the edge on the other side of the coverslip. The filter paper starts to absorb the liquid and the salt water flows under the coverslip and surrounds the cells that you should carefully look at.
- Remove the solution of salt, use another pieces of filter paper, and add distilled water. Now, the distilled water runs under the coverslip and substitute the water solution. Again, take a look at the cells under 100× magnification.

2. Does the cell membrane regulate the movement of substances?

Material:

- suspension of yeasts in water
- solution of Congo red in a bottle with a dropper
- dropper
- 5 small test tubes
- test tube holder and test tube rack
- slides
- coverslips
- microscope
- Bunsen burner
- thermometer

PERFORMANCE:

- First prepare a microscopic preparation of the yeasts suspension and take a look at yeasts under small and big magnification.
- Add approximately 1 mL of the yeasts suspension to 2 small test tubes. Warm up one of the test tubes as long as the content boils and that the yeasts are dead. Add 5 drops of Congo red to both test tubes.
- Prepare a microscopic preparation from each of the test tubes and examine each of them carefully under small and big magnification.

IMPROVING THE LAB WORK

The first part: Test the cells of the leaf of red onion bulb, of pondweed, and of sea algae (e.g. *Ceratocorys armata*) and examine them in tap water, in the 3% solution of salt, in the 20% solution of salt, and also in distilled water.

PERFORMANCE:

- Add a drop of water to the slide.
- Cut into the onion, remove the layer of the epidermis on the inner side of the leaf of red onion bulb and put it in the water on the slide. Cover the preparation with the coverslip.
- Take a look at the cells of the leaf of red onion bulb under 100x magnification in tap water (which is not totally clean).
- Then put a piece of filter paper next to the edge of the coverslip so that the water will be drawn from under the coverslip and add the 10% solution of NaCl next to the edge on the other side of the coverslip. The filter paper starts to absorb the liquid and the salt water runs under the coverslip and surrounds the cells that you should carefully look at.

– Remove the 3% solution of salt, use another piece of filter paper and add the 10% solution. This also runs under the coverslip and substitute the 5% solution of salt. Again, take a look at the cells under 100× magnification.
– Repeat the process with the 20% solution of salt and distilled water. Repeat the entire process with the cells of waterweed and sea algae.

HYPOTHESES:

Hypothesis 1: When the cells of the leaf of red onion bulb are surrounded by tap water, there won't be any changes. With the increase in the concentration of the solution of salt, the protoplast will move further away from the cell wall as long as the cell becomes dry. When the cells are surrounded by distilled water, the protoplast will come closer to the cell wall and the turgor will rise even more compared to the tap water.

Hypothesis 2: During the experiment, the cells of the pondweed will behave very similarly to the cells of the leaf of red onion bulb. When surrounded with water, there will not be any changes. With the increase in the concentration of the solution of salt, the protoplast will move further and further away from the cell wall as long as the cell becomes dry. When the cells are surrounded by distilled water, the protoplast will come closer to the cell wall again and the turgor will rise even more compared to the tap water.

Hypothesis 3: When the cells of the sea algae are surrounded with tap water, the turgor will rise, the protoplast will come even closer to the cell walls and the entire cell will swell. The turgor will decrease in the presence of the 3% solution of the salt and the cell will come to its original state because this is its best environment. In the 10% solution of the salt, the protoplast will detach whereas in the 20% solution of the salt the difference will become even more noticeable. The turgor will come back in the distilled water, it will be even bigger than in the previous cases because of a great amount of water that enters the cell.

The second part: The yeasts are not boiled but gradually warmed up.

PERFORMANCE:

– First prepare a microscopic preparation of the yeasts suspension and take a look at yeasts under small and big magnification.
– Add approximately 1mL of the yeasts suspension to 5 small test tubes. The first test tube should be warmed up at 40°C, the second one at 60°C, the third one at 60°C, and the fourth one at 100°C, whereas the fifth one should be left at the original temperature for control. Add 5 drops of Congo red to each of the test tubes.
– Prepare a microscopic preparation from each of the test tubes and examine each of them carefully under small and big magnification. Give a special attention to the number of coloured cells in each of the test tube.

HYPOTHESES:

Hypothesis 1: In the first (40°C), second (60°C) and fifth test tube, the most cells will remain uncoloured. Some of them will change their colour because of being injured or decayed.

Hypothesis 2: In the third (80°C) test tube, the majority of the yeast cells will colour and in the case of the fourth test tube almost all of them will colour.

Sources:
– BIOLOGIJA Navodila za laboratorijsko delo, Smilja Pevec, Ljubljana, DZS, 2000
– BIOLOGIJA Laboratorijski delo, Smilja Pevec, Ljubljana, DZS, 2000

CHEMISTRY

ST. STANISLAV'S INSTITUTION

Performing Chemical Experiments (Sint-Calasanzinstituut, Nijlen, March 2015)

DIFFUSION OF DYE IN AGAR

Introduction:

What is diffusion?

To simplify, diffusion is a spontaneous process of particles movement between two substances that lasts until the concentration of the particles of the first substance which was added to the second substance is not everywhere the same. To tell it with an example: if you take two solutions with different concentrations, you can observe diffusion originating from the difference in concentration. According to the definition, substance particles always move from a region of high concentration to a region of low concentration. Physical or convective mixing should not take place through diffusion. Diffusion is also very much dependent on conditions, such as temperature and can occur in all states of matter.

Diffusion is usually presented with a simple experiment. For example, we carefully pour water over the fruit syrup so that the substances do not mix with each other. We notice that the line between both phases is clearly visible. If we leave this mixture for a while and observe it, we soon notice that the water phase is coloured what is a consequence of diffusion and the line between the phases becomes less evident.[1]

Fick's laws of diffusion describe diffusion, but they are too advanced for our level. However, they consider that diffusion takes place until thermodynamic balance is not reached.[2]

The purpose of this exercise and the selection of a technique to carry out the experiment:

The purpose of this exercise is to present diffusion with a simple experiment and find out the influence of temperature on the speed of diffusion.

We are going to perform diffusion of a coloured solute in a home-made gel or in other words diffusion of the dye from the gel. In this way, it will be easier for us to follow the speed of diffusion and sufficiently compare samples at different temperatures.

PERFORMANCE:

This exercise is time-consuming, because the experiment will last for several days.

Equipment:

- four 250-mL beakers
- 1000-mL beaker
- glass rod
- burner

Chemicals:

- agar
- water
- water solution of a food dye (it can be made from an egg dye)
- distilled water

PERFORMANCE:

Following the instructions of the producer (it is usually between 2 and 3 g of agar per 100 mL of water), cook 400 mL of gel which is made of agar and water in a 1000-mL beaker. Then divide one half this gel (it should be still hot) into two beakers.

Add 4 mL of food dye to the second half (food dye should be concentrated), stir it well and then further divide this coloured agar into two beakers. Agar in all four beakers should cool down and solidify. Then put one beaker with pure agar (Beaker 4) and one beaker with agar and dye (Beaker 2) into the fridge and leave the other two beakers (Beaker 1 and Beaker 3) at room temperature.

When agar – stored in the fridge – reaches a constant temperature, add 4 mL of colour to the beaker without dye and 100 mL of water to the other two beakers with coloured gel. After doing this, observe how colour diffuse out of the gel and to the gel and how the speed of diffusion depends on the temperature.

A DRAFT:

RESULTS:

Write down your observations of colour diffusion.

Time	**Beaker 1 (coloured gel/ water, room temperature)**	**Beaker 2 (coloured gel/ water, the fridge temperature)**	**Beaker 3 (gel/food dye, room temperature)**	**Beaker 4 (gel/food dye, the fridge temperature)**
1 hour				
2 hours				
4 hours				
12 hours				
24 hours				
48 hours				
72 hours				

FINDINGS:

- How does temperature affect the speed of diffusion (your explanation should be based on your observations)?
- Considering the results, assume whether the diffusion from the gel in the water is as fast as the diffusion from the water phase in the gel.

Appendix:

Sources:

[1] Osmoza in difuzija v kemiji, Tilen Lindič (avtor), Martin Tine Perger (mentor), projektna naloga na ŠKG, 2009

[2] Laboratorijske vaje iz fizikalne kemije, Ljubljana, FKKT, 2000

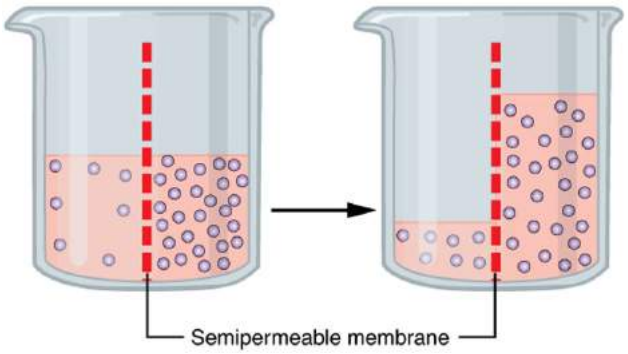
EGG OSMOSIS EXPERIMENT

Introduction:

What is osmosis?

First a short explanation for understanding: there is a beaker divided into two parts with a semi-permeable (selectively permeable) membrane (the picture below). Solution of water and another substance (e.g. sugar) with low concentration is added to the left part and high concentration of the same solution is added to the right part of the beaker. After some time, one will notice that water (solvent molecules) moves through this permeable membrane into a region of the solution. This process is called osmosis. From this simple experiment, one can make a definition of osmosis stating that osmosis is diffusion of solvent molecules through a semipermeable membrane from an area of higher concentration of solvent to an area of lower concentration. Longer osmosis occurs, higher the level of solution in the part of the beaker with higher concentration meaning that hydrostatic pressure is also higher. Osmotic flow stops when hydrostatic pressure equals osmotic pressure.

Osmotic pressure is defined as the pressure required to stop the net flow of water across the membrane and is influenced by temperature and difference in concentration between the solutions on both sides of the membrane.[1]



The most basic equation to calculate osmotic pressure is defined by **Van't Hoff law**:

$$\Pi = i\,c\,R\,T$$

In this equation, factor i is Van't Hoff factor, c is mass concentration,
R is universal gas constant, T is temperature in Kelvin.
Van't Hoff factor i is a unitless empirical constant that expresses the extent of dissociation or association of the solute in the solution.

Semipermeable or selectively permeable membranes can be divided into two bigger groups: natural and artificial.

The purpose of this experiment and a technique to prove the semi-permeability of a membrane

The purpose of this experiment is to obtain egg membrane and then find out whether it is also semi-permeable (selectively permeable) for water molecules and not only for gases (oxyen and carbon dioxide).

First, you should carefully remove the eggshell because the egg membrane is directly under it.
The easiest way to remove the eggshell is with dissolving it in acetic acid.

With gravimetric method (accurate weighing of the egg in various experiment phases), you are going to prove whether the membrane is permeable or not.

PERFORMANCE:

This experiment is time-consuming because the results are obtained after several days.

Equipment:

- four 600-mL beakers
- bigger pot
- accurate scales
- table spoon

Chemicals:

- alcohol vinegar or acetic acid (6–9 %)
- distilled water
- NaCl solution (9%)
- 5 chicken eggs

PERFORMANCE:

Put five eggs in a bigger pot and pour acetic acid solution over them. Dissolving the shell is quite a slow process; therefore, you can leave eggs in the solution for at least 12 hours. Upon noticing that the shell disappeared, use a table spoon to take four eggs out of the solution and carefully wash them with distilled water.

Weigh each of the eggs and put each of them into one beaker, weigh also the egg that is left in the solution. Pour distilled water over two eggs and NaCl solution over the other two. Weigh each of the eggs five times accurately to 1/100th gram (see the table).

A DRAFT:

Calculations and results:

Time	The mass of egg 1 in distilled water (g)	The mass of egg 2 in distilled water (g)	The mass of egg 3 in NaCl solution (g)	The mass of egg 4 in NaCl solution (g)	The mass of egg 5 in acetic acid (g)
Start (after 0 hours)					
After 2 hours					
After 3 hours					
After 4 hours					
After 24 hours					

The biggest difference in mass is for egg number ..... (for ..... g).

Mass increase in percentage:

	The percentage of mass increase of egg 1	The percentage of mass increase of egg 2	The percentage of mass increase of egg 3	The percentage of mass increase of egg 4	The percentage of mass increase of egg 5
After 2 hours					
After 3 hours					
After 4 hours					
After 24 hours					

FINDINGS:

- Does the change in mass depend on the kind of liquid in which the egg was immersed? Is the egg membrane semipermeable?
- In which liquid does the mass of the egg in respect to its mass increase the most?
- How does the mass of individual eggs change with time – in which time interval is the speed of diffusion the greatest?

Appendix:

Sources:

[1] Osmosis and diffusion in chemistry, Tilen Lindič (author), Martin Tine Perger (mentor), project work at the Diocesan Classical Gymnasium, 2009

[2] https://commons.wikimedia.org/wiki/File:0307_Osmosis.jpg

MEASURING THE SPEED OF A CHEMICAL REACTION

Introduction:

The speed of a chemical reaction can be measured in various ways depending how the transformation of reagents into products is observed. One of the easiest ways to measure the speed is colorimetry.

Colorimetry is a technique used to determine the concentration of coloured compounds in a solution. A colorimeter is a device that measures the absorbance of the solution at a certain wavelength.[1]

The purpose of this exercise and the basics of colorimetry method:

Using a simple colorimeter (spectrophotometer), we are going to observe how the concentration of $K_2Cr_2O_7/H^+$ is changing when ethanol is added to this solution. Alcohol oxidation will occur in the presence of the oxidant acidified potassium dichromate(VI):

The speed of this reaction can be indirectly determined by observing the change of the transmittance (permeability of the light beam through the sample in the cuvette).

In case of dilute quantities, absorbance is proportional to the concentration of the solute c (**Beer–Lambert law**):

$A = \varepsilon \times l \times c$

ε – absorbance coefficient (dependent on the substance)
l – the distance the light travels through the cuvette (usually 1 cm)
c – molar concentration of a solute

When using the same kind of the solution and the cuvette, the equation can be written as:

$A = k \times c$ k – constant

During the reaction, the concentration of $K_2Cr_2O_7/H^+$ is changing, therefore, the absorbance A is also changing. The device we are going to use for this experiment can also show the transmittance or permeability T – the proportion of light that travels through and is linked with the absorbance in the following equation:

Equipment:

- Logger Lite programme
- Vernier interface
- Vernier colorimeter
- 2 cuvettes (l = 1 cm)
- pipettes

Chemicals:

- dilute $K_2Cr_2O_7/H^+$ solution (e.g. 0,1 M)
- ethanol
- water

$A = -\log_{10} T$

PERFORMANCE:

Connect the colorimeter to a computer through Vernier interface and run the Logger Lite programme. First add 2,5 mL of acidified potassium dichromate(VI) solution to the cuvette (the solution should not be concentrated because Beer-Lambert law should apply), place it into the colorimeter (Picture 1), close the lid of the calorimeter and set it to the desired wavelength (565 nm).

Then calibrate the colorimeter (by pressing the button CAL) and set permeability T at 100 %. In the programme, set a measurement time period (500 s) with frequent measurement intervals (3 s) and press the button Collect – the absorbance measurement starts and it is visible on the screen. Then open the lid, use a pipette to add 0,5 mL of ethanol to the cuvette, stir everything as fast as possible (with a pipette or a dropper) and close the lid. Even though the programme has already collected the data, remember the time when you close the lid – since the measurements are correct from the time the lid is closed.

If everything is done correctly, smooth curve should occur (Appendix: Picture 2, Picture 4). In Table 1, insert the absorbance measurements obtained every 9 seconds. Draw a graph of the absorbance A in relation to time. Parallel to this; you can follow the change of colour of the solution in another cuvette outside the calorimeter. The change of colour will be more than obvious (Picture 3).

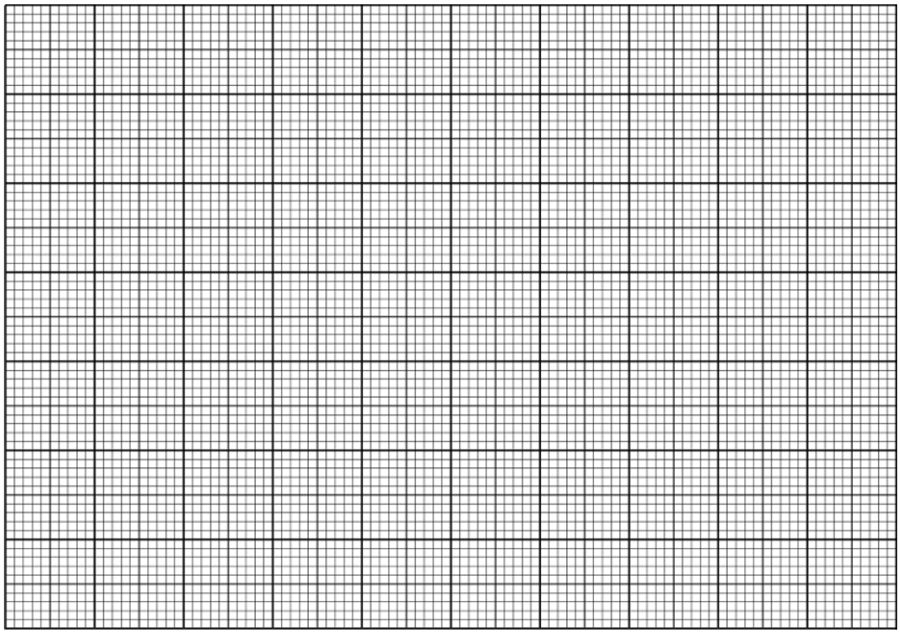
A DRAFT OF THE DEVICE:

Table 1:

Time (s)	Absorbance A

Time (s)	Absorbance A

Graph: The absorbance of the reaction mixture in relation to time



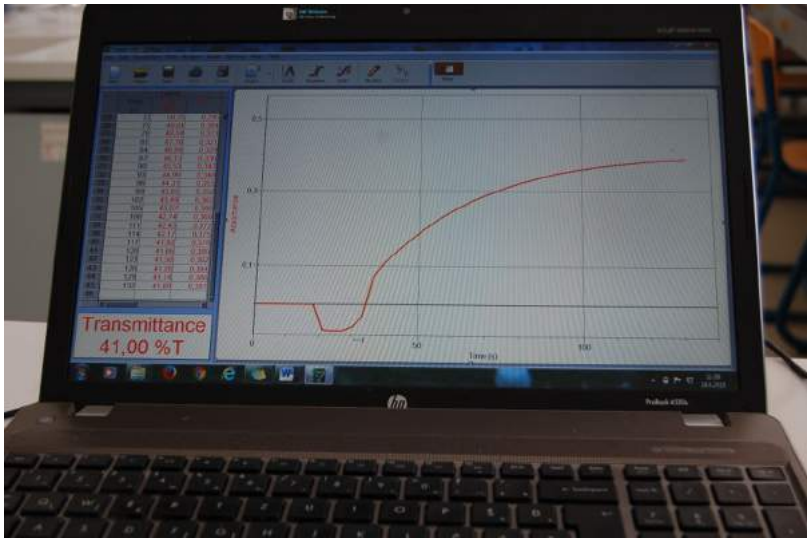
THE RESULTS:

- Circle the area on the graph where the speed of the reaction is the greatest. Explain why.
- After how much time is the reaction finished? (See on the graph).
- Plot a curve that would arise in case of lower concentration of potassium dichromate and the same amount of added ethanol.

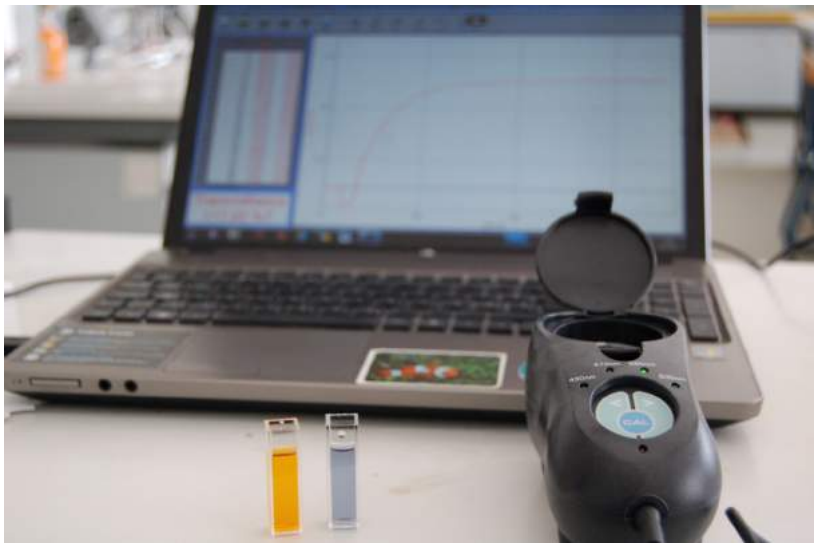
Appendix:

Picture 1:

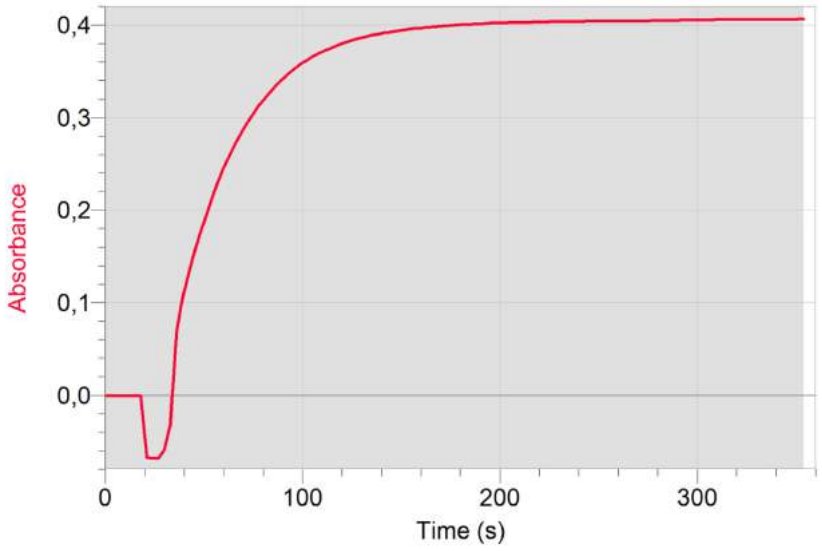
Picture 2:



Picture 3:



Picture 4:



Source: http://sl.wikipedia.org/wiki/Kolorimetrija

OXIDATION OF APPLE SLICES

Fresh food should be preserved if we want to store it. There are several ways for preserving fruit; however, the quality depends on the way of preservation. Fruits can be frozen, preserved with sugar, dried or boiled.

In principle, preservation is actually a protection against oxidation or a deceleration of the process of oxidation. Fruit and vegetable oxidation is a process that is slow enough to be observed. While observing oxidation, we can define factors which decelerate or accelerate it.

The purpose of this exercise and the selection of a technique to carry out the experiment:

The purpose of this exercise is to find out how different factors influence the oxidation of apple slices. Apples if they are cut in slices become brown (they oxidise) in a quite short period of time. With this exercise, we are going to check how temperature, a medium that surrounds the slices, chemicals (chemical preservatives), and pH affect the speed of oxidation.

The course of the exercise:

This exercise is based on the observation of apple slices' colour under different conditions. Juicy apples that become brown in a reasonable amount of time should be used for this experiment (golden delicious apples are not recommended because they become brown very slowly).

Material:

- big test tubes
- test tube rack
- droppers
- thermometer
- aluminium foil
- beaker

Chemicals:

- tap water
- crumbled ice
- boiled water
- oil
- brine
- sugar syrup
- $Na_2CO_3(aq)$
- NaOH(aq)
- HCl(aq)
- alcohol vinegar
- 10% ethanol
- 96% ethanol

PERFORMANCE:

Peel an apple, cut it in small slices and give one slice in each of the test tubes (test tubes should be labelled). Pour liquid over it (see Table 1). Wrap several slices in aluminium foil to observe how they become brown at different times (unwrap each slice at a given time). The influence of temperature is only relevant if water is used as a medium for preservation, other ways of preservation are measured at a given time in the lab. Leave one slice in the air and use it as a standard (for comparison).

A DRAFT:

OBSERVATIONS AND RESULTS:

Influence	**The way of preservation**	**Visible changes after 15 minutes**	**Visible changes after 30 minutes**	**Visible changes after 60 minutes**	**Visible changes after 120 minutes**
Temperature (preservative – water)	Warm tap water (50°C)				
	Tap water (lab temperature)				
	Tap water with ice (0°C)				
	Crumbled ice				
Preservative – liquid	Boiled water + a layer of oil				
	Brine				
	Na_2CO_3 (aq)				
	NaOH (aq)				
	HCl (aq)				
	Alcohol vinegar				
	Sugar syrup				
	10% ethanol				
	96% ethanol				
Preservative – non-transparent foil	Aluminium foil 1		/	/	/
	Aluminium foil 2	/		/	/
	Aluminium foil 3	/	/		/
	Aluminium foil 4	/	/	/	
/	Air				

FINDINGS:

- How does temperature affect oxidation?
- Which of the liquid preservatives is the best preservative? Is it used to preserve fruits?
- Does the aluminium foil wrapped around an apple have an influence on the fact that it becomes brown? How?

Sources:

– Kemija 2000, Priročnik za učitelje 1, DZS, Ljubljana 2000

– Kemija 2000, Delovni zvezek 1, DZS, Ljubljana 2000

SALT IN BREAD

Introduction:

According to an old Slavic tradition, guests were first given bread and salt by their hosts. Slavic nations show great respect towards bread and salt plays an important role in folk traditions and customs – it was used for healing, driving away evil spirits or blessing ...

Today, we eat bread that is too salty according to the recommendations of a healthy lifestyle. Some estimation suggests that an average Slovenian consumes between 15 and 25 g of salt per day, whereas health workers recommend a consumption of 6 g per day (this is one teaspoon).[1]

Are we aware of our intake of salt? There are some food items that can be hidden storages of salt.

The purpose of this exercise and techniques to carry out the experiment:

The purpose of this exercise is to determine the amount of salt in bread using secondary-school equipment. The exercise can be conducted in several ways; the most appropriate ways are gravimetry and measuring electrical conductivity.

Gravimetric analysis of a sample includes methods to determine the mass of a certain substance in the sample. Partial methods of gravimetry can very much differ from one another: secretion of substances with the help of electric current (electrolysis), with the help of evaporation of the solvent from the solution, with the help of heating of a solid sample (thermogravimetry) ...

Electrical conductivity is usually determined by measuring electrical conductivity of the entire substance (solution, solvent, and solid substance) based on the resistance measuring or voltage measuring of the solution with metallic electrodes. For the determination of only one variety of ions in the solution, ionsselective electrode is used.

THE COURSE OF THIS EXERCISE:

1. Determination of the amount of salt in bread using gravimetric method

This method is one of the simplest, thus very accurate. However, in case of determining the salt in bread, it will be less accurate, because we will presuppose that the only substance in bread which dissolves in water is salt, but in reality this is totally true.

Material:

- 1000-mL beaker
- glass rod
- 600-mL beaker
- funnel
- filter paper
- scales
- drying oven

Chemicals:

- distilled water
- bread

PERFORMANCE:

Add 500 mL of water to the 1000-mL beaker and crumble one slice of bread into it. Before crumbling the bread into water, weigh it carefully. Stir the mixture as long as the bread does not fall apart and then filter it. The filtrate should be clear, colourless liquid, otherwise filter it again. Weigh and leave the filtrate in the oven heated at 40–50°C for several hours. If you do not have an oven at your disposal, you can leave it at room temperature for several days. Weigh the solid rest and calculate the mass of salt in the 100 g of bread.

A DRAFT:

CALCULATION AND THE RESULTS:

The mass of bread =

The mass of the solid rest of the filtrate =

Calculation of the mass of salt in one slice of bread (100 g) =

2. Determination of the amount of salt in bread by measuring electrical conductivity

This method is accurate provided that only NaCl ions out of all soluble salts in the solution conduct electric current. For this example, this is true; therefore, we can conclude that the results will be accurate enough.

Material:

- ten 100-mL beakers
- 10 volumetric flasks with flat bottom (100 mL)
- glass rod
- two 600-mL beaker
- funnel
- filter paper
- scales
- computer with the Logger Pro programme
- Vernier interface
- Vernier conductivity meter

Chemicals:

- NaCl solutions with different concentrations
- unknown sample

PERFORMANCE:

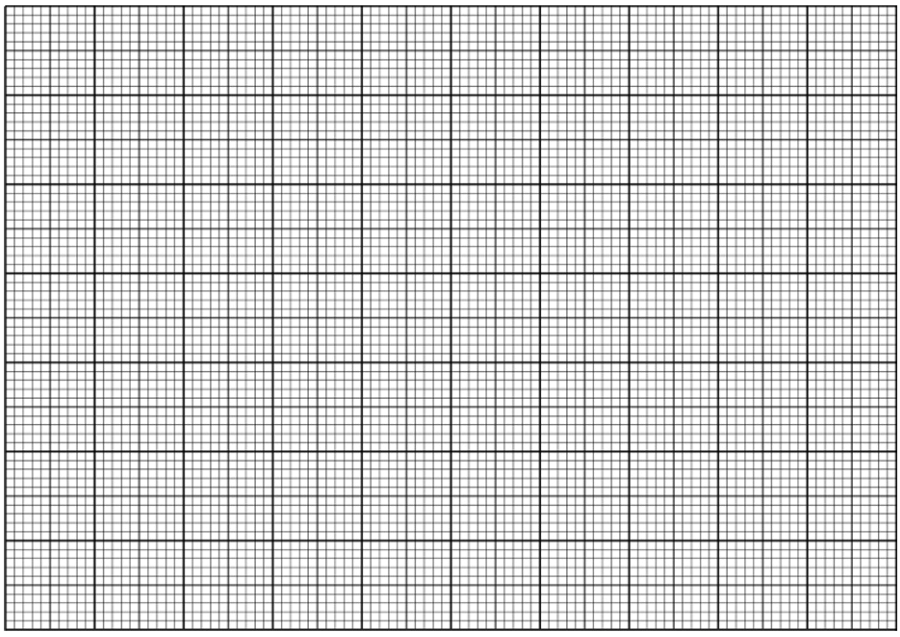
To indirectly weigh the mass of salt in bread by using conductivity meter, you should prepare a filtrate (following the same steps as by gravimetric method). Before doing it, the bread that is put in a certain amount of water with the volume V_2 (e.g. 500 mL) should be weighed carefully. In addition, standard NaCl solutions should be prepared to draw a calibration curve to determine the concentration of salt in the filtrate (Table 1). To prepare standard solutions, add accurately weighed amount of NaCl to the volumetric flasks with flat bottom and add water to the mark.

A draft of the device:

Table 1:

Mass concentration ($m_{salt}/V_{solution}$)	**Electrical conductivity**
0,1 g/L	
0,2 g/L	
0,5 g/L	
1,0 g/L	
2,0 g/L	
5,0 g/L	
8,0 g/L	
10 g/L	
15 g/L	
20 g/L	
Sample	

Diagram of mass concentration (abscissa axis) vs. electrical conductivity of solutions (ordinate axis) at a given temperature T (..... °C):
Connect all the points on the diagram to draw a curve.
For the sample, read the value on the abscissa axis.



Sample's mass concentration read from the diagram: γ_{sample} = ... g/L

CALCULATION:

The mass of bread =

The mass of salt in this slice of bread = $\gamma_{sample} \times V_2$ = ... g/L × ..... L = ... g

A calculation of the mass of salt in 100 g of bread =

RESULTS:

Comparison of the results of Method 1 and Method 2

– How much do the results obtained in two different ways differ from one other?

– What is the reason for this mistake?

Source:

[1] http://m.slovenskenovice.si/lifestyle/zdravje/v-zdravih-jedeh-vec-soli-kot-v-vrecki-cipsa

SATURATED AND UNSATURATED FATS

Introduction:

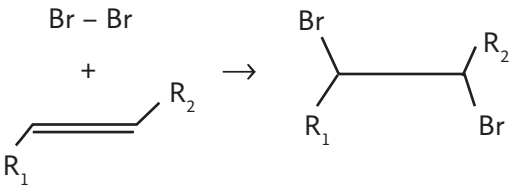
There are different fats that can be divided into saturated and unsaturated fats. In addition to single bonds between carbon atoms, unsaturated fats have double bonds (or even triple bonds) between their carbon atoms. Unsaturation of fat is, nowadays, linked with the notion of healthy diet; however, the position of double bonds is also something that is important for health (e.g. Omega 3 and Omega 6).

The purpose of this exercise and a technique:

The purpose of this experiment is to show whether a selected fat is saturated or not. By adding bromine water, we are going to determine which fats are the most and which the least saturated. A technique of titration of fat with bromine water is a basic method of titration. Using this method, we observe discoloration of bromine water – as long as there are double bonds in the fat, bromine from bromine water will react with the fat (Picture 1).[1]

This is an electrophilic addition reaction, because the atoms of bromine in the bromine molecule bind to the carbon atoms which were bonded with a double bond before. Bromine molecules give colour to bromine water, therefore when forming a bond, the colour changes (disappears).

Picture 1:



PERFORMANCE:

This experiment is not time-consuming. A special attention is needed when dealing with bromine water. It is harmful to health if eaten or if its vapour is inhaled. It irritates the skin and causes burns in case of longer contact with the skin.[2]

Equipment:

- droppers
- test tubes with rubber stoppers

Chemicals:

- dilute bromine water
- coconut fat
- beef fat (can be obtained from the surface of soup and cooled down in a fridge
- olive oil
- butter
- rapeseed oil
- margarine
- 96% ethanol

PERFORMANCE:

Add five drops of oil or equal volume of fat to a test tube. Then add ethanol to a depth of about 2 cm and stir it well. Use a dropper to add three drops of dilute bromine water, plug the test tube and shake it for several seconds (hold the rubber stopper with your finger to prevent it from being ripped off). If the colour does not disappear (from golden brown to colourless), add three drops of bromine water to the test tube and shake it again.

Repeat this until the bromine water does not discolour anymore. Count how many drops you add to the sample of fat or oil.[1]

DRAFT:

RESULTS:

Substance	**Number of added drops**
Coconut fat	
Beef fat	
Olive oil	
Butter	
Rapeseed oil	
Margarine	

FINDINGS:

- Why do we first add ethanol to oil or fat before bromine water is added?
- Which of the fats is the most unsaturated and which is the least saturated?

Sources:

[1] Kemija 2000, Priročnik za učitelje 1, DZS, Ljubljana 2000

Kemija 2000, Delovni zvezek 1, DZS, Ljubljana 2000

[2] http://www.kii3.ntf.uni-lj.si/e-kemija/file.php/1/output/keto_enol/

AGRICULTURE

The world's population is increasing; therefore, more and more food must be produced. Actually there is enough food to feed the entire Earth's population; but unfortunately it is not evenly distributed across the globe. The reasons for the lack of food are underdevelopment, poverty, wars, and natural disasters. On the other hand, tonnes of perfectly good food are thrown away in the developed world every day.

Developed world produces enough food. This is possible with the use of artificial fertilisers which provides the soil with substances that the plants take from the soil to grow and thus impoverish it. In addition to artificial fertilisers, food producers also use pesticides, the substances for pest control. All these substances are called agrochemical substances and their production is one of the biggest industries in the world.

In this unit you will get to know:

- **the elements that plants need for their growth and how these elements circulate in the nature**
- **what mineral fertilisers are and how they are produced**
- **how to calculate the nitrogen content in a compound of mineral fertiliser**

In this unit you will do the following experiments:

- **the influence of heating on ammonium chloride**
- **ammonium fountain**
- **the synthesis of mineral fertiliser**

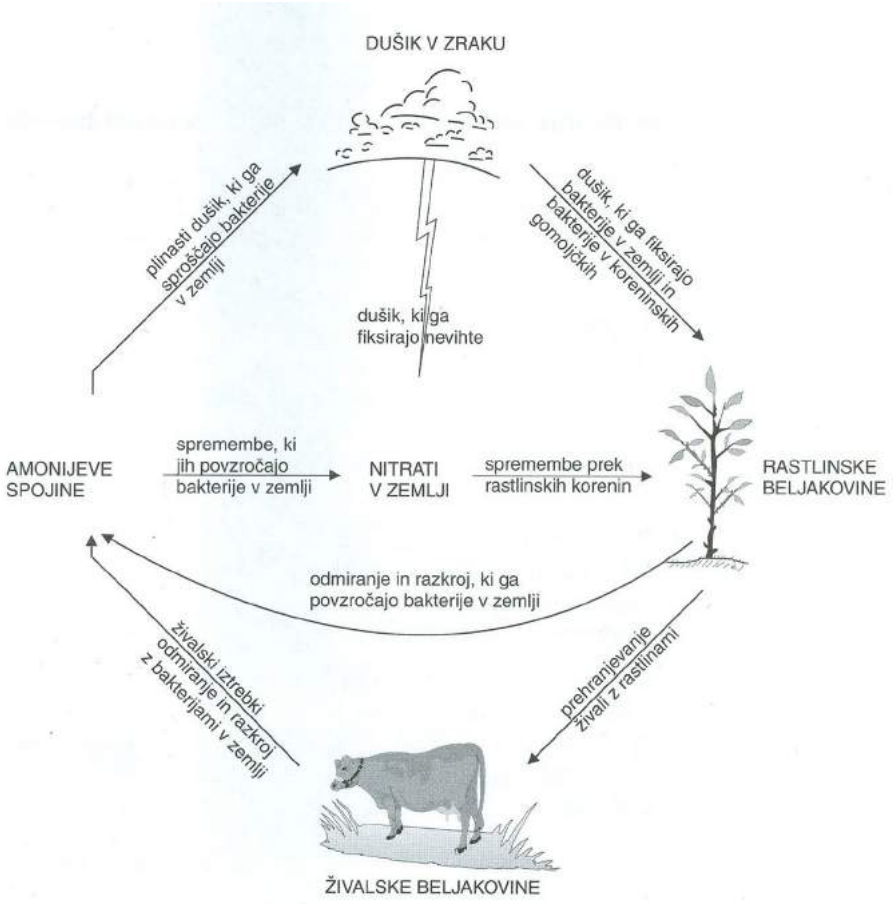
In this unit you can conduct research on your own:

- **the influence of mineral fertilisers on the growth of plants**

Soil is a mixture of decayed mineral rocks and organic substances. These particles make a porous fabric with lots of air and water. Mineral substances that are needed for the growth of plants are dissolved in water (in large quantities: C, H, O, N, P, K, Ca; in moderate quantities: S and Mg; and in small quantities: Fe, Mn, B, Cu, Zn, Mo, Cl, Co, and others). Plants receive carbon, hydrogen and oxygen from photosynthesis. Carbon dioxide and water react together in the presence of light and chlorophyll to make monosaccharide glucose and oxygen. With the respiration and decay of plants, these elements again transform into carbon dioxide and water and thus circulate.

Plants obtain other elements through water-soluble compounds of these elements that can be received and absorbed with their roots. One of the most important of these elements is nitrogen which is needed for the construction of proteins. It is absorbed from the soil and restored as nitrates(V), the compounds with NO^{3-} anions. In natural way, nitrates(V) are made when lightning occurs. Nitrogen and oxygen from the air react with each other and form nitrogen oxide NO, which further reacts with oxygen and forms nitrogen dioxide NO_2, which with further oxidation and reaction with water converts into nitrogen(V) acid or nitrates(V). Some plants have tubers on their roots in which the so-called nitrification bacteria live that are able to convert the unreactive nitrogen N_2 from the air into nitrates so the plants can use them. However, these two ways do not provide the soil with as much nitrogen as plants absorb from it. Farmers have always helped themselves with fertilisers (compost, barn manure); however, today even this is not enough.

Therefore, nitrogen has to be added in the form of mineral substances, which are well soluble in water, easy to store, and simple to use (the solid state of matter). The picture shows the circulation of nitrogen in nature. The basic principle of agriculture is to return to the soil as much as it was taken from it.



So the question was how to convert the nitrogen from the air into nitrates? The reaction between nitrogen and hydrogen which leads to the formation of ammonia was already known for long time. It was the same with the oxidation of ammonia which leads to the formation of nitrats(V). The chemists who invented the procedure and put it into practice were Fritz Haber and Karl Bosch. The process of producing ammonia is named after them: Haber-Bosch process. The nitrogen and hydrogen gases are reacted over an iron catalyst into ammonia. The reaction is carried out under conditions of 200 bars and 450–500°C. The efficiency of the reaction can be increased with simultaneously removing liquid ammonia from the reaction mixture and returning the unreacted nitrogen and hydrogen back to the reactor.

Ammonium nitrate(V) NH_4NO_3 is an artificial fertiliser with a high content of nitrogen. Calculate the mass percent of nitrogen in this compound and compare it with the mass fraction of nitrogen in urea with formula NH_2CONH_2.

(answer: mass fraction in ammonium nitrate(V) is 0,350 and in urea 0,467)

EXPERIMENTS:

1. The influence of heating on ammonium chloride

Equipment:

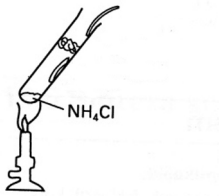
- test tube
- test tube rack
- Bunsen burner
- spatula
- glass stirring rod
- piece of cotton wool
- two pieces of universal indicator paper

Chemicals:

- ammonium chloride NH_4Cl

PERFORMANCE:

- Put around 3 g of ammonium chloride in a test tube.
- Put a wet ribbon of universal indicator paper over ammonium chloride, add a piece of cotton wool and again a wet ribbon of universal indicator paper.
- Heat the test tube with a small non-shining gas flame as long as the colour of both indicator papers changes and there is no further change anymore.



OBSERVATIONS AND EXPLANATION:

- How does the colour of the indicator papers change during the heating?
- Which gases were produced during the heating of ammonium chloride? Write the chemical equation with the states of matter.

Hydrogen chloride has a greater molar mass than ammonia and its molecules move slower than the molecules of ammonia. That is why the indicator shows an acid reaction on the lower part of the indicator paper and a basic reaction on the upper part.

2. Ammonia fountain

Equipment:

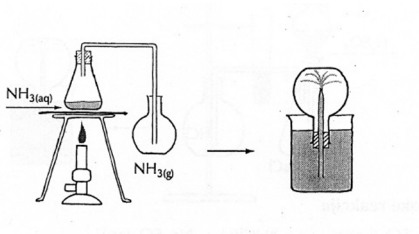
- Erlenmeyer flask
- glass pot
- dry Florence flask
- 2 tubes
- 2 bungs with holes
- Bunsen burner
- rack
- tripod
- clamp

Chemicals:

- 25% saturated ammonia solution
- phenolphthalein solution

PERFORMANCE:

- Construct the apparatus according to the picture.
- Add 20 mL of ammonia solution to an Erlenmeyer flask and heat it.
- The gaseous ammonia arising from the saturated solution travels through the glass tube to the Florence flask. When the Florence flask is full, plug it with a bung. (This bung has a small tube in it which is narrowed at the top.)



- Turn around the Florence flask into the beaker where the water solution of phenolphthalein is.

OBSERVATIONS AND EXPLANATION:

- Explain why gaseous ammonia comes out when you heat saturated ammonia solution?
- Why does a fountain appear in the Florence flask when it is connected with water?
- Why does the indicator phenolphthalein change its colour to violet?
  Write an equation for the proteolytic reaction of gaseous ammonia with water.

The solubility of gases in water is inversely proportional to the temperature, therefore, if water solution is heated, the solubility is decreased and undissolved ammonia is eliminated from the solution. When gaseous ammonia is connected with water, it dissolves in it very well. At 200°C, approximately 500 g of ammonia dissolves in one litre of water. The first drop of water dissolves all of the ammonia in the Florence flask. A negative pressure is formed, therefore water penetrates through the tube into the Florence flask and this looks like a fountain. The water solution of ammonia is a weak base; therefore, the indicator phenolphthalein becomes violet.

3. The synthesis of ammonium sulphate (VI) – solid mineral fertiliser

Equipment:

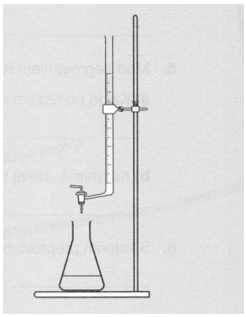
- funnel
- buret
- rack
- Erlenmeyer flask
- evaporating dish
- 100-mL measuring cylinder
- Bunsen burner
- tripod with glass ceramic plate
- spatula
- glass stirring rod
- filter paper

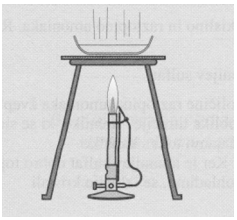
Chemicals:

- 1,0 M sulphuric(VI) acid
- 2,0 M ammonia solution
- indicator phenolphthalein

PERFORMANCE:

- Add 20,0 mL of sulphuric(VI) acid and some drops of the indicator phenolphthalein to an Erlenmeyer flask.
- Fill a buret with ammonia water solution; add ammonia water solution by drops until the indicator changes its colour and stir (shake) the Erlenmeyer flask all the time.
- Pour the solution into an evaporating dish and evaporate it until around one fourth of the original volume remains.
- Cover the evaporating dish with a piece of perforated filter paper and cool it down until the crystals of ammonium sulphate(VI) appear.
- Pick the crystals on a piece of filter paper and let them dry.





OBSERVATIONS AND EXPLANATION:

- Write an equation for the chemical reaction – neutralization – that took place.
- Which substances will appear in the evaporating dish after the titration ends?
- Why is it necessary to evaporate water out of the solution?
- Why do the crystals of ammonium sulphate occur during the cooling of the water solution?
- What is the difference in shape and size between the crystals you prepared and the commercial ammonium sulphate(V) for fertilizing?

CONDUCTING RESEARCH ON YOUR OWN

»What happens if plants lack nourishment?«

Equipment:

- seven 500-mL beakers
- scales
- teaspoon
- glass rod
- four 100-mL Erlenmeyer flasks
- black paper
- cotton wood
- four rectangular bent glass tubes
- 25-mL measuring cylinder
- Petri dish
- barley seeds

Chemicals:

- KNO_3
- $MgSO_4$
- KH_2PO_4
- $CaSO_4$
- K_2SO_4
- $Fe_2(SO_4)_3$
- $Mg(NO_3)_2$
- $FePO_4$
- distilled water

PERFORMANCE:

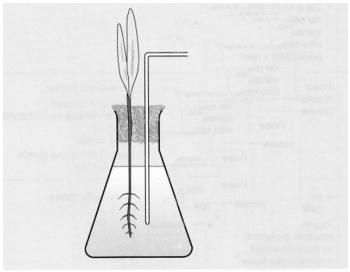
- Prepare water solutions of salts in 500-mL beakers (weigh the salt (see below), add 500 mL of distilled water and stir with a rod until it dissolves).

  0,500 g of salt in 500 mL of water: KNO_3, K_2SO_4, $Mg(NO_3)_2$
  0,125 g of salt in 500 mL of water: $MgSO_4$, KH_2PO_4, $Fe_2(SO_4)_3$
  0,100 g of salt in 500 mL of water: $CaSO_4$

- Prepare the mixture of four water solutions in 100-mL Erlenmeyer flasks (measure out 25 mL of each).

Erlenmeyer flask	**Label of the Erlenmeyer flask**	**25 mL water solution**	**25 mL water solution**	**25 mL water solution**	**25 mL water solution**
1.	Complete	KNO_3	$MgSO_4$	KH_2PO_4	$CaSO_4$
2.	Without nitrogen	K_2SO_4	$MgSO_4$	KH_2PO_4	$CaSO_4$
3.	Without phosphorus	KNO_3	$MgSO_4$	$Fe_2(SO_4)_3$	$CaSO_4$
4.	Without potassium	$Mg(NO_3)_2$	$MgSO_4$	KH_2PO_4	$CaSO_4$

- Add a knife tip of $FePO_4$ to the second and fourth Erlenmeyer flask.
  - Two weeks before the performance of this experiment, put 12 barley seeds in a moist cotton wood in a covered petri dish, so that they sprout
  - After they sprout, we make these little plants and their roots grow upright by putting two of them into each of the Erlenmeyer flasks. They should be wrapped in a black paper to prevent algae from growing on the walls of the flask (instead of using black paper, we can paint the Erlenmeyer flask on the outside with a black colour); label the Erlenmeyer flasks with a corresponding number or inscription; use a bent glass tube and carefully blow new the air to the Erlenmeyer flask every day to renew the oxygen.



OBSERVATIONS AND EXPLANATION:

- Observe the size and look of the plants after a certain amount of time. Draw a table.
- In literature (biology, agronomy course books) or on the Internet find pictures or photos of similar experiments that show how the lack of certain elements influences the growth of plants. Compare the obtained results with your results.

ASSINGMENT:

The table below shows the elements that are found in the nutrient solution on which a plant named impatiens feeds in an experiment similar to the experiment described above.

Experiment number:	Elements in each solution				
	Nitrogen	Phosphorus	Potassium	Magnesium	Iron
1.	+	–	+	+	+
2.	+	+	+	+	+
3.	+	+	+	–	+
4.	+	+	+	+	–
5.	–	–	–	–	–
6.	–	+	+	+	+
7.	+	+	–	+	+

- Which experiments show the lack of:

  nitrogen:

  phosphorus:

  potassium:

  magnesium:

  iron:

LITERATURE:

- G. Hill, J. Holman, J. Lazonby, J. Raffan, D. Waddington, Kemija 2000, Učbenik za tehniške in strokovne šole, Učno sredstvo v gimnazijskih programih, DZS, Ljubljana 2000
- Kemija 2000, Priročnik za učitelje 1, DZS, Ljubljana 2000
- Kemija 2000, Delovni zvezek 1, DZS, Ljubljana 2000
- V. Falatov, Dotik, barva, vonj, zvok, svetloba; Zavod RS za Šolstvo, Ljubljana 1996
- P. Kral, W. Rentzsch, H. Weissel, Preprosti kemijski poskusi za šolo in prosti čas; DZS, Ljubljana 1994

BEVERAGES

In this unit you can *perform experiments* in which coloured solutions are made that remind us of beverages:

- artificial beer
- artificial Coca-Cola
- enchanted juice
- blueberry juice – wine – whiskey – spirit

EXPERIMENTS:

1. Artificial beer (for three experiments):

- Use a 500-mL beaker and dissolve 0,29 g of Na_2SO_3 in 500 mL of water. Add 2,5 mL of ethanol and 1 mL of conc. H_2SO_4.
- In another 500-mL beaker, dissolve 2,12 g of KIO_3 in 500 mL of water.
- Use a beer glass and pour some dish detergent in it and then simultaneously 150 mL of each of the solutions.

2. Artificial Coca-Cola (the solutions should be fresh):

Pour 200 mL of distilled water in an original Coca-Cola bottle. Put it on a magnetic stirrer, stir it and 3,0 mL of 0,2% water solution of starch (0,1 g of starch and water till 50 g). Then add 4 mL of water solution of Na_2SO_3 (2,1 g of Na_2SO_3 in 100 mL of water) and drops of 1 M HCl(aq) until the change in colours appears. Use an original Coca-Cola bottle.

3. Enchanted juice (for four experiments):

- Juice A: Pour 100 mL of tap water in a 250-mL beaker, add methylorange, baking powder (half of a teaspoon) and a drop of dish detergent. Pour 50 mL of this solution into an empty glass which contains 100 mL of 0,1 M HCl(aq).
- Juice B: Pour 400 mL of tap water in a 500-mL beaker, add methylorange and a drop of dish detergent. Pour 100 mL of this solution into an empty glass which contains 10 mL of 0,1 M HCl(aq).

4. Blueberry juice – wine – whiskey – spirit:

Put a small amount (!) of $KMnO_4$ on the bottom of a 100-mL beaker and add 50 mL of solution of tartaric acid (12 spoons of tartaric acid in 300 mL of warm water). Wait for the change in colour. You can accelerate the experiment with heating the beaker.

METALS

If we look around, we can see that metals play an important role in our everyday lives. We know many different metals that are used in different ways for different purposes. Most of the metals are extracted from ores. The first widely used metal was copper, because it was easily extracted. Later people started to use bronze and iron. Aluminium – one of the most important metals – was first produced only after 1886. Iron is used for manufacturing different products, because it is relatively cheap and has big mechanical toughness. One disadvantage of iron is that it quickly reacts with air and water. This corrosion of iron is called rusting.

In this unit, you will perform the following experiments:

- **Burning of magnesium ribbon in a porcelain pot**
- **Reactions of different metals with water**

In this unit, you can also carry out experiments on your own:

- The influence of conditions on the rusting of iron
- Can other metals prevent iron from rusting?

EXPERIMENTS:

1. Burning of magnesium ribbon in a porcelain pot

Equipment:

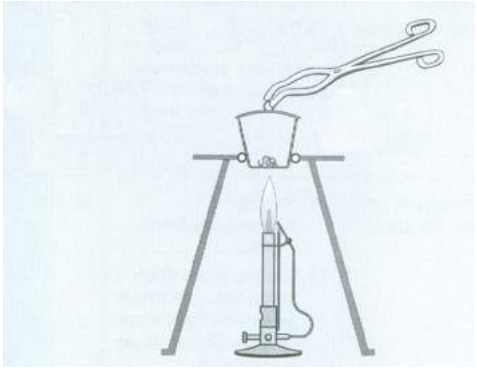
- porcelain pot with lid
- pliers
- ceramic triangle
- Bunsen burner

Chemicals:

- magnesium ribbon cleaned with sandpaper

PERFORMANCE:

- Roll a piece of 5 cm magnesium ribbon and put it into a porcelain pot.
- First cover the pot and weigh the pot with the lid. Then weigh the pot with the lid and the magnesium ribbon.
- First heat the pot over medium flame and later over hot flame.
- Approximately every 30 seconds open the pot for a few seconds and then cover it again.
- When the magnesium starts to burn, cover the pot as soon as possible to prevent smoke from leaving the pot.
- When the pot cools, weigh it with the lid and the content.



OBSERVATIONS AND EXPLANATION:

m (pot, lid):

m (pot, lid, magnesium ribbon):

m (pot, lid, the product of burning):

- Why is it necessary to uncover the lid during the burning of magnesium?
- Why is it important that the smoke does not escape while uncovering the lid?
- Why does the pot have to be covered when cooling down?
- What does the product of burning look like?
- What is the change in mass after the burning and why?
- Write the chemical reaction of magnesium burning.

From the mass of the magnesium ribbon calculate the theoretical mass of the product of burning in relation to the stoichiometry of the equation. Compare to the real mass and calculate the efficiency of the reaction.

2. Reactions of different metals with water

Equipment:

- four 250-mL beakers
- four test tubes
- Bunsen burner

Chemicals:

- small clean pieces of calcium
- magnesium ribbon
- iron
- copper

PERFORMANCE:

- Pour water into a beaker to fill one half of it and add a piece of metal to the beaker. Put a test tube, which is filled with water to the rim, over this piece of metal. Do this by closing the test tube with a Petri dish or your thumb, turning it upside down and opening it under water.
- Observe if the metal piece reacts with water. Be aware of bubbles and the colour of the metal piece. If the bubbles are made, intercept them into a test tube. You can catch the gas in the test tube if you close it with a thumb already under the water.
- To prove hydrogen, move the end of the test tube closer to the flame and open it right by the flame.

OBSERVATIONS AND EXPLANATION:

- Which of the four metals does react with cold water the fastest?
- Which of the metals does react with cold water slowly?
- Which two metals do not react with cold water?

Compare these experiments with the experiment with sodium (a demonstrative experiment) and classify the metals in the redox row. To distinguish between the last two metals, you can use dilute hydrochloric acid instead of water (in this case do not perform the test with a test tube). Which gas was formed in the reaction of metals with water and how does it react when heated? Write down chemical equations with the states of matter.

CARRYING OUT EXPERIMENTS ON YOUR OWN:
»The influence of conditions on the rusting of iron«

Equipment:

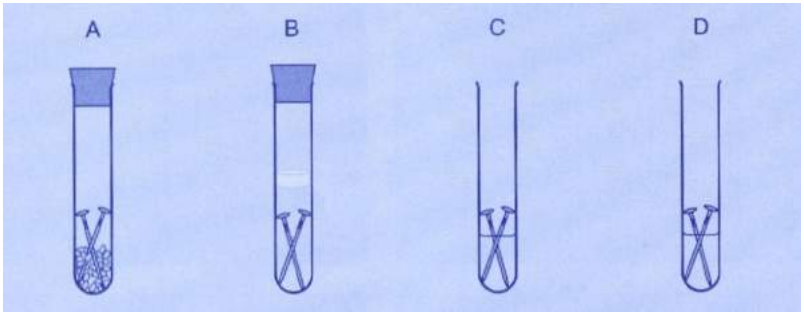
- dropper
- spatula
- test tube stand
- 4 clean test tubes
- 8 small iron nails
- 2 rubber stoppers,
- label or marker

Chemicals:

- paraffin oil
- waterless calcium chloride
- salt water
- freshly boiled water

PERFORMANCE:

- Prepare and label 4 test tubes, put them in the stand on a firm floor; test tubes A in B must be closed with a stopper.
- In the table below, write down your prediction (what do you think it will happen).
- After a few days, look at the test tubes and write down how the iron nails look like.
- After several additional days, look at the test tubes again and write down how the iron nails look like.



Test tube	The predicted result	Nails	
		After ..... days	After ..... days
A			
B			
C			
D			

OBSERVATIONS AND EXPLANATION:

- Which conditions are needed for iron to rust?
- What is the influence of salt on rusting?

CARRYING OUT EXPERIMENTS ON YOUR OWN:
»Can other metals prevent iron from rusting?«

Equipment:

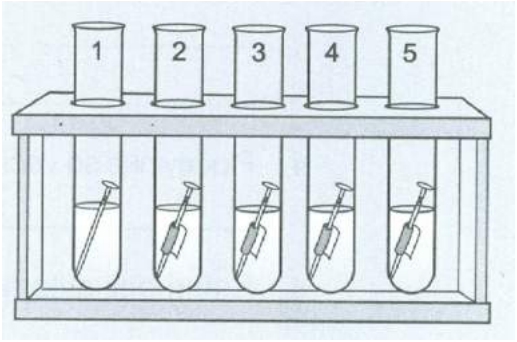
- test tube stand
- 5 test tubes
- labels or marker
- sandpaper

Chemicals:

- 5 iron nails
- ribbons of zinc, tin, copper, and magnesium
- salt water

PERFORMANCE:

- Label the test tubes and put them in the stand.
- Clean the nails and metal ribbons with sandpaper.
- Put one nail in the first test tube and add salt water to the half of the test tube.
- For the rest of the nails, wrap the metal ribbon tight around the middle of the nail and add salt water to cover the wrapped metal. The tip of the nail must be outside the salt water.
- The stand should stand on a firm floor. Observe the test tubes and write down the results.



		Look of iron			Look of the other metals		
Test tube	**Metal in the test tube**	**After ..... days**	**After ..... days**	**After ..... days**	**After ..... days**	**After ..... days**	**After ..... days**
1							
2							
3							
4							
5							

OBSERVATIONS AND EXPLANATION:

- Name the metals that accelerate and slow down the rusting of iron?
- How do these results match with the position of these metals in the redox row?

Sources:

- G. Hill, J. Holman, J. Lazonby, J. Raffan, D. Waddington, Kemija 2000, Učbenik za tehniške in strokovne šole, Učno sredstvo v gimnazijskih programih, DZS, Ljubljana 2000.
- Kemija 2000, Priročnik za učitelje 1, DZS, Ljubljana 2000
- Kemija 2000, Delovni zvezek 1, DZS, Ljubljana 2000

PLASTIC

In the first half of the 20th century, chemists researched the kinetics of the reactions under very high pressures. One of these reactions was a reaction between benzaldehyde and ethene. When the autoclave was opened, aprox. 1 gram of a white, waxy substance was found, its simple formula was CH_2. It was polythene that was formed and benzaldehyde under these conditions did not even react. This was a big surprise, because it was believed that ethene was not reactive enough for polymerisation. When this experiment was described in an international meeting of chemists, it was rejected by the leading chemist from the field of polymers.

It was impossible to repeat the experiment, until it was found out that in the first experiment ethene accidentally contained additions of oxygen that catalysed polymerisation. A lot of experiments followed, also some explosions, before the right conditions were found and the production of polythene began. At first, polythene was not widely used, for example it was used for submarine cables. The consumption grew from hundred tons at the beginning to several million tons per year nowadays. Let it be enough of polythene.

The first plastic was produced in the middle of 19th century. With the nitration of cellulose, nitrocellulose was produced (known as celluloid). At first, it was used for the production of billiard balls. Over the course of time, the progress went on and plastic started to replace many natural materials, such as wood, metals, minerals, and other materials. The main advantages are mainly in the simplicity and cheapness of sources and manufacturing. In 2010, several hundred million tons of plastic were produced in the world, approximately one fourth of it in Europe. It is necessary to be aware that this extensive production of plastic also causes environmental pollution. The production of plastic itself is already responsible for the pollution; however, waste plastic on disposal sites or in the natural environment (some parts of the Pacific Ocean became a kind of marine soup whose main ingredient is floating plastic debris) is even a bigger problem.

The possible solutions to this problem are recycling and the use of waste plastic as a fuel. The disadvantages of the first solution are expensive sorting and worse quality of such plastic whereas the disadvantages of the second solution are toxic gases as combustion by-products. Most of the plastic is made of non-renewable, fossil energy sources. This plastic decomposes very slowly in nature. Recently, the production of plastic from renewable sources has become more commonplace (for example from biomass). Such plastic is also biodegradable.

In this unit, you will get to know:

- **the areas of usage and key features of plastic**
- **chemical composition of plastic**
- **what bioplastic is**

In this unit you will perform experiments:

- **decomposition of polythene**
- **production of bioplastic**

In this unit you can conduct research on your own:

- comparison of composting different materials

Plastic is a very important part of today's world. The basic source of plastic is crude oil (around 4% of it is consumed for manufacturing plastic). Plastic is used in all kinds of industries for different purposes: packaging, construction, electrical engineering, furniture industry, transport, toys, sport and free time equipment, etc. Plastic is cheap, strong, light, easy to design, resistant to chemicals and can be dyed. One of the great advantages is that it is possible to produce "made to measure" plastic with features determined in advance. There are around 20 different types of plastic in the world; however, it is manufactured in several thousand ways.

Plastic is made of long polymer chains with big molar mass, with repeated units. When lots of monomer are connected end-to-end in a chain by a chemical reaction that breaks the double bond, a polymer is formed. The name of the polymer is derived from the name of a monomer, for example polythene, polypropene ...

Bioplastic is biodegradable and/or made of biological material (fossilized material does not fit in this category) or biomass. Biodegradability means that a product is capable of undergoing decomposition into carbon dioxide, methane, water, biomass and inorganic compounds.

EXPERIMENTS:

1. Decomposition of polythene and the proof reaction

Equipment:

- test tube made of heat resistant glass
- 3 test tubes
- glass tube with test tube stopper
- 500-mL beaker
- Bunsen burner

Chemicals:

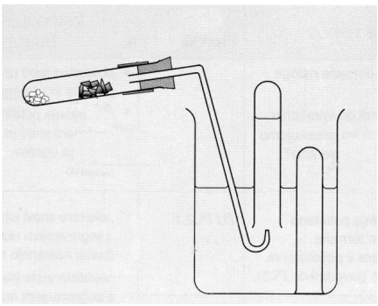
- polythene (in small pieces)
- ceramic shards
- dilute bromine water

Safety: Be careful that the glass tube does not get clogged and that the test tube stopper does not fall off the test tube; the gas which is made in this experiment is flammable; dilute bromine water is toxic if inhaled and is corrosive.

PERFORMANCE:

- Construct the apparatus. The clamp should be at safe distance from the place where the test tube is heated.
- First, strongly heat the ceramic shards and then gently heat the polythene.
- When the shards are heated enough, heat polythene until it becomes gaseous; afterwards heat polythene and shards alternately.
- Release the first bubbles of gas in the air but then trap the gas produced in two test tubes.
- The end of the glass tube should be removed from the beaker filled with water before you stop heating.

- Carefully smell the gas which was trapped in the first test tube.
- Shake the gas which was trapped in the second test tube with 1 mL of dilute bromine water.
- In another experiment shake some pieces of polythene with 1 mL dilute bromine water.



OBSERVATIONS AND EXPLANATION:

- Why the first bubbles of gas were not used for testing?
- Why is it necessary to remove the glass tube from the beaker filled with water before you stop heating?
- What is the smell of the gas?
- Write a chemical formula and the name of the gas which was produced in this experiment.
- What happens when you shake dilute bromine water:
    - with the gas produced
    - with polythene

  Explain the change in colour and write the chemical reaction that occurred.

2. Production of bioplastic from corn starch

Equipment:

- stove
- pot
- small tool for stirring
- teaspoon
- tablespoon
- plastic mat (it will be used for spreading plastic)

Chemicals:

- corn starch
- water
- vinegar
- glycerol

PERFORMANCE:

- Add one tablespoon of corn starch, four tablespoons of water, one teaspoon of glycerol, and one teaspoon of vinegar to the pot and stir everything well.
- Put this mixture on the stove and continue with stirring; this milky white liquid will start to thicken.
- When the substance becomes sticky and almost transparent, stop heating and spread it on the plastic mat; the thickness of the spread is optional.
- When it cools down, put it in the oven and dry it at 80°C for about two hours until it becomes transparent.
- If you want, you can add some drops of food dye at the beginning of the procedure to get coloured plastic.

Follow the link to see the experiment online: http://www.youtube.com/watch?v=5M_eDLyfzp8

CONDUCTING RESEARCH
»Comparison of composting different materials«

Equipment:

- oil
- water
- scales
- glass beaker or small pot for planting
- mosquito net
- different materials (apple slice, banana peel, piece of textile, piece of polythene bag, coin or nail, piece of paper, piece of bag for biological waste made of biodegradable plastic)

PERFORMANCE:

This experiment can last for the entire year.
At the beginning of the school year, put the samples in the soil and examine every month what happened with the material.

- Fill half of a beaker or small pot with soil.
- Put the materials for composting into the mosquito net, weigh them and take pictures of them.
- Tie the sample on the line or metal wire, put in a small pot, add soil and water.
- Dig the samples out of the soil once a month, wash them, dry and weigh and then dig again.

OBSERVATIONS AND EXPLANATION:

In this way, we can follow the decomposition of different materials over a longer period of time and compare the decomposition of a common polythene bag with the decomposition of a bag for composting biological waste. Because the temperatures of composting are not the same as in case of industrial composting, it is possible that the decomposition of the bag will take more than half a year.

ASSINGNMENT:

Instead of enamelling or galvanic coating of metallic objects, it is possible to laminate them, dip them into melted plastic. For this purpose, four types of plastic are appropriate: teflon, polythene, plexiglass and urea-formaldehyde resin. Some of their key features are shown in the table.

	Solidity regarding polythene	**Plasticity**	**Maximum temperature when used**	**Resistance towards dilute acids**	**Resistance towards oil substances**	**Price in EUR/kg**
Teflon	30	Moderate	250°C	Excellent	Excellent	12,42
Polythene	1	Very supple	70°C	Good	Good	1,03
Plexiglass	9	Rigid	90°C	Good	Good	1,46
Urea-formaldehyde resin	9	Very rigid	75°C	Bad	Good	1,29

Which plastic is best for:

a) the handle of a small screwdriver?

b) the isolation of an electric cable?

c) the coating of the inner side of a pan?

(answer: a) urea-formaldehyd resin / b) polythene / c) teflon)

Sources:

- P. W. Atkins, M. J. Frazer, M. J. Clugston, R. A. Y. Jones, KEMIJA zakonitosti in uporaba, Tehniška založba Slovenije, Ljubljana 1995
- G. Hill, J. Holman, J. Lazonby, J. Raffan, D. Waddington, Kemija 2000, Učbenik za tehniške in strokovne šole, Učno sredstvo v gimnazijskih programih, DZS, Ljubljana 2000.
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- M. Šprajcar, P. Horvat, A. Kržan, Biopolimeri in bioplastika (informacijsko – izobraževalno gradivo za profesorje in laborante kemije na osnovnih in srednjih šolah), Kemijski inštitut, Ljubljana

PHYSICS

ST. STANISLAV'S INSTITUTION

Science Classroom (Sint-Calasanzinstituut, Nijlen, March 2016)

MEASUREMENT OF THE HORIZONTAL COMPONENT OF THE EARTH'S MAGNETIC FIELD

Introduction:

Compass is normally oriented to the horizontal component of the Earth's magnetic field. Besides determining the direction, compass can be also used for the measurement of the magnitude of this magnetic field component (B_Z). For this purpose we can use additional homogeneous magnetic field (B_T) with direction perpendicular to the horizontal component of the Earth's magnetic field. In this case, compass will be oriented in the direction of the vector sum of both vectors. Declination from the original position is noted as angle ϕ. (Figure 1 is "ground plan")

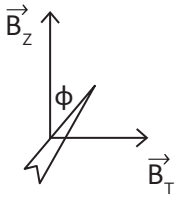


Figure 1: Compass is directed to the vector sum of magnetic fields.

Homogeneous magnetic field is obtained in a long coil. For perfect homogeneity, it should be tightly coiled up. This type of coil is not practical for experiments with compass. Instead we can use a more convenient Helmholtz coil. In the centre of this coil, there is very homogeneous magnetic field. Helmholtz coil consists of two ring-type coils joined up in series. For obtaining optimal magnetic field inside these coils the radii of the coils should equal its centre distance. An advanced calculation leads to the magnetic field equation inside Helmholtz coil:

$$B_T = \mu_0 \frac{NI}{r} \frac{8}{\sqrt{125}},$$

where N is number of turns in each coil,
I is electric current and r is radius of ring (Figure 2).

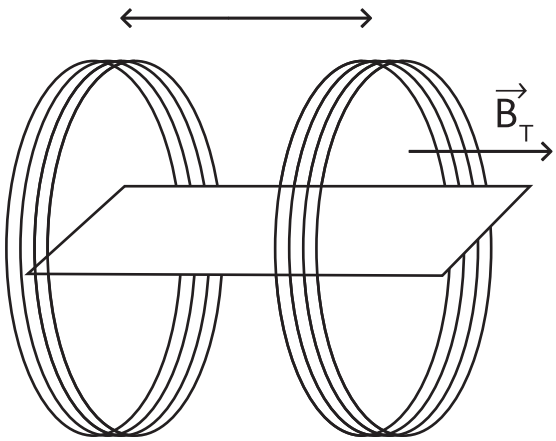


Figure 2: Both ring-type coils are connected in series (a connection is not marked). The distance marked by an arrow equals the radii of turns. In the space between the rings, there is a wooden board with compass on it. The direction of the magnetic field of coil is along the axis of this coil.

EXERCISE:

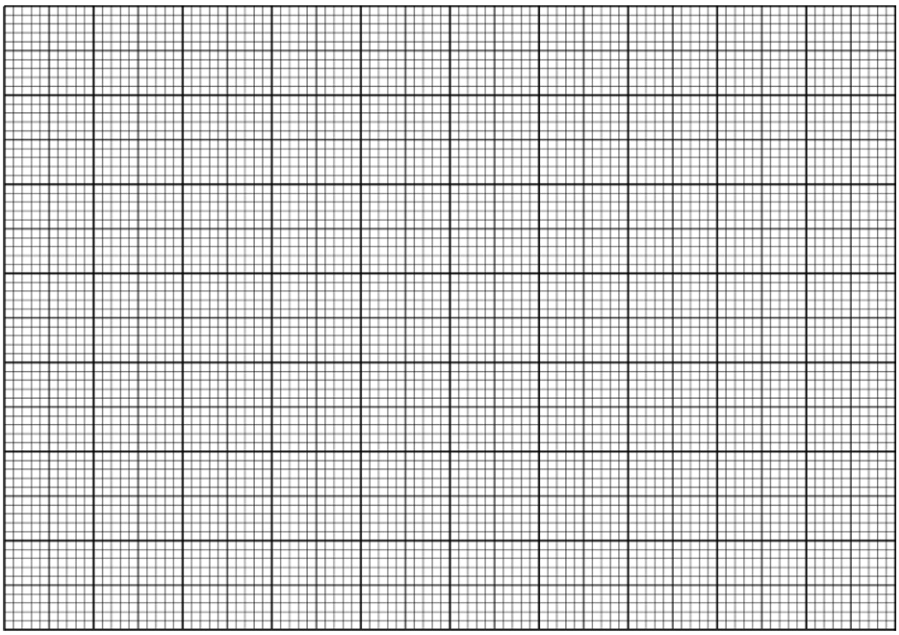
Place the Helmholtz coil in a way that the orientation of the magnetic needle is perpendicular to the coil axis.
Turn on a power source and set the current to the value written in the table below. Determine an angle of the magnetic needle declination from its original orientation. Draw two graphs: declination angle as a function of current and the linearized graph. Using a slope of second graph, determine the horizontal component of the Earth's magnetic field. In our case N = 20 and *r* determine by yourself.

Equipment:

- Helmholtz coil with compass
- heater
- power supply
- ampere metre
- magnifying glass

Warning: An electric heater is joined in circuit in series. This enables more stable electric current. Electric resistance of the coil is very low and a little change in voltage would result in a huge change of the current. By using the heater, the resistance of the entire circuit is larger. The heater is warming up during the measurement; therefore, you should not touch it. The current should be set according to the table below.

I [A]	0,00	0,10	0,15	0,20	0,25	0,30	0,35	0,40	0,50
ϕ [°]	0								
tan ϕ	0								



ELECTRIC CIRCUITS IN SERIES AND IN PARALLEL AND SOME ELECTRONIC ELEMENTS

Two batteries in series are used as a power supply. **Be careful not to cause a short circuit.** Wires which are attached to the batteries should not be directly connected. There should always be at least one element.

First connection

Connect the batteries with one light bulb first, then with two bulbs in series and finally two bulbs in parallel. Draw the schema of these connections and observations for each case.

Second connection

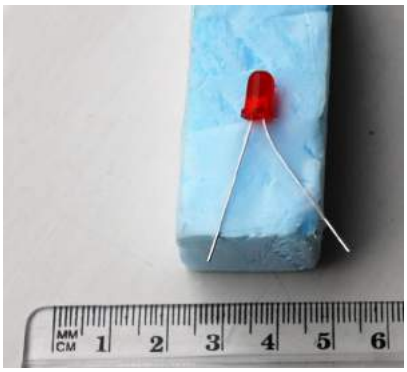
This time connect an electric bulb and the electric element on this figure in series:
Why is it asymmetrically marked? What is its name?
What are its features? Write down your conclusions.

Third connection

Connect an electric bulb in series with another element, which is glued to the holder (it should stay that way).

Is there any similarity with the previous element?

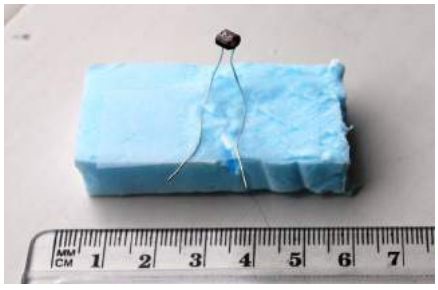
How is this one called? Write down your answers and conclusions. Why is this type of illuminants frequently used instead of electric bulbs? What happens, if only this element is connected to the battery (without a bulb)?



Fourth connection

Find this element in a box. Do not bend its wires, because they can easily tear apart.
Connect this element with an electric bulb in series. Comment this.

Connect it also in parallel. Comment this, too.



Fifth connection

The element from third connection connect with element from fourth connection in series. Cover up the last element. Is there any change? Is there any change in its resistance with less illumination?

Substantiate your answer with the experiment and conclusions.

Sixth connection

Slide resistor and electric bulb connected in series. Slide resistor will be given to you by your professor.

RADIOACTIVE DECAY SIMULATION

EXERCISE:

Radioactive decay simulation using gambling dice. Calculation of half-life and the decay constant.

Equipment:

- dice (a bit more than 200)
- two containers

Introduction:

Some atoms (isotopes) are unstable and can decay. Radioactive decay is a random process and the moment of decay cannot be foreseen in advance. However, the number of nuclei which will decay in a time period can be estimated. According to it, each nucleus has an equal probability of decay.

Our sample contains N particles. The number of nuclei (ΔN), which decays in a short period of time (Δt), is proportional to this interval and to the initial number of nuclei N:

$$\Delta N = -\lambda N \Delta t \quad (1)$$

The constant λ is called the decay constant. Its value depends on the type of atom. The sign minus indicates that N is decreasing. To evaluate a connection between N and time, we should solve the equation (1). This procedure requires integration, the result is

$$N = N_0 e^{-\lambda t} \quad (2)$$

At time t = 0, there are N_0 nuclei. Equation (2) is called a **radioactive decay law**.

INSTRUCTION:

Each dice represents one atom. First count all the dice, their number is $N(t = 0) = N_0$.

Throw all the »dice-atoms« in one of the containers. Some of them are positioned with red king up. They represent the decayed nuclei. They are taken out of the container and counted to get the new number nuclei. The procedure is then repeated nine times with the rest of dice.

Each throw represents a time interval of 20 seconds. Fill in the first three columns of the table below. Then you should draw a graph N(t). Using linearization procedure for the equation (2), an expression with logarithm is obtained and written down in the last column of the table. Finally draw a graph $N(t)$ and a linearized graph. Determine the slope of the line in this graph. What is its meaning? How can half-life be determined out of it? What is a value of half-life theoretically? Estimate the accuracy of the measured result.

LINEARIZATION:

$$\frac{N}{N_0} = e^{-\lambda t}$$

$\ln(N/N_0) = -\lambda t \times \ln(e)$

$\ln(N_0/N) = \lambda t$

Throw no.	"Time" [s]	Removed dice	N left dice	Ln (N_0/N)
0	0	0		
1	20			
2	40			
3	60			
4	80			
5	100			
6	120			
7	140			
8	160			
9	180			
10	200			

A label *removed* marks the number of the removed dice in each step. It does not mean the total number of the removed dice. A label N marks the difference between the initial number (N_0) and the total number of the removed dice. It is a current number of momentarily undecayed nuclei.

ELECTRIC VOLTAGE AND POTENTIAL

Importance of this topic:

Students are in theory and in practice acquainted with the basic terms concerning electric consumers, which can do mechanic work or emit heat.

Theory: Electric potential, voltage, electrical current

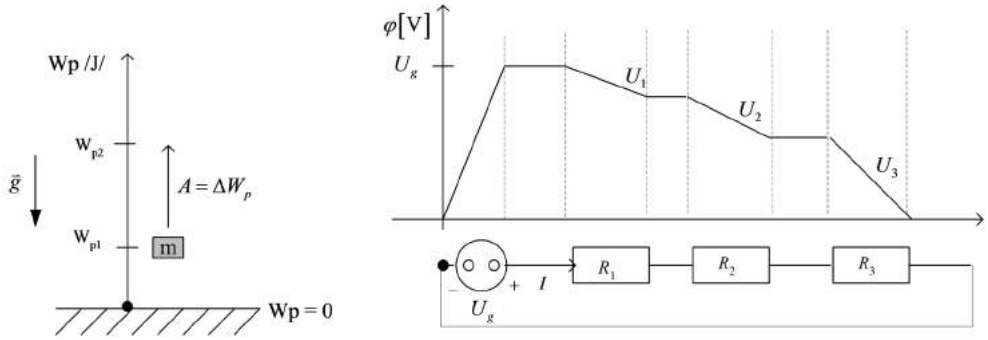
In electric circuits, there are two types of voltage:

a) Driving voltage $U_g = \frac{A_e}{e}$ is an amount of electric work done by a power supply after an electric charge e is pushed. It is fixed for batteries and can be set in case of DC power supplies.

b) Voltage drop $U_i = \frac{A_e}{e}$ is a voltage on a consumer through which the elecric current flows. It equals the received electric work after a certain amount of electric charge flows through it.

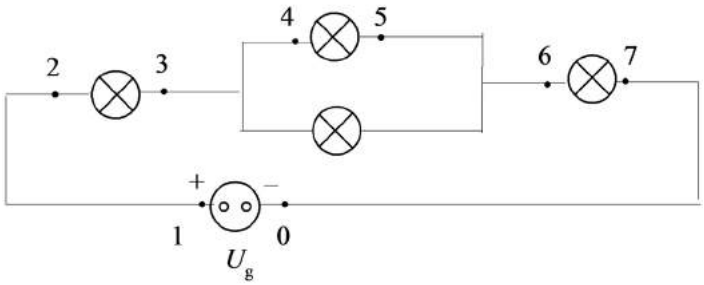
Electric potential can be compared with potential energy, where zero is set arbitrary. In electric circuits, zero is negative connection of the battery, whereas in case of power supplies it is the ground. The voltage drops of the consumer equals the change of the potential: $U_1 = j_2 - j_1$.

On the figure below, there are three consumers R_1, R_2 and R_3 in serie and a voltage distribution in the circuit. Driving voltage is positive, voltage drops negative.



1. EXERCISE:

Out of four electric bulbs and one battery make an electric circuit using the scheme below. Using Logger Pro program, measure the voltage distribution in the points from 0 to 7.

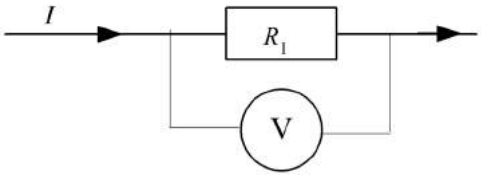


2. EXERCISE:

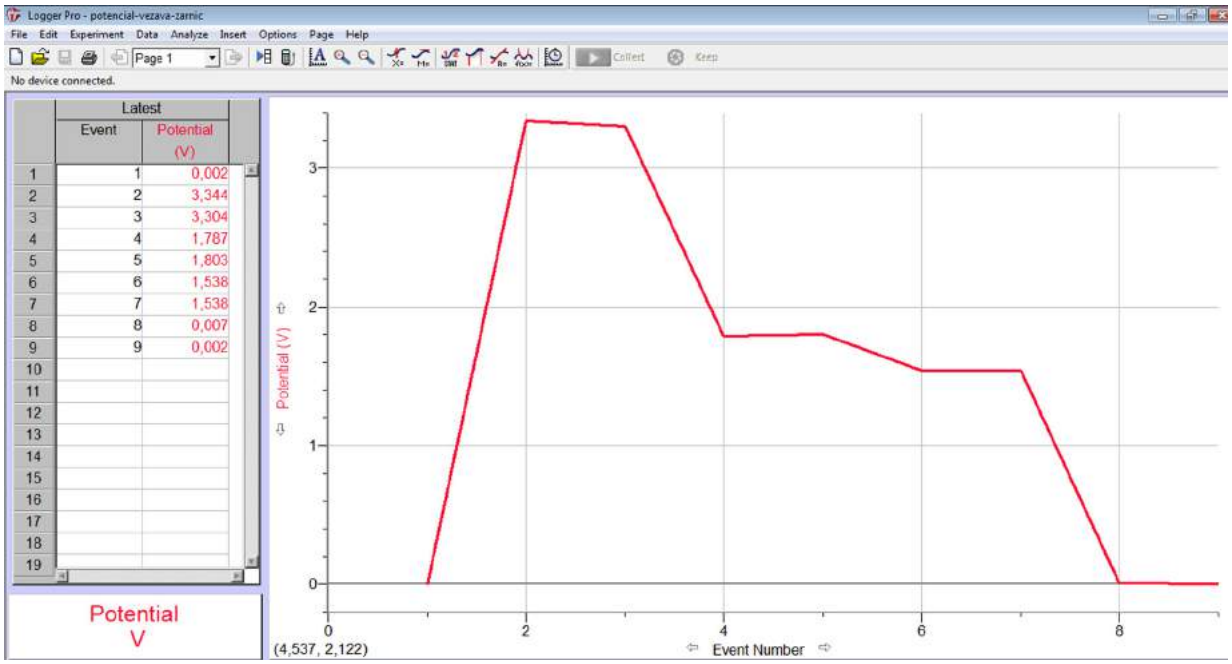
Using two potential meters, set up a voltage meter and compare the results with a digital voltmeter.

3. EXERCISE:

Using the resistance measured with an ohm-meter and a potential meter, set up an amperemeter as in the scheme below. Measure the electrical current through the electric bulb.



RESULT:



RESISTANCE OF CONSUMERS AND ALTERNATING CURRENT

Importance of the topic:

Students are to become acquainted with electric resistance and alternating current in theory and in practice.

Theory: Electric resistance of a consumer is a value, typical for a certain consumer.
It equals voltage on the consumer, divided by the current I through it:

$$R = \frac{U}{I}\,\frac{V}{A} = W$$

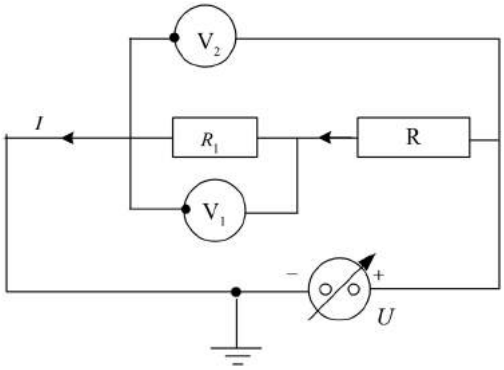
Grid voltage is alternating, it can be written as:

$U = U_0 \sin(2\pi n)$,

where U_0 is amplitude 324 V and frequency 50 Hz.

1. EXERCISE:

Set up a circuit as shown on the scheme below. It simultaneously measures the electrical current through the wire (R) and the voltage on this wire.



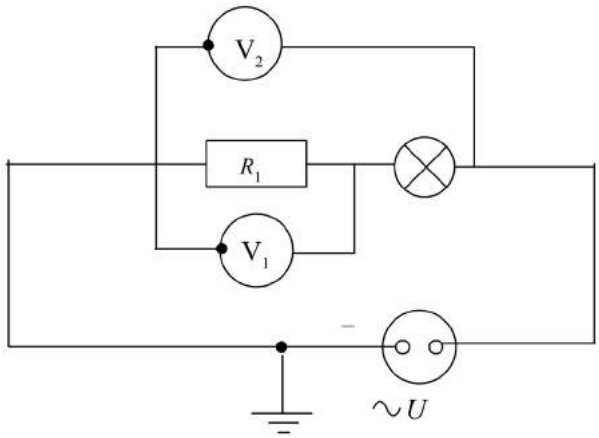
Potential V_1 is the voltage drop on the resistor R_1 = 1,1 Ω.
Resistance of the wire can be calculated using the formula:

$$R = \frac{V_2 - V_1}{V_1} R_1$$

Set the above formula in the program Logger Pro. Verify how the resistance of wire changes due to the change of its length.

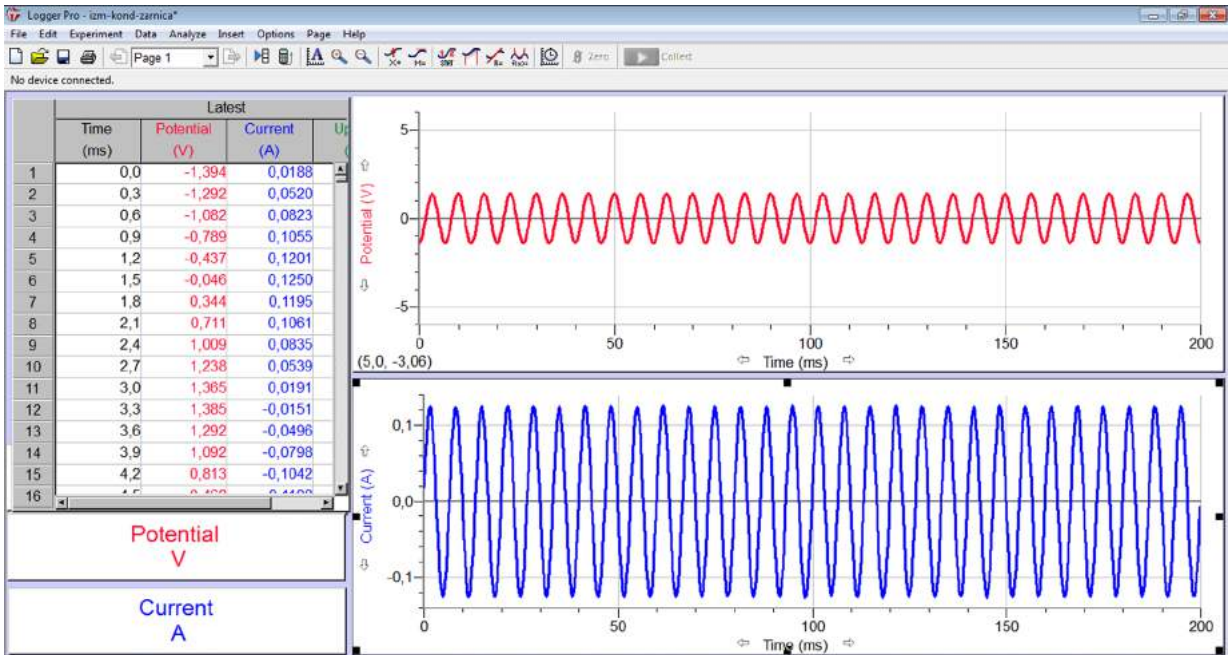
2. EXERCISE:

Instead of an electric grid, which can be dangerous for experiments, an oscillator can be used.
Set up an electric circuit using an electric bulb, oscillator and two potential meters as in the scheme below:



Observe voltage oscillation and light oscillation of the bulb.

RESULT:



MEASURING THE CAPACITANCE OF THE CAPACITOR

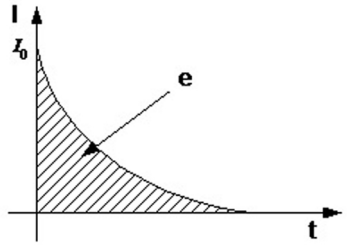
Importance of the topic:

Students are in theory and in practice acquainted with the capacitor as a unit for storing electric charge.

Theory: Capacitance is a value for a certain capacitor.
It is an amount of charge which can be stored at a certain voltage:

$$C = \frac{e}{U}\,\frac{A}{V} = F$$

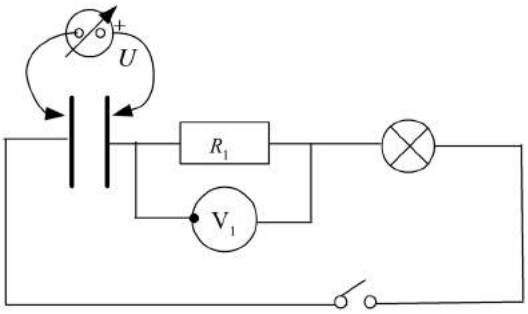
During discharging capacitor, the voltage on it exponentially decreases:



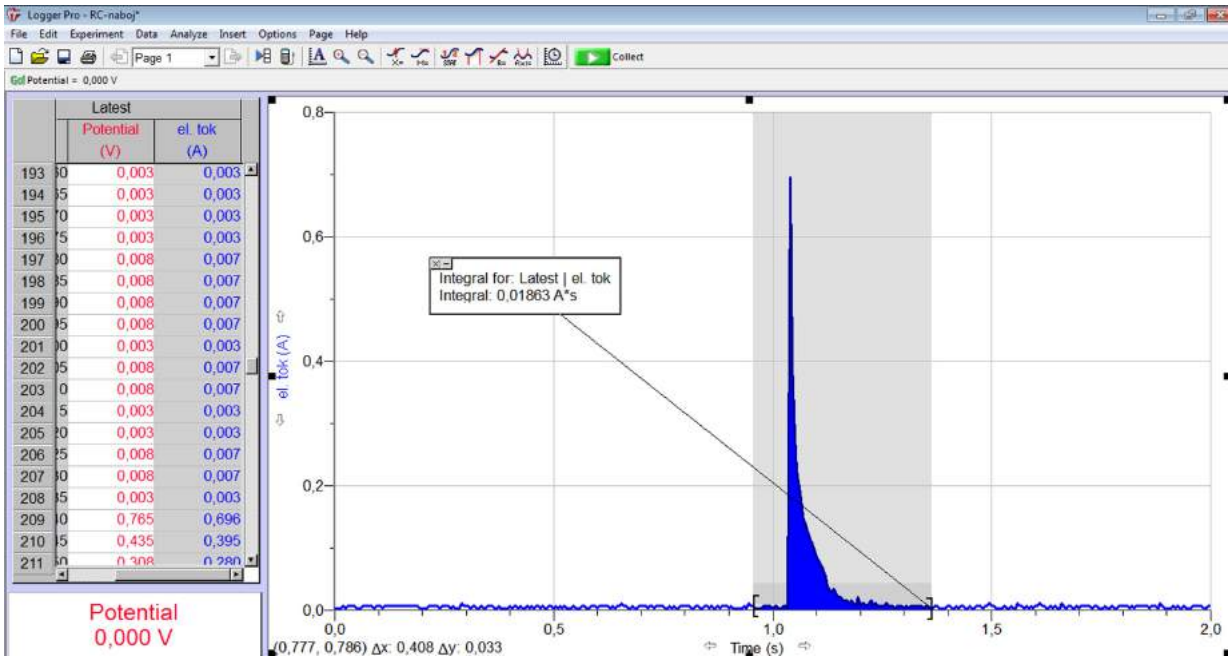
The marked area equals the stored electric charge.

EXERCISE:

Charge the capacitor with a certain voltage and discharge it through an electric bulb. Determine the electric charge by measuring the area below the curve in the graph I = I(t). Repeat the measurement with different initial voltages and calculate the capacitance of the capacitor. Compare this value with the label on the capacitor.



RESULT:



RESISTANCE OF THE CAPACITOR

Importance of this topic:

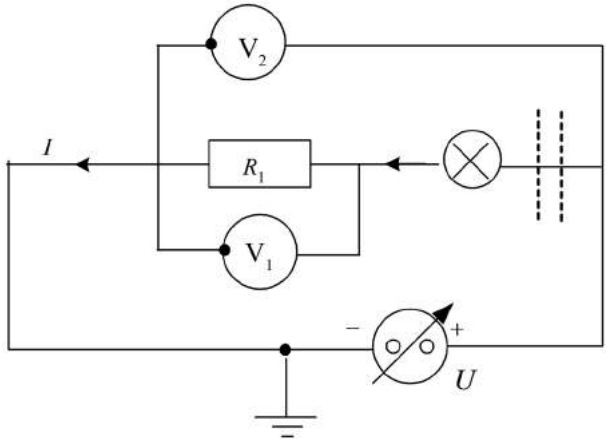
Students verify that capacitor conduct AC current and not DC current. This is important when dealing with electric grid.

Theory: At DC current, when frequency is zero, the capacitor's resistance is infinite.
At AC current, the resistance depends on the capacitance and frequency:

$$R_C = \frac{1}{C}\frac{V}{A} = W$$

EXERCISE:

Set up an electric circuit for measuring the voltage on the electric bulb and electrical current through the bulb simultaneously.



Potential V_1 is a voltage drop on the known resistor R_1 = 1,1 Ω, the current through the bulb is then calculated using the formula:

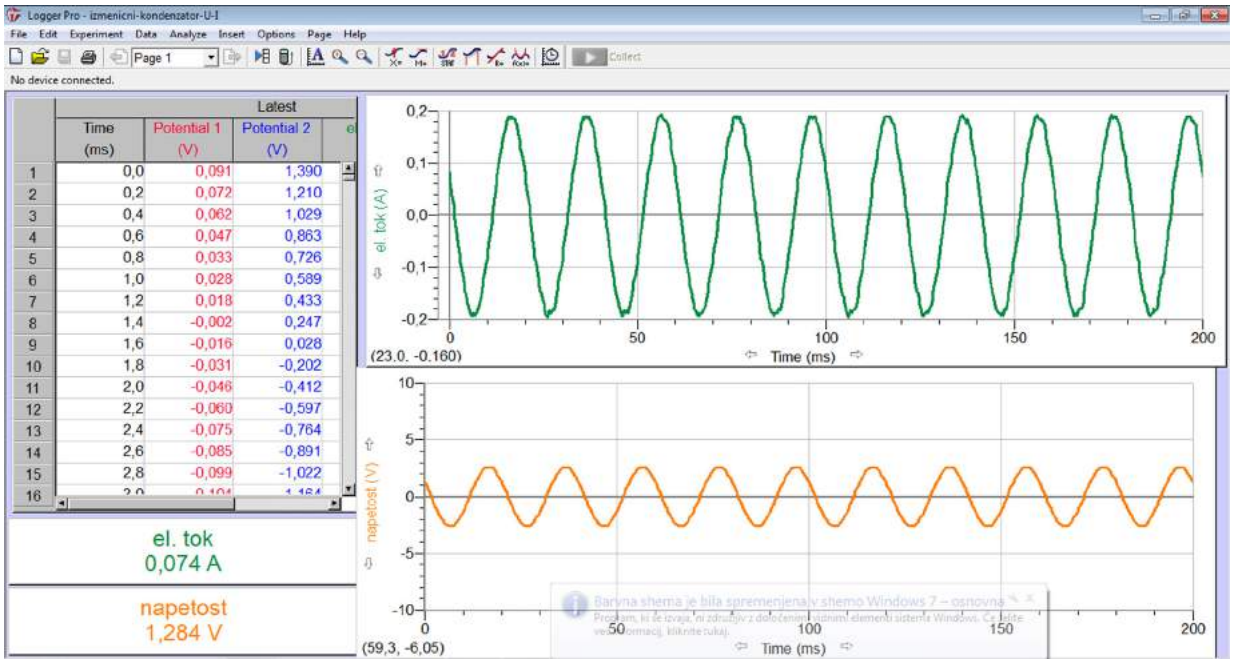
$$I = \frac{V_1}{R_1}$$

The voltage drop equals potential difference: $U = V_2 - V_1$

TASK:

First, set up an electric circuit without the capacitor. Measure the voltage and current.
Second, insert the capacitor. What happens with the current? Change the battery with AC source and repeat the measurement. Using the amplitude of the voltage and current, determine the resistance of the capacitor and verify the formula above.

RESULT:



LC CIRCUIT

Importance of the topic:

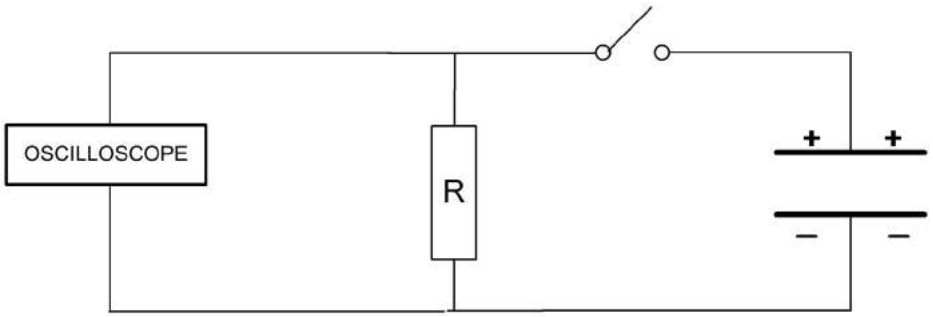
Students realize that LC circuit oscillates without external influences.
It is a basic circuit of all radio transmitters and receivers.

Theory: LC circuit consists of a capacitor and a coil. L is inductivity of the coil.
The period of oscillation is

$$t_0 = 2\pi\sqrt{LC}$$

1. EXERCISE:

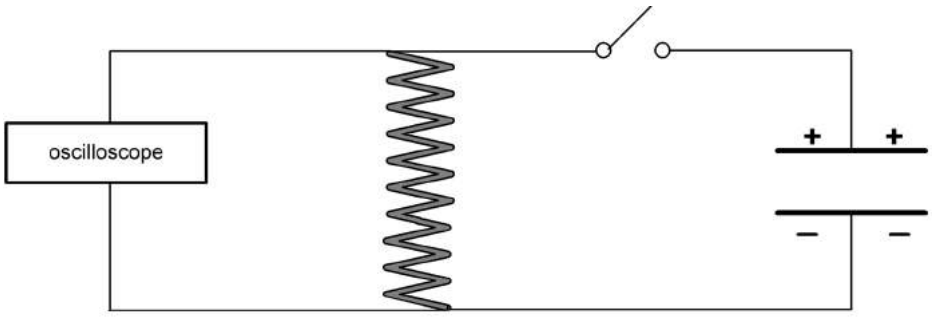
With the capacitor, resistor and battery set up the circuit below.
Put a switch on and measure the voltage. System Logger Pro is used as an oscilloscope.



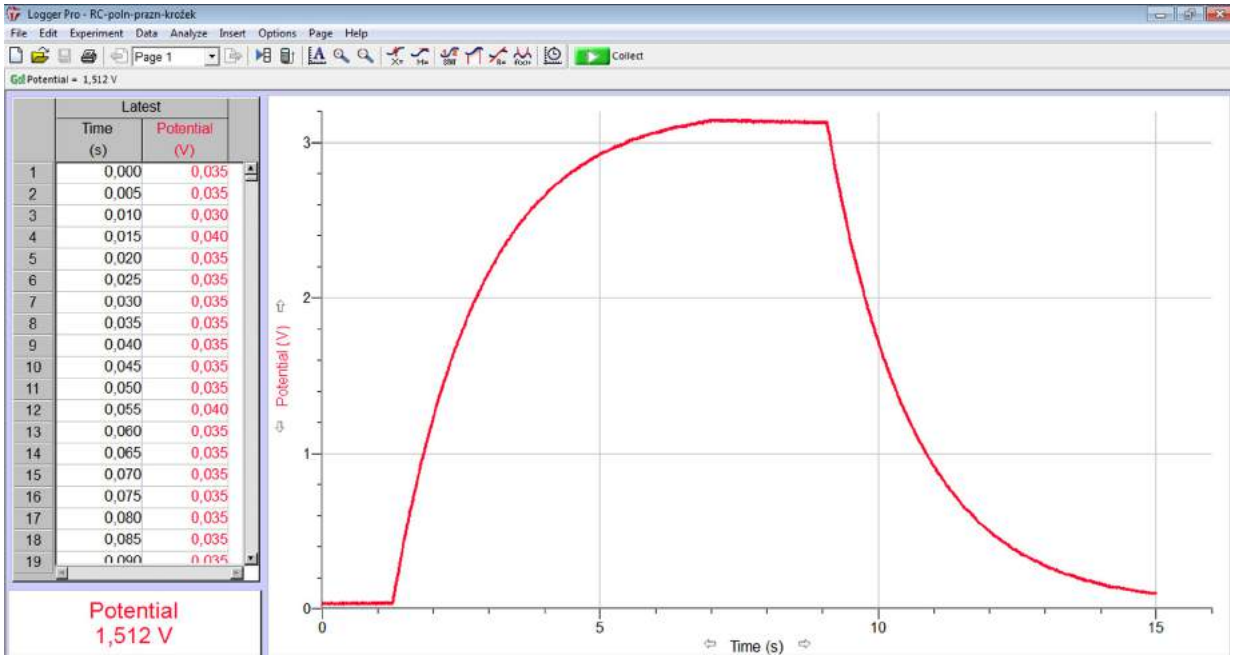
2. EXERCISE:

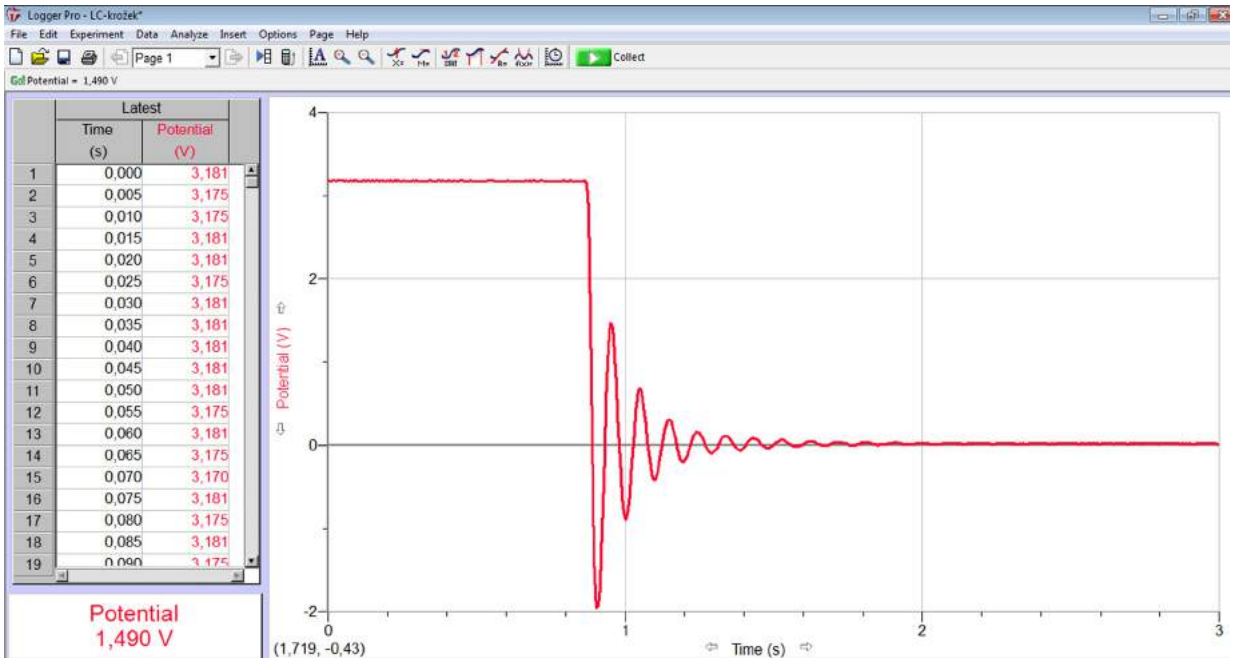
Set up an electric circuit as shown in the scheme below. Charge the capacitor with the battery and discharge it through the coil. Determine the period of oscillation. Connect another capacitor parallel to the previous one and repeat the measurement. In each case determine the value t_0^2/C.

Compare both values.



RESULTS:


Logger Pro - RC-poln-prazn-krožek
File Edit Experiment Data Analyze Insert Options Page Help
Page 1
Collect
Gd Potential = 1,512 V
Latest
Time (s)
Potential (V)
1 0,000 0,035
2 0,005 0,035
3 0,010 0,030
4 0,015 0,040
5 0,020 0,035
6 0,025 0,035
7 0,030 0,035
8 0,035 0,035
9 0,040 0,035
10 0,045 0,035
11 0,050 0,035
12 0,055 0,040
13 0,060 0,035
14 0,065 0,035
15 0,070 0,035
16 0,075 0,035
17 0,080 0,035
18 0,085 0,035
19 0,090 0,035
Potential
1,512 V
Potential (V)
Time (s)
0
1
2
3
5
10
15


Logger Pro - LC-krožek*
File Edit Experiment Data Analyze Insert Options Page Help
Page 1
Collect
Gd Potential = 1,490 V
Latest
Time (s)
Potential (V)
1 0,000 3,181
2 0,005 3,175
3 0,010 3,175
4 0,015 3,181
5 0,020 3,181
6 0,025 3,175
7 0,030 3,181
8 0,035 3,181
9 0,040 3,181
10 0,045 3,181
11 0,050 3,181
12 0,055 3,175
13 0,060 3,181
14 0,065 3,175
15 0,070 3,170
16 0,075 3,181
17 0,080 3,175
18 0,085 3,181
19 0,090 3,175
Potential
1,490 V
Potential (V)
Time (s)
(1,719, -0,43)
-2
0
2
4
1
3

ELECTRIC BULB CHARACTERISTICS

Importance of the topic:

Students get to know that linear dependencies between quantities in physics are mostly just linear approximations of relatively small changes of the quantities. A simple example for this is Ohm's law for an electric bulb.

Theory: Ohm's law, temperature dependence of resistance.

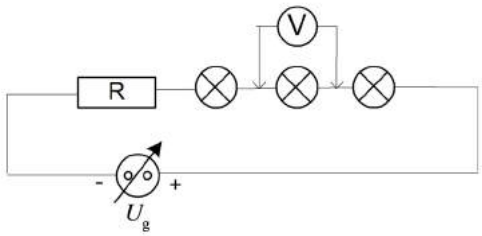
a) Ohm's law for an element describes the connection between a potential drop on the element and the current, flowing through the element:

$$I = \frac{U}{R}$$

b) With the increase in temperature, the resistance of most electric elements grows meaning that in upper relation the current is no longer proportional to the potential drop and a characteristic of the element I = I(U) is no longer a straight line.

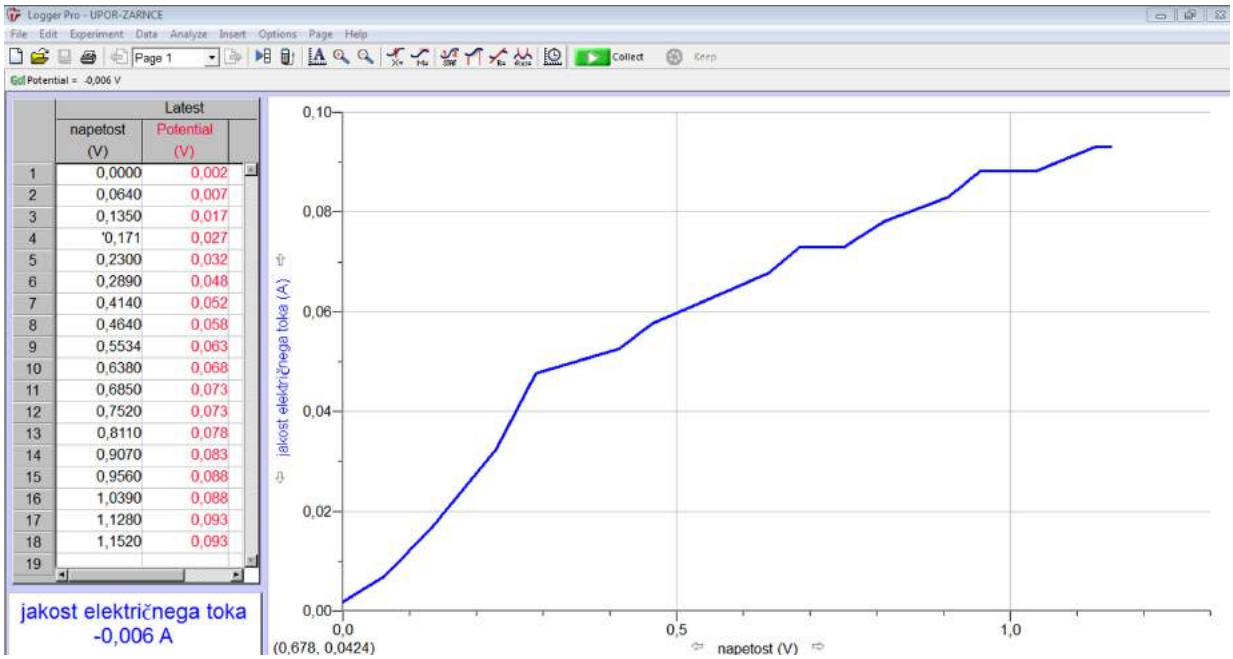
EXERCISE:

Put together the elements as it is shown on the figure below.
Using a voltmeter determine the distribution of potential in this circuit.



Connect the potential meter's ground to the negative pole of the power supply and connect the other connection of the potential meter to the resistor R. In this case, the measured potential equals the potential drop on this resistor. Since this potential drop is proportional to the electrical current, it can be used for current calculation. In the program Logger Pro insert a new column in which electrical current is calculated according to the formula above. Current and voltage on the light bulb are measured simultaneously. You should change the voltage of the power supply and measure the characteristics of the electric bulb which shows how electrical current through the bulb depends on the voltage on it.

RESULT:



EXERCISE:

Out of the measurement determine the resistance of the cold and hot bulb.
At which current the bulb starts to glow?

CAPACITOR CHARGING

Importance of the topic:

Students get to know that electric charge can flow on and off the capacitor. For DC current, its resistance is infinite, for AC current, the resistance decreases with increasing frequency.

Theory: definition of capacitance, voltage on the capacitor during charging.

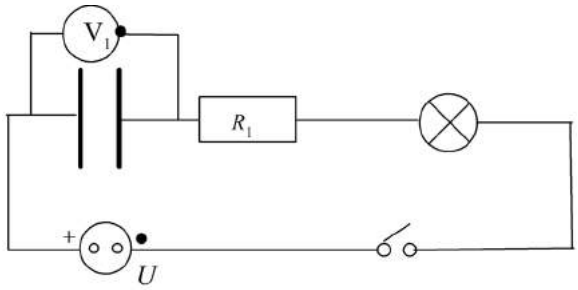
After turning the switch on, the capacitor is charging and the LED diode emits light.
When the capacitor is fully charged, the LED does not shine anymore.
Voltage on the capacitor increases according to the equation:

$$U = U_0\,(1-e^{-bt})$$

where U_0 is final voltage (voltage of power supply) and $b = \frac{1}{RC}$

EXERCISE:

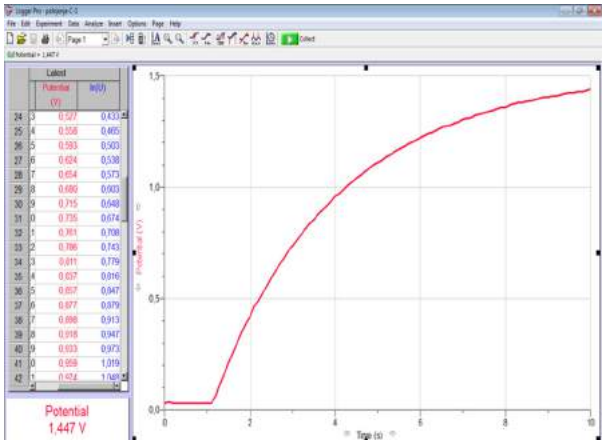
Connect elements in a circuit as shown on the scheme below.
Ground connection is marked as a black dot and should be connected exactly as it is shown in scheme.

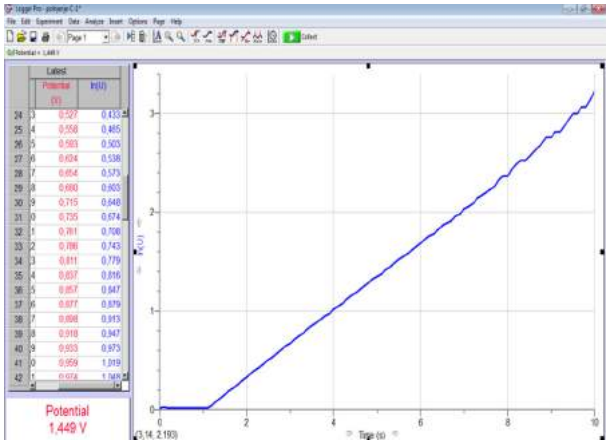


After turning the switch on, the capacitor is charging and the electrical bulb glows. After the capacitor is charged, there is no current and the bulb doesn't glow anymore. Voltage on the capacitor increases according to equation above.

EXERCISE:

Record a graph U = U(t), linearize it and determine the coefficient *b*. Carry out linearization so that in the programme Logger Pro a new column is defined Log (U_0/U). Using the slope of the line in this graph, determine the coefficient *b* and verify it with a calculation.





ALTERNATING CURRENT

Importance of this topic:

Students become theoretically and practically aware of the characteristics of alternating current.

Theory: Grid voltage is alternating and can be written in the equation

$$U = U_0 \sin(2\pi n)$$

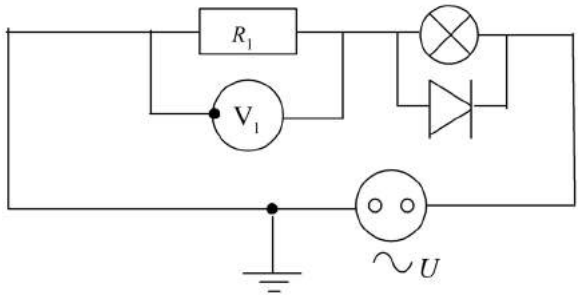
where U_0 is voltage amplitude 324 V and n frequency, which is 50 Hz.
The resistance of semiconductor diode depends on the direction of the current.
In one direction it is approximately kΩ, in the other direction it is more than MΩ.

1. EXERCISE:

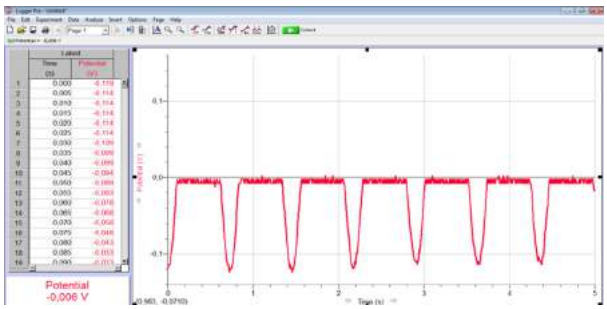
Connect the electric bulb, resistor and power supply in a circuit as on the scheme. Observe the oscillation of voltage on the resistor. Determine the frequency directly and by using fast fourier transformation (FFT).

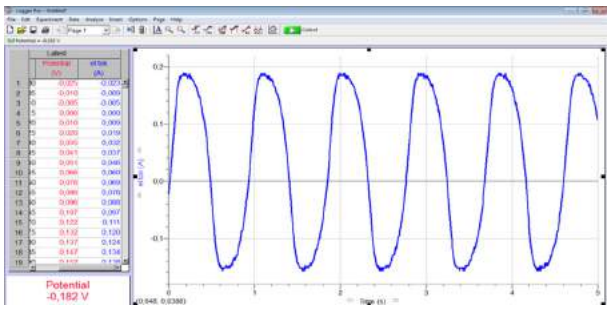
2. EXERCISE:

Add a LED diode to this circuit. Compare the glowing of the bulb and diode. Observe the oscillation of voltage on the resistor. How can you explain the difference in the glowing of the bulb and diode?



RESULT:



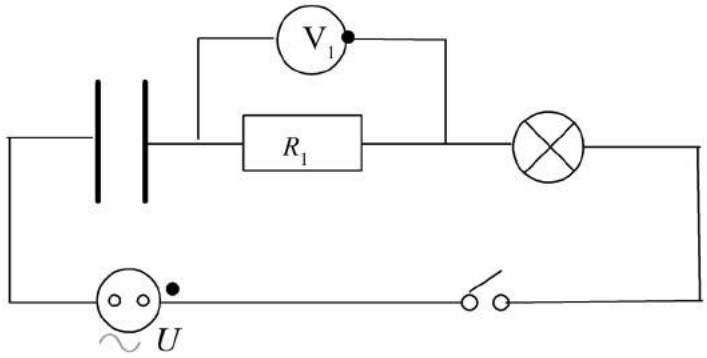


Questions:

- Voltage oscillates as a function sinus. Why does the current through the bulb differ from the sinus?
- Why does in the second case the LED oscillate with a two times lower frequency as in the case of the bulb?

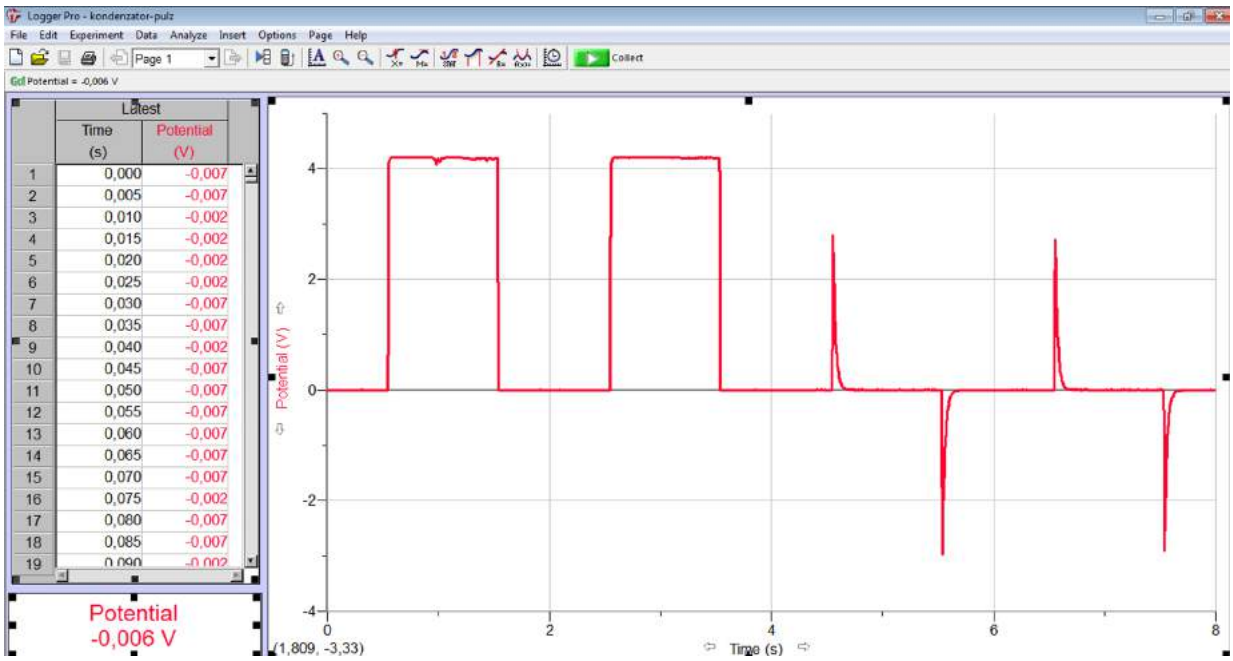
3. EXERCISE:

Connect the elements in a circuit as shown in the scheme below. Pay attention to the ground.



By measuring the drop of voltage on the known resistor, electric current through the bulb is measured. At this exercise, the voltage shape is square type. At the beginning of the measurement, short-cut the capacitor with a wire. During the measurement, a short-cut is removed.

Is there any current through the capacitor? How does the bulb glow?
Measure the current through the bulb.

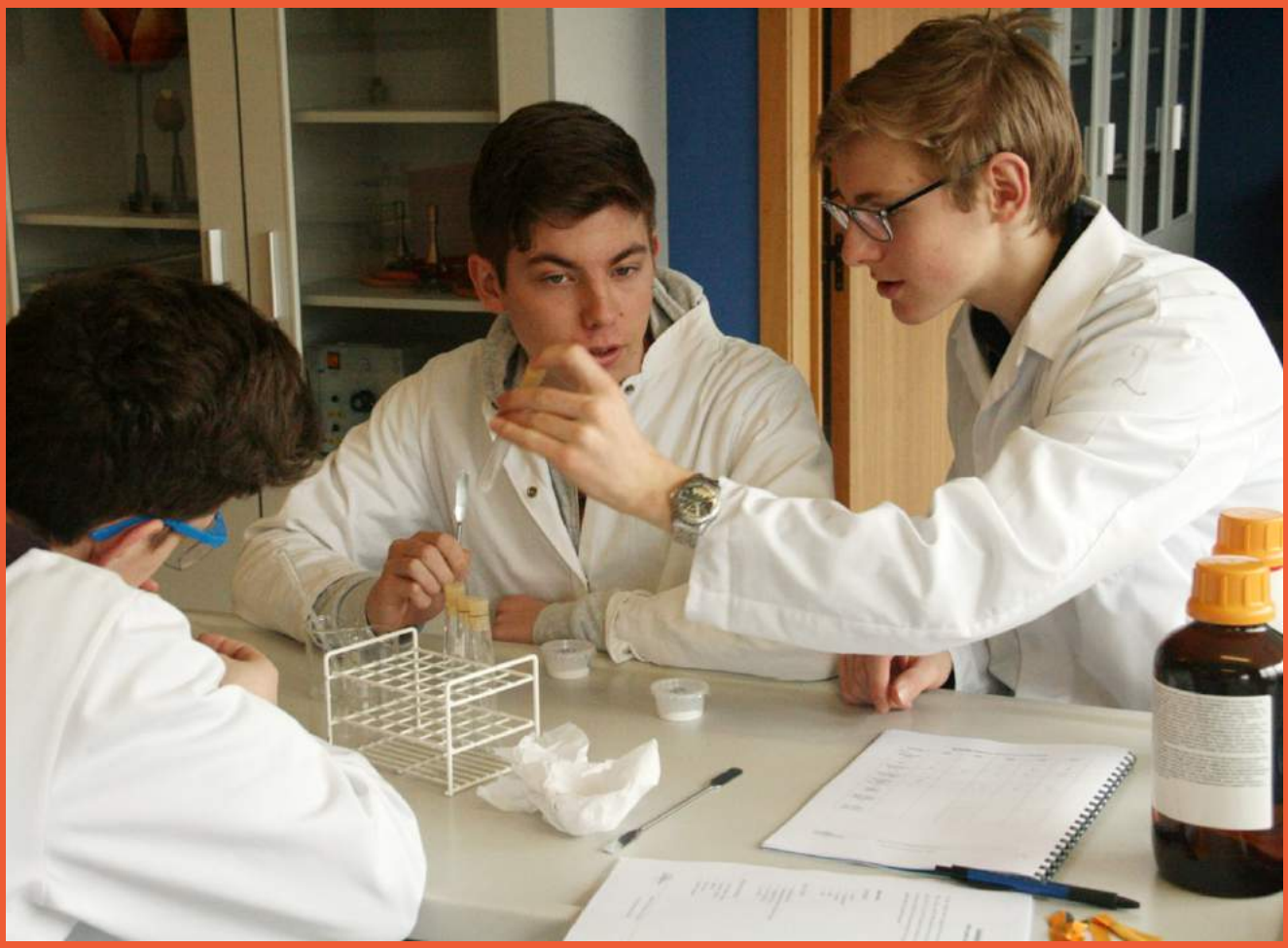


Question:

- Why are there positive and negative voltage pulses, when the capacitor is part of the circuit?

BIOLOGY

SINT-CALASANZINSTITUUT



Performing Chemical Experiments (Sint-Calasanzinstituut, Nijlen, March 2016)

BIODIVERSITY

This exercise allows a number of ecological concepts.
Through fictional research material and simulations you can 'measure' biodiversity.

Pre-research:

- Search for information about Simpson's Diversity Index and Yule's Index on the Internet or in reference books. Don't forget your reference.
- **Give an explanation for the following concepts:**
  - Pioneer species
  - Ecosystem
  - Dynamism
  - Abiotic factors
  - Inheritance
  - Biodiversity
  - Biological equilibrium

Research questions:

- How can you measure biodiversity?
- How can you express the biodiversity of an ecosystem?
- Which variables determine the biodiversity?
- Which abiotic factors have an influence on the biodiversity?
- Which abiotic factors disturb the biological equilibrium?
- What is the relationship between dynamism and biodiversity?
- What is the relationship between biodiversity and biological equilibrium?

RESEARCH/PERFORMANCE:

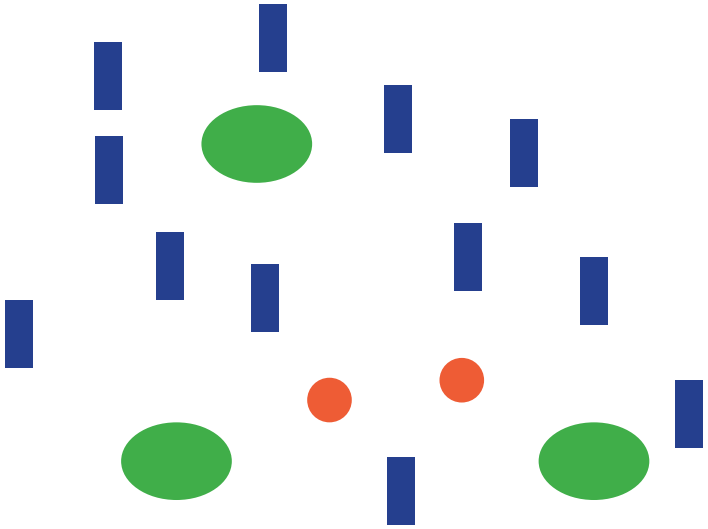
- Determine the biodiversity with the aid of the Simpson's Index and the Yule's index of the ecosystem simulations on the following pages.
- Write down the amount of species and the total amount of individuals.
- Critically interpret your results and try to understand the causes and the consequences of the variables.

REPORT:

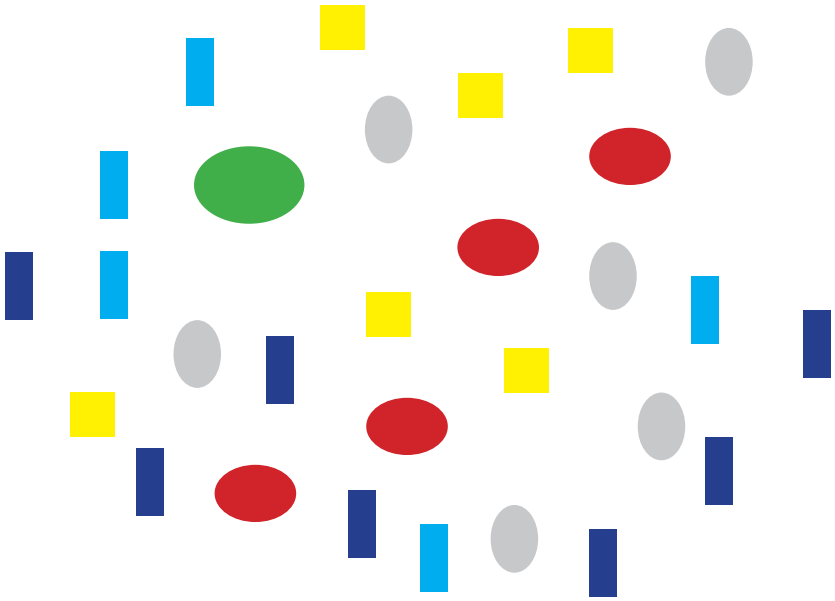
Make a report that contains the following aspects:

- Pre-research
- Research
  - Research questions with hypothesis
  - Tables and graphs of your perceptions
  - Conclusions
- Reflection

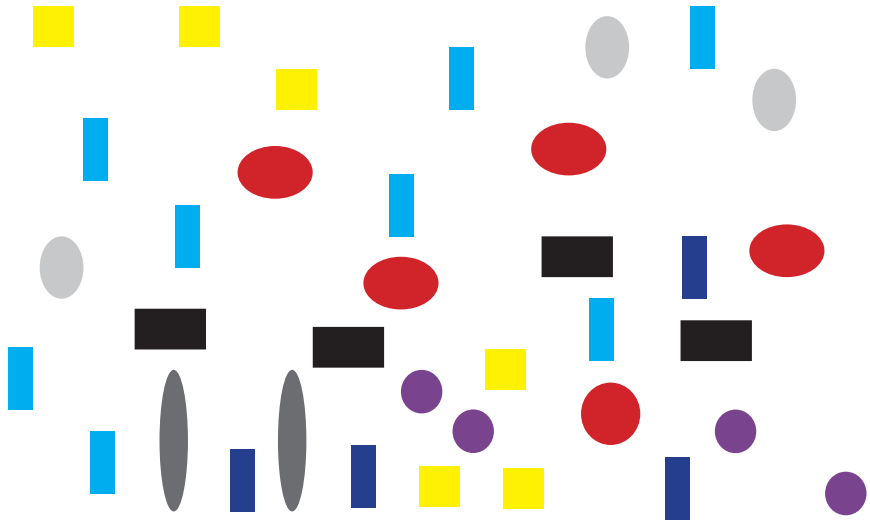
PIONIEER VEGETATION



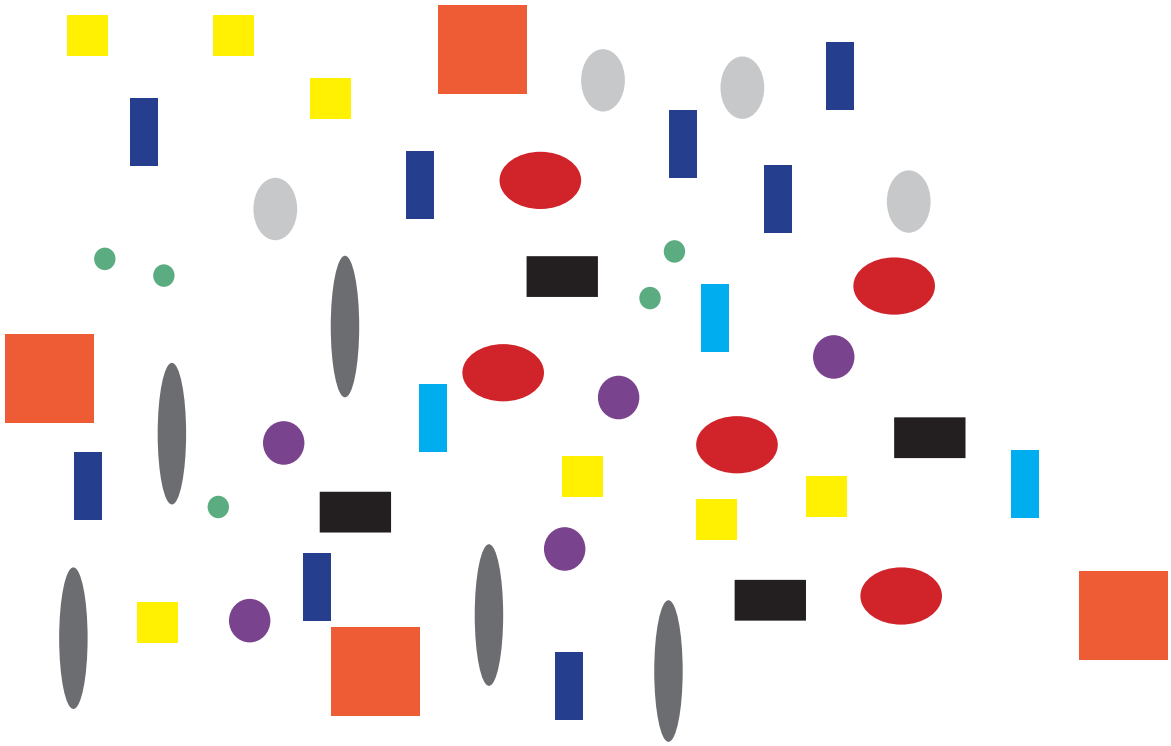
INHERITANCE 1



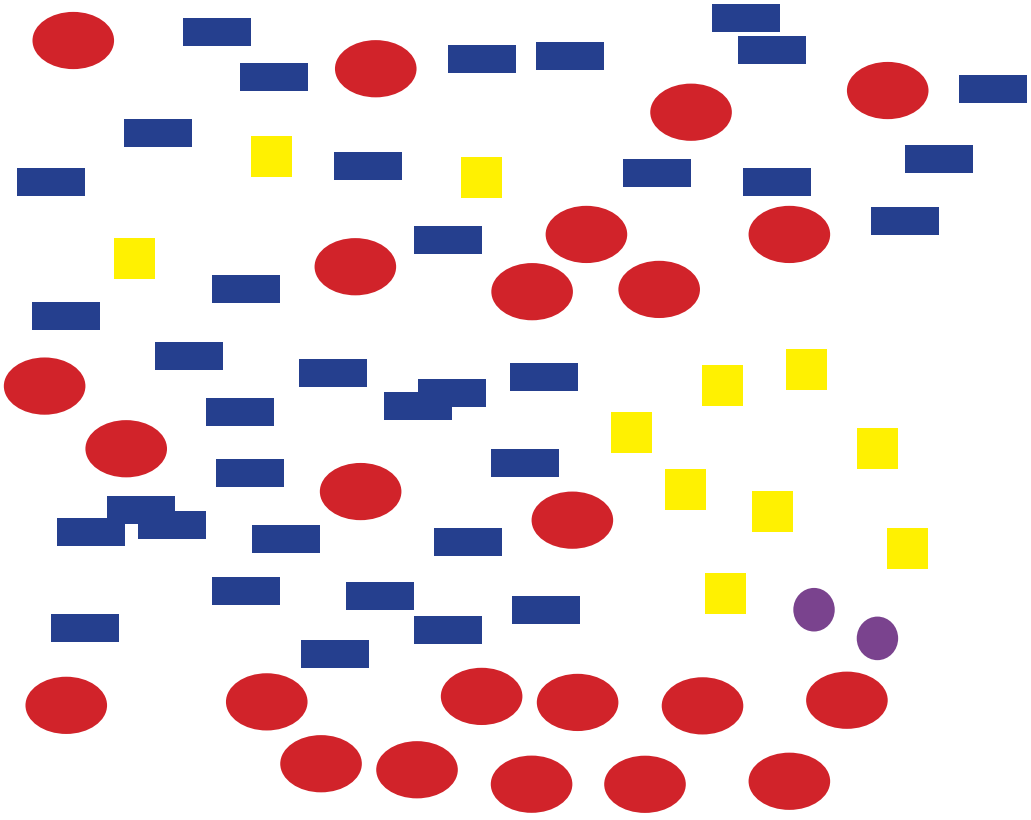
INHERITANCE 2



CLIMAX (BIOLOGICAL EQUILIBRIUM)



DISTURBED BIOLOGICAL EQUILIBRIUM



DETERMINATION OF THE THRESHOLD VALUE FOR SMELL AND TASTE

Introduction:

The smell receptors in our nose need a minimum concentration of a substance in the air in order to be able to detect the smell. In a similar way, the taste receptors on our tongue require a minimum concentration of a substance in food or liquids in order to be able to detect the taste. In the following experiments, we are going to find out what these 'treshold values' for smell and taste are.

1. DETERMINING THE THRESHOLD VALUE FOR SMELL

PROCEDURE:

Materials:

- Eau de Cologne
- water
- 250-mL beakers (8)

Procedure:

- Number the beakers (1–8). Make dilutions of Eau de Cologne as indicated in the following table. Bring the correct amount of Eau de Cologne in each beaker and add water to a total volume of 250 mL.

Beaker number	1	2	3	4	5	6	7	8
Volume of Eau de Cologne (mL)	25	50	75	100	125	150	175	200

- Subsequently try to smell the scent of Eau de Cologne above each beaker, starting with beaker number 1 (the lowest concentration).
- Put an 'x' in the measurements table:
  - under the beaker where you could first smell the Eau de Cologne (personal result).
  - under the beaker with the lowest result of your class.
  - under the beaker with the highest result of your class.

Measurements:

Beaker number	1	2	3	4	5	6	7	8
Personal result								
Lowest result								
Highest result								

REFLECTION:

Answer the following questions:

- My personal smell threshold value is **lower than/higher than/equal to** the smell threshold value of my classmates.
- How would you describe the meaning of 'smell threshold value'?
- The **higher/lower** your smell threshold value, the more sensitive you are to detecting smells.

2. DETERMINING THE THRESHOLD VALUE FOR TASTE

PROCEDURE:

Materials:

- sugar
- water
- 250-mL beakers (8)
- spoons (8)
- a beaker of water to drink
- balance

Procedure:

- Number the beakers (1–8). Make dilutions of sugar as indicated in the following table. Bring the correct amount of sugar in each beaker and add water to a total volume of 250 mL. Stir well (using another spoon for each dilution and leaving the spoon to rest in its beaker).

Beaker number	1	2	3	4	5	6	7	8
Mass of sugar (g)	0,1	0,2	0,3	0,4	0,5	0,6	0,7	1,0

- Using the spoon, subsequently taste the sugar solution in each beaker, starting with beaker number 1 (the lowest concentration). Rinse your mouth with pure water after each beaker.
- Put an 'x' in the measurements table:
  - under the beaker where you could first taste the sugar (personal result).
  - under the beaker with the lowest result of your class.
  - under the beaker with the highest result of your class.

Measurements:

Beaker number	1	2	3	4	5	6	7	8
Personal result								
Lowest result								
Highest result								

REFLECTION:

Answer the following questions:

- My personal taste threshold value for sugar is **lower than/higher than/equal to** the taste threshold value of my classmates.
- How would you describe the meaning of 'taste threshold value'?
- The **higher/lower** your taste threshold value, the more sensitive you are to detecting smells.

If you have some time left, you can repeat this experiment with salt instead of sugar.

- Are the results the same for sugar and salt? Comment.

DNA EXTRACTION FROM KIWI CELLS

Orientation:

- **Research questions:**
  - Can you extract DNA from a kiwi?
  - How can you make DNA visible?
  - Is DNA acid or alkaline?
- **Divide the research questions into smaller questions:**
  - Which mechanical action can you perform to get loose cells of kiwi?
  - Where is DNA located in a kiwi cell?
  - How are the membranes built?
  - Are these molecules absorbent or waterproof?
  - Do you know an emulsifier that can demolish the molecules?
  - How is DNA packed in kiwi cells?
  - Are there enzymes present which can refract DNA? How can you eliminate these enzymes?
  - Which separation technique can you use to separate DNA and proteins from the rest of the kiwi mixture?
  - DNA is polar and does not dissolve in alcohol. How would you get a layer of alcohol on the top of the kiwi mixture's filtrate? Is the temperature of the kiwi mixture and of the alcohol important?
  - Is the sediment pure DNA or does it contain other molecules?
  - What do you expect from the acidity of DNA?
  - What does the term 'extraction' mean?
- **Formulate a hypothesis**

PREPARATION:

- Search for information on the Internet or in reference books. Don't forget your reference.
- Divide the tasks equally between the students in your group. Make a work plan.
- Make a trial set and collect all the materials to extract DNA from kiwi cells.

PERFORMANCE:

Procedure:

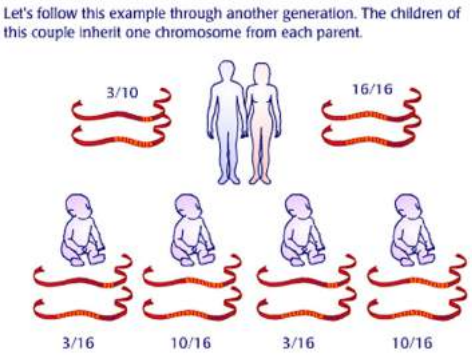
- At the beginning of the experiment put a cold bottle of alcohol in a bin with ice cubes.
- Measure 3 g of kitchen salt and put it in a small beaker of 250 mL.
- Take 10 mL of dishwashing detergent and put it in the beaker with the salt.
- Dilute this mixture with water to 100 mL.
- Stir this mixture until the salt dissolves.
- Peel half of a kiwi and flatten it in a Petri dish until it becomes mushy.
- Put the mush in the beaker with salt – dishwashing mixture.
- Put this beaker in a warm water bad of 60°C for 15 minutes (large beaker of 1 L). Stir regularly.
- Filtrate the mixture in a graduated cylinder until you get 20 mL of the filtrate.
- With a pipette, in one time, along the inner surface of the graduated cylinder carefully add approximately 20 mL ice cold ethanol.
- Wait a few minutes and do not move the Petri dish. Make notes of your perceptions.
- Try to catch some DNA with a pipette from the fluid in the graduated cylinder.
- Measure the acidity.

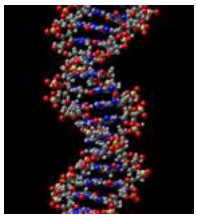
REPORT:

Make a report that contains the following aspects:

- Orientation
- Preparation
- Research
  - Perceptions
  - Analysis
  - Conclusions
- Reflection

HUMAN IDENTIFICATION BY DNA





Different systems for human identification are possible.

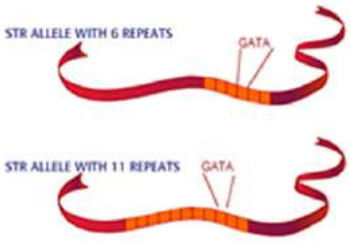
In this lesson, we will explain how CODIS works.

http://www.biology.arizona.edu/human_bio/activities/blackett2/overview.html

http://www.dnai.org/index.htm

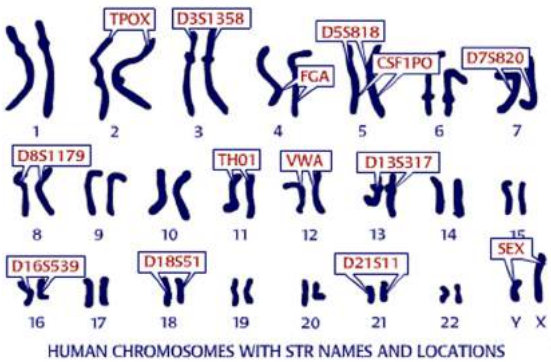
Polymorphism = many different forms (in this case, length)
Tetramer = group of 4 nucleotides
bp = base pair

Most of our DNA is identical to the DNA of other people. However, there are inherited regions of our DNA that can vary from person to person. Variations in DNA sequence between individuals are called "polymorphisms". As we will discover in this activity, sequences with the highest degree of polymorphism are very useful for DNA analysis in forensics cases and paternity testing. This activity is based on analysing the inheritance of a class of DNA polymorphisms known as "Short Tandem Repeats" or simply STRs.



STRs are short sequences of DNA, normally of length 2–5 base pairs (bp) that are repeated numerous times in a head-tail manner, i.e. the 16 bp sequence of "gatagatagatagata" would represent 4 head-tail copies of the tetramer "gata". The polymorphisms in STRs are due to the different number of copies of the repeat element that can occur in a population of individuals.

The picture below represents the homologous chromosomes 7.



HUMAN CHROMOSOMES WITH STR NAMES AND LOCATIONS

D7S280 is one of the 13 core CODIS STR genetic loci. This DNA is found on human chromosome 7. The tetrameric repeat sequence of D7S280 is "gata". Different alleles of this locus have from 6 to 15 tandem repeats of the "gata" sequence. How many tetrameric repeats are present in the DNA sequence shown?

Children inherit the sequences of their parents.

The 13 STR's, which are used for identification, are located on different chromosomes, so they are inherited independently.

When a sample of DNA is found, the DNA is multiplied by PCR and the STR's are marked with fluorescent dyes.

They can be separated by gel electrophoresis.

Let's first look at STR D8S1179. The table below shows some of the allele frequencies for D8S1179 in different populations. The frequencies vary for different groups.

Let's calculate the frequency of a Caucasian being heterozygous for D8S1179 for alleles 12 and 14 repeats.

According to Hardy-Weinberg law:

2pq = 2×(0,1454)×(0,2015) = 0,0586 or nearly 6 %

D8S1179 (Alleles)	Asians (N = 196)	African American (N = 210)	Caucasians (N = 203)	Hispanic (N = 209)
9	0.0024	0.0056	0.0102	0.0025
10	0.0119	0.0250	0.1020	0.0936
11	0.1214	0.0361	0.0587	0.0616
12	0.2905	0.1083	0.1454	0.1207
13	0.3071	0.2222	0.3393	0.3251
14	0.2000	0.3333	0.2015	0.2463
15	0.0548	0.2139	0.1097	0.1158
16	0.0048	0.0444	0.0128	0.0246
17	0.0048	0.0083	0.0026	0.0074

For allele D21S11 the calculation is:

2(pq) = 2(0,1658)×(0,2321) = 0,0770

The probability for this combination is 0,0770 x 0,0586 =

Table adapted from:
Budowle et. al., 2001. Journal of Forensic Science 46(3): 453-489.

D21S11 (Alleles)	Asians (N = 196)	African American (N = 180)	Caucasians (N = 196)	Hispanic (N = 203)
24	0.0000	0.0000	0.0000	0.0000
25	0.0000	0.0000	0.0000	0.0000
26	0.0026	0.0028	0.0000	0.0000
27	0.0102	0.0615	0.0459	0.0099
28	0.0969	0.2151	0.1658	0.0690
29	0.2474	0.1899	0.1811	0.2044
30	0.2015	0.1188	0.2321	0.3300
31	0.1071	0.0922	0.0714	0.0690
32	0.0408	0.0084	0.0153	0.0123
33	0.0051	0.0084	0.0000	0.0000
34	0.0026	0.0084	0.0000	0.0000

When we combine the probability of 13 polymorphisms of a genome, you become a larger number than the number of people on Earth.

There are many advantages to the CODIS STR system:

- The CODIS system has been widely adopted by forensic DNA analysts.
- STR alleles can be rapidly determined using commercially available kits.
- STR alleles are discrete and behave according to known principles of population genetics.
- The data are digital and therefore ideally suited for computer databases.
- Laboratories worldwide are contributing to the analysis of STR allele frequency in different human populations.
- STR profiles can be determined with very small amounts of DNA.

EXERCISE:

DNA Profile of a "Missing Person"

In this activity, you will assume the role of a forensic DNA analyst. Your task will be to determine the DNA profile for a "missing person" from the analysis of close family members.

A death body of a tourist is found. It is unrecognizable.
Steve is missed in that region. Is the dead body Steve?

You have the CODIS-numbers of his wife and his 3 daughters.
What are the CODIS-numbers of Steve?

STR	Karen	Tiffany	Melissa	Amanda	Steve
D3S1358	15, 18	15, 16	15, 16	16, 18	
vWA	14, 18	14, 17	17, 18	17, 18	
FGA	21, 25	21, 24	21, 22	21, 24	
AMEL	X X	X X	X X	X X	
D8S1179	13, 13	13, 13	13, 15	13, 15	
D21S11	29, 31	28, 31	28, 29	28, 29	
D18S51	16, 17	17, 18	17, 18	16, 18	
D5S818	11, 12	11, 12	11, 11	11, 11	
D13S317	11, 11	8, 11	11, 11	11, 11	
D7S820	10, 13	10, 13	9, 10	9, 13	
D16S539	11, 11	11, 11	11, 11	11, 12	
THO1	9, 9.3	8, 9	9, 9.3	9.3, 9.3	
TPOX	8, 11	8, 11	8, 8	8, 8	
CSF1PO	11, 13	13, 13	11, 12	13, 13	

INFLUENCE OF SMELL ON TASTE

Introduction:

In this experiment, we will try to find out if we can taste substances without smelling them. So we will try to determine if smell and taste have an influence on each other or not.

PROCEDURE:

Materials:

- blindfold
- spoons (8)
- beaker of drinkable water
- grated apple
- honey
- cheese
- vanilla sugar
- cinnamon
- grated onion
- bread crumps soaked in rose water
- lemon

Procedure:

- One student gets blindfolded and squeezes his/her nose.
- The other student puts a little bit of the test substance on the blindfolded student's tongue. The test student may close his/her mouth, but chewing the test substance is not allowed.
- The test student whispers the name of the substance in the other student's ear who will write the result in the measurement table.
- Then the test student stops squeezing his/her nose and determine the substance in his/her mouth again. Again the test student whispers the result and the other student writes the result in the measurement table.
- Repeat the previous steps for all of the substances, making sure to rinse your mouth in between the tasting. Feel free to taste the substances in a different order than mentioned in the measurement table!

Measurements:

Substance	With squeezed nose	With 'free' nose
Grated apple		
Honey		
Cheese		
Vanilla sugar		
Cinnamon		
Grated onion		
Bread crumbs in rose water		
Lemon		

REFLECTION:

Answer the following questions:

- Smell **does/does not** have an influence on taste.
- Compared to using taste without smelling, using smell and taste together makes us capable of determining **more/less/an equal amount of** tastes.
- Now, try to explain why your food does not taste as good when you have a cold?

INVESTIGATION OF THE BEHAVIOUR OF POTATO BUGS

On the basis of the following three investigations, study the native behaviour of potato bugs and the reaction on different stimulants.

Pre-research:

- Search for information about the living environment of potato bugs on the Internet or in reference books. Don't forget your reference.
- Divide the tasks of three investigations equally between the students in your group. Make a work plan.
- Make a trial set and collect all the materials needed:
  - deep plate
  - at least ten potato bugs
  - filter paper or kitchen paper
  - water (hot and cold)
  - piece of cardboard
  - stopwatch

RESEARCH:

1. Investigation of the stimulant: light or dark environment

Research question: Are potato bugs nocturnal animals?

– Hypothesis?

– Performance:

Put all of the potato bugs in a deep plate and cover half of the deep plate with a piece of cardboard for 5 minutes. Count every 30 seconds how many potato bugs are there in the light and in the dark environment. Make a table of your perceptions.

2. Investigation of the stimulant: dry or moist environment

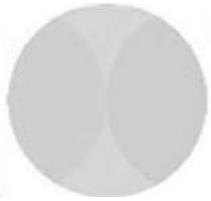
Research question: Do potato bugs prefer a moist environment?

– Hypothesis?

– Performance:

Put half of a filter paper or kitchen paper in an amount of water and put it on the bottom of a deep plate. Put all of the potato bugs in the deep plate and count every 30 seconds how many potato bugs are there in the dry and in the moist environment. Make a table of your perceptions.

3. Investigation of the stimulant: warm or cold environment



Research question: Do potato bugs prefer a warm environment?

– Hypothesis?

– Performance:

Put half of a filter paper or kitchen paper in an amount of cold water and the other half in an amount of hot water. Afterwards put it on the bottom of a deep plate. Put all of the potato bugs in the deep plate and count every 30 seconds how many potato bugs are there in the dry and in the moist environment. Make a table of your perceptions.

REPORT:

Make a report that contains the following aspects:

– Pre-research

– Research

- Research questions with hypothesis
- Tabels and graphs of your perceptions
- Conclusions

– Reflection

PROJECT POTATO CHIPS: LIGHT VERSUS NATURAL

Orientation:
Research questions:

- What is the composition of potato chips?
  - How can you prove fat in potato chips?
  - What are the differences in fat between light potato chips and natural potato chips?
    - What is the percentage of fat in light potato chips and in natural potato chips?
    - How can you extract fat from potato chips?
  - Which sorts of fat contain potato chips?
    - What is saturated and what is unsaturated fat?
    - How can you distinguish saturated fat from unsaturated fat?
  - Is there a difference in fat between the most expensive and the cheapest mark of potato chips?
  - How can you prove starch in potato chips?
  - How can you prove glucose in potato chips?

Formulate a hypothesis.

PREPARATION:

- Search for information on the Internet or in reference books. Don't forget your reference.
- Divide the tasks equally between the students in your group. Make a work plan.
- Make a trial set and collect all the materials to investigate the composition of potato chips (light versus natural).

PERFORMANCE:

Research 1: the proof of fat in potato chips

- Sudan(III) test
- Spot test
- Emulsion test

Research 2: quantitative determination of fat content in potato chips

- Extraction of fat
  - with a separating funnel
  - with a Soxhlet device
- Removal of extraction fluid
  - evaporation
  - distillation
  - with a rotavapor

Research 3: determination of the grade of saturation

– Determination with the jodium addition number

Research 4: the proof of the starch in potato chips

– With the aid of Lugol solution

Research 5: the proof of the glucose in potato chips

– Fehling test

REPORT:

Make a report that contains the following aspects:

– Orientation

– Preparation

– Research
  - Perceptions
  - Analysis
  - Conclusions

– Reflection

RESPIRATORY RATE OF A GOLDFISH

Research question:

Does the oxygen content of water have an effect on the respiratory rate of a goldfish?

Pre-research:

- Search for information on the Internet or in reference books. Don't forget your reference.

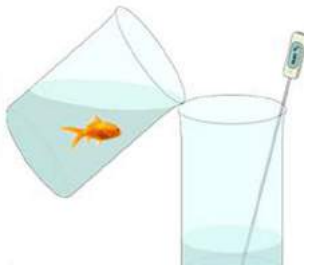
1. How does a fish breathe?
2. What does respiratory rate mean?
3. How can you modify the oxygen content of water?

- Make a work plan
- Make a trial set and collect all the materials needed:
  - goldfish
  - 2 measuring cups (500 mL)
  - stopwatch
  - thermometer
  - ice cubes
  - demineralized water
  - small fishing net

RESEARCH/PERFORMANCE:

Procedure of determining the respiratory rate of regular aquarium water by room temperature.

- Fill one measuring cup with aquarium water (± 500 mL).
- Put the goldfish carefully in the measuring cup with the aid of a small fishing net.
- Wait until the goldfish subsides (2 minutes).
- Count the amount of breathing of the goldfish in 3 minutes.
- Make a note of your perceptions.



Procedure of determining the respiratory rate of 50 % regular aquarium water and 50 % demineralized water by room temperature.

- Pour half of the aquarium water over in the other measuring cup. Watch out that you do not touch the goldfish.
- Complete the first measuring cup with demineralized water (± 250 mL).
- Wait until the goldfish subsides (2 minutes).
- Count the amount of breathing of the goldfish in 3 minutes.
- Make a note of your perceptions.

Procedure of determining the respiratory rate of cold water

- Fill the second measuring cup with aquarium water (± 500 mL).
- Carefully put the goldfish in the measuring cup with the aid of a small fishing net.
- Put an ice cube in the aquarium water.
- Wait until the water has dropped 2 degrees.
- Wait until the goldfish subsides (2 minutes).
- Count the amount of breathing of the goldfish in 3 minutes.
- Make a note of your perceptions.

REPORT:

Make a report that contains the following aspects:

- Pre-research
- Research
  - Research questions with hypothesis
  - Tabels and graphs of your perceptions
  - Conclusions
- Reflection

SIMULATION OF MITOSIS AND MEIOSIS WITH SOCKS

Materials:

– 2 pairs of children socks
– 2 pairs of sports socks
– 2 pairs of tights
– scissors

MITOSIS TASKS

– Make the karyotype of a cell with 6 chromosomes.
– Simulate a nucleus of a cell in G1 phase just after mitosis.
– Simulate the nucleus of a cell after the S-phase.
– Simulate the cell in metaphase.
– Simulate the two cells just after mitosis.

CONCLUSION

Students can formulate the conclusion. The two cells are genetically identical.
When students study the laws of Mendel, a teacher can bring a mark (gene) on the socks.

For example: bring on each of the two children's socks one colour card with a mark blood type A and on the other two a card with a blood type B.

MEIOSIS TASKS

– Simulate the nucleus of a cell in G1 phase just after meiosis.
– Simulate the nucleus of a cell after the S-phase.
– Simulate the cell in prophase I:
  • simulate pairing of the homologous chromosomes
  • simulate crossing over by cutting the socks on one or two places
– Simulate the cell in metaphase I.
– Simulate the two cells after meiosis I.
– Simulate the cells in metaphase II.
– Simulate the cells after meiosis.

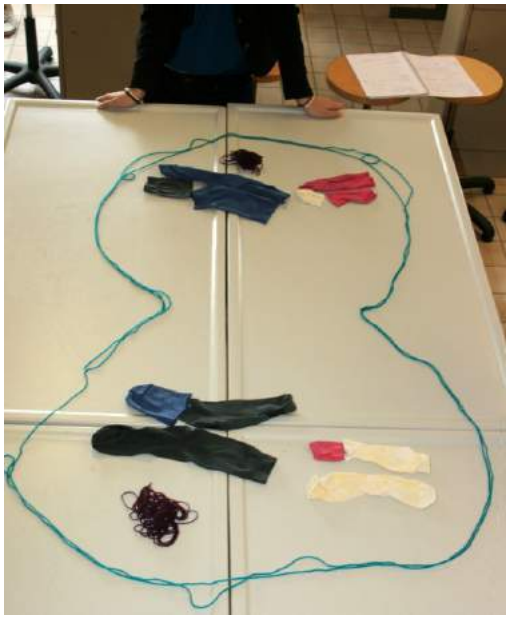
When students study the laws of Mendel, they can bring marks on the socks.
Two on each pair of socks.

CONCLUSION

Students can formulate conclusions. The four cells are genetically not identical.

On the picture, you can see a simulation of the cell in anaphase I of meiosis.

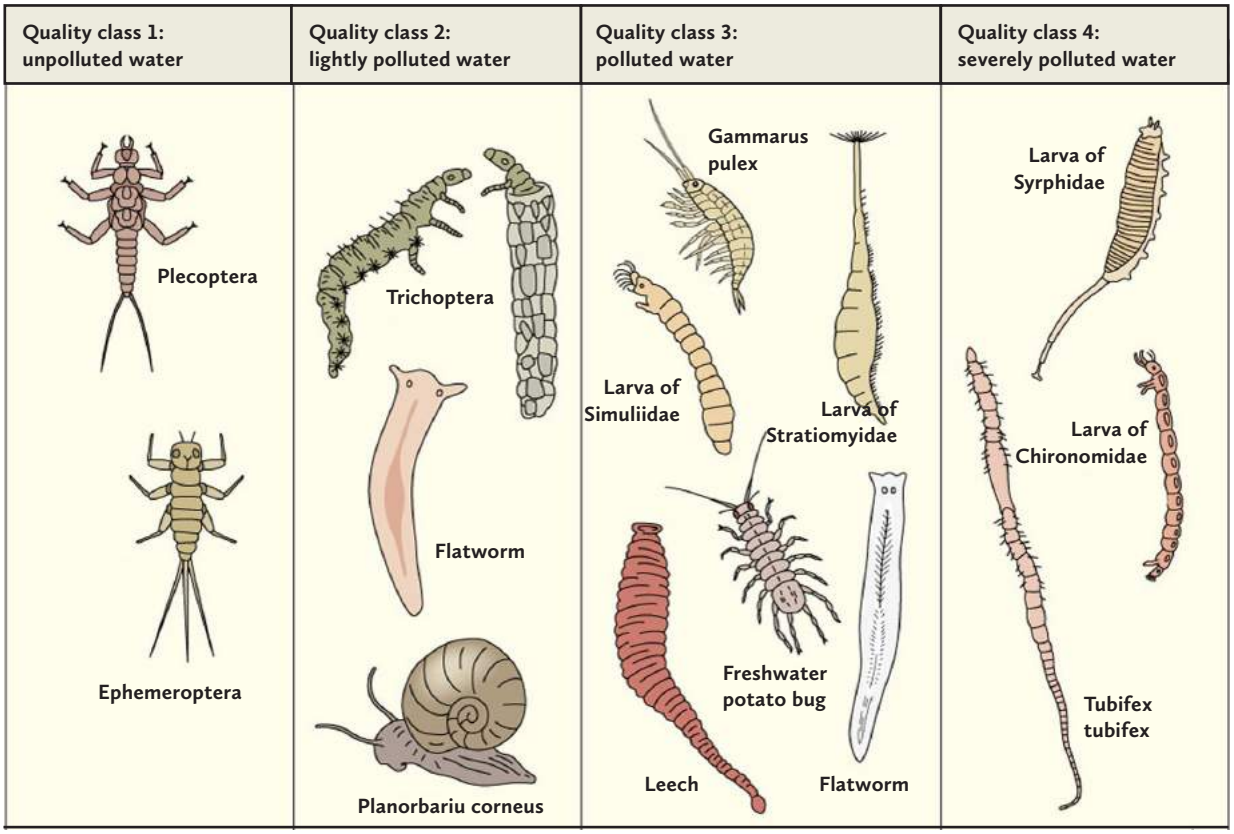
Mark the crossing over on the children's socks and on the sports socks.



SPECIFICATION OF THE BIOTIC INDEX OF FRESHWATER

Introduction:

On the basis of the appearance of invertebrates or the presence of plankton organisms, you can divide stationary or flowing water into four quality classes. It is typical that some organisms disappear in a certain sequence out of water due to their sensitivity to pollution. In this measurement, the only indicator you have to consider is organism. You measure some abiotic factors and look for the presence of some freshwater organisms.



Considering the located organisms, give the water a value between 1 and 10. This value is a **biotic index**. When you have severely polluted water, the value is low. When you determine the biotic index, the exact amount of individuals of one species does not matter. The diversity of species, genus or families in the habitat is important and is reproduced in '**systematic units**' (S.U.) per **indicator group**.

There are 7 different indicator groups:

- *Indicator group 1:* Plecoptera or flat Ephemeroptera
- *Indicator group 2*: Trichoptera
- *Indicator group 3*: Acroloxus lacustris or Ephemeroptera (except flat larva)
- *Indicator group 4*: Aphelocheirus aestivalis, larva of Odonata, Gammarus pulex, mollusk (except Sphaerium corneum)
- *Indicator group 5*: Freshwater potato bug, leech, Sphaerium corneum, Heteroptera (except Aphelocheirus aestivalis)
- *Indicator group 6*: Larva of Chironomidae or Tubifex
- *Indicator group 7*: Larva of Syrphidae

Biotic index and the quality of water:

Biotic index	Quality of water
10–9	Unpolluted water: very good quality of water
8–7	Lightly polluted water: good quality of water
6–5	Moderately polluted water: critical condition of the water
4–3	Polluted water: bad quality of water
2–0	Severely polluted water: very bad quality of water

Determination of the biotic index:

You find the biotic index in the crossing of the column with the total amount of S.U. and the row with the most sensitive indicator group in the water.

For example:
– Total amount of S.U. = 8
– Absent:
  • Plecoptera or flat Ephemeroptera
  • Trichoptera
  • Acroloxus lacustris or Ephemeroptera
– Present:
  • larva of Odonata

→ biotic index = 5

Indicator organisms		**The total amount of systematic units**				
Indicator group 1	> 1 S.U.	0–1	2–5	6–10	11–15	16 +
		Biotic index				
		–	7	8	9	10
	= 1 S.U.	5	6	7	8	9
Indicator group 2	> 1 S.U.	–	6	7	8	9
	= 1 S.U.	5	5	6	7	8
Indicator group 3	> 1 S.U.	–	5	6	7	8
	= 1 S.U.	3	4	5	6	7
Indicator group 4	All S.U. above absent	3	4	5	6	7
Indicator group 5	All S.U. above absent	2	3	4	5	–
Indicator group 6	All S.U. above absent	1	2	3	–	–
Indicator group 7	All S.U. above absent	0	1	1	–	–

EXERCISE:

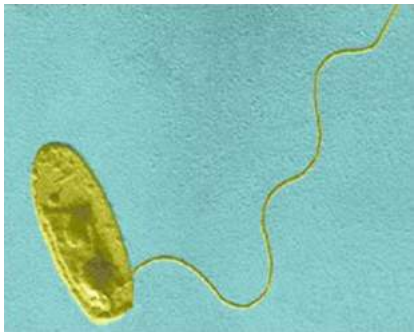
Perform an ecological study and determine the total amount of S.U., the biotic index, and the quality of water.

VIRUS OR BACTERIUM

When you are ill:

If you walk around coughing and sniffling and you need a tissue, then you are infected by a virus. Another famous disease caused by a virus is the flu.

There are also diseases caused by bacteria. Tetanus is an example of such disease. The Tetanus bacterium lives in the ground. When you fall and you have an open wound, then you get an injection against the infection with the Tetanus bacterium. Other examples of diseases caused by a bacterium are the plague and scarlet fever.



← *Microscopic photo of a bacterium.*

What is the difference between a virus and a bacterium?

A bacterium is a living **organism**. A virus is not.
A **bacterial infection** is curable. A **viral infection** is not.
Viruses are a lot smaller than bacteria.

Useful bacteria:

Bacteria can also be useful for human beings. Believe it or not, they can decompose leaked oil.
In a cleaning plant, the bacteria eat water pollutants. In your intestines, there are bacteria that help digest food.

EXERCISES:

1. When you have the flu or cold, you can easily infect other people.
   Bacterial infections can also be contagious. You can prevent this by adhering to advice.
2. Search for information about the spreading of viruses and bacteria on the Internet or in reference books. Afterwards make a poster which contains 6 pieces of advice (3 for each). Each advice must consist of a photo with a short instruction.
3. Make a report about differences between viruses and bacteria.
   This report must contain the following aspects:
   - Characteristic (structure, size ...)
   - Multiplication
   - Examples
   - Treatment and prevention of infections

CHEMISTRY

SINT-CALASANZINSTITUUT

Diamond Museum (Nijlen, March 2016)

COMPLETE SCIENTIFIC INVESTIGATION: VITAMIN C

Introduction:

Science students are supposed to practice their scientific investigation skills. The title also contains the word 'complete' meaning the following aspects will be integrated:

- formulation of the research question,
- formulation of the hypothesis,
- preparation: searching and selecting useful information, looking for the experimental method, making a plan;
- performing the experiment according to the plan and collecting experimental data;
- comparing experimental data with literature values;
- reflecting on the method and the results;
- writing a report;
- presenting the results and reflection to other students.

Orientation:

Using the 'DCPIP method' (explained further on), the amount of vitamin C in foods and beverages can be determined quite easily. Each lab group should make its own research question which can be investigated using this method. So, in the end, each group will have background information, calculations, results, reflections, and a report different from the other groups.

The first steps to take are:

– looking for a good research question (for instance: 'Is the amount of vitamin C in freshly squeezed orange juice the same as in orange juice from a bottle?')

– formulating a hypothesis (for instance: 'We assume the amount of vitamin C in freshly squeezed orange juice is higher than in juice from a bottle') – you can state your hypothesis by looking up the amounts of vitamin C in fruits and vegetables or you can look for the amount of vitamin C indicated on the product.

PREPARATION:

– Collect background information:

  What is vitamin C? Why is the presence of vitamin C in food so important?
  What are the consequences of too much or too little vitamin C for the human body?
  Which food contains a lot of vitamin C?

– What is DCPIP? How does DCPIP react with vitamin C (reaction/colour switch)? Why do you need to add a little bit of acid (e.g. acetic acid) before the titration of the sample with DCPIP?

– Find out how the DCPIP method works and give a stepwise description of the lab method (a DCPIP solution containing 185 mg DCPIP/L will be available in the lab – 1 mL of this DCPIP solution equals 0,1 mg of vitamin C in the sample).

– Preparatory calculations (the required amounts of solutions and products).
  Check if you need to dilute the food sample. If you need a dilution, go through the necessary calculations and prescribe how to make the dilution.

Also calculate the volume of DCPIP solution you will need to perform the experiment (triple analysis per sample is necessary to obtain reliable results).

– Are there any special safety precautions to be taken when performing the experiment?

PERFORMING THE EXPERIMENT:

– Now you can actually perform the experiment in the lab.
– Bring together all the data you need to answer your research question.

REFLECTION:

– Compare your lab results to your hypothesis;
– Make an analysis of the results and the method – give possibilities to improve the technique you used.

REPORT:

Make sure your report contains all the following issues:
– research question and hypothesis
– background information
– preparatory calculations
– materials and method
– results
– conclusion and analysis of results and method

DETERMINATION OF THE AMOUNT OF ACETYLSALICYLIC ACID IN ASPIRIN

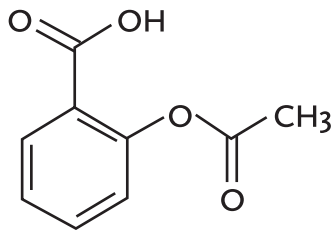
Orientation:

Acetylsalicylic acid (ASA), probably better known as 'Aspirin', is used as a painkiller, a febrifuge and an anti-inflammatory drug. Before the discovery of paracetamol, acetylsalicylic acid was the most frequently used painkiller.

The objective of this experiment is to check, if the indicated amount of medicine is actually present in this drug.

PREPARATION:

Acetylsalicylic acid ($C_9H_8O_4$) has a molecular mass of 180,16 g/mol and a structural formula as indicated below.



Question 1:

Looking at the structural formula of ASA, what kind of functional groups do you recognize in this molecule?

Question 2:

What is the IUPAC name of acetylsalicylic acid? (you may look for this on the internet)

Question 3:

Since ASA is an acid, which reagent could possibly be used to determine the amount of ASA in this medicine? Write down the chemical reaction that occurs.

Question 4:

Which indicator do you suggest to determine the equivalence point in this reaction? What kind of colour switch of this indicator do you expect in the reaction from question 3?

Question 5:

How many moles of ASA does one tablet of medicine (Aspirin 500 mg) contain?

Question 6:

What volume of a sodium hydroxide solution (0,1 M) do you need to reach the equivalence point for one tablet of Aspirin 500 mg?

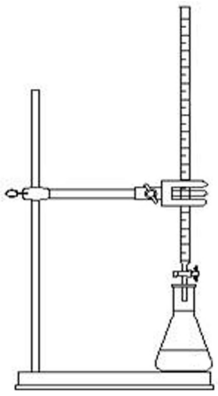
MATERIALS AND METHOD:

Materials:

- stand
- clamp
- burette
- beaker
- funnel
- mortar and pestle
- Erlenmeyer flask
- indicator
- wash bottle filled with demineralized water
- Aspirin 500 mg tablets (no effervescent tablets!)
- 0,1 M NaOH solution

Method:

- Using beaker and funnel, fill the burette with 0,1 M NaOH solution.
- Using mortar and pestle, crush one tablet of Aspirin 500 mg.
- Quantitatively transfer the Aspirin powder to the Erlenmeyer flask (rinse mortar and pestle with some water from the wash bottle, make sure this rinsing liquid is also transferred to the Erlenmeyer flask).
- Add a few drops of indicator to the solution in the Erlenmeyer flask.
- Using the burette filled with NaOH solution, perform the titration to the equivalence point.
- Write down the added volume of NaOH solution.
- In order to get reliable results, you may perform this experiment three times.



RESULTS AND CALCULATIONS:

- Make a table containing the volumes of NaOH determined.
- Calculate the average volume needed for the titration of one tablet of Aspirin 500 mg.
- Calculate the mass of acetylsalicylic acid in one tablet of Aspirin 500 mg (also write down the intermediate results of your calculations!).

DISCUSSION AND REFLECTION:

- Does the experimentally determined amount of ASA equal the amount mentioned on the medicine box? Calculate the relative deviation.
- State possible causes of the deviation between the experimental value and the value mentioned on the medicine box.
- Mention some possibilities to upgrade the method.
- Why is it not possible to use the described method for effervescent tablets? How could this problem be solved?

DETERMINATION OF THE AMOUNT OF CRYSTAL WATER

Determine the amount of crystal water in the formula of a hydrated salt.

Goals:

- **Investigation of the physical changes during dehydration and hydration of a salt.**
- **Determination of the number of molecules of crystal water in the formula of the hydrated salt.**

Materials:

– test tube
– test tube rack (or beaker)
– spatula
– balance
– pincers to hold the test tube
– Bunsen burner
– demineralized water
– gloves and safety glasses
– $CuSO_4 \cdot xH_20$

METHOD:

– Determine the mass of the empty test tube (clean and dry!): **m(empty tube)**

– Using a spatula, fill the test tube approximately 1 cm with copper sulphate, weigh the mass of the filled test tube: **m(filled tube)**

– Calculate the mass of copper sulphate in the test tube: **m($CuSO_4 \cdot xH_2O$)**

– Gently heat the filled test tube while constantly turning it.

– Write down the physical changes you observe in the test tube during the heating process.

– Keep on heating the test tube until no further changes can be observed.

– Allow the test tube to cool down.

– Weigh the mass of the dehydrated copper sulphate: **m($CuSO_4$)**

– Add a little bit of demineralized water to the test tube – observe temperature change and colour switch during this process and write these observations down

– Calculate the number of molecules of crystal water (x) in the formula of the hydrated salt ($CuSO_4 \cdot xH_2O$).

$$x = \frac{n\,(H_2O)}{n\,(CuSO_4)}$$

RESULTS:

– Physical changes during heating?

– Physical changes (temperature/colour) while adding water?

– Calculate the amount of molecules of crystal water in the formula of a hydrated salt.

m(empty tube) =

m(filled tube) =

m($CuSO_4 \cdot xH_2O$) =

m($CuSO_4$) =

x=

DISCUSSION:

– Give an explanation for the physical changes during the heating process and while adding water.

– Compare the experimental value of x with the real number of molecules of crystal water in the formula. Is the result satisfactory?

– What possible factors have influenced the result? How could you improve this experiment?

DETERMINATION OF WATER HARDNESS

Goal:

- **Determine the hardness of rainwater and tap water.**

Introduction:

Water is mostly not a pure substance. It is a mixture and some of the substances in water make it 'hard water'. Water hardness can be expressed with a 'foam number', this is the amount of soap solution to be added to the water in order to achieve a foam layer which lasts for at least 30 seconds after shaking it vigorously.

Find some more information on this item on the Internet:

- Which reaction takes place between the soap and the calcium ions in water?
- Which units are used to express the hardness of water?
- When do we speak of 'soft water' or 'hard water'?
- How 'hard' do you expect the tap water and rainwater to be in your region?
- What are the main disadvantages of hard water?
- How can you turn hard water to soft water?

Materials:

- standard soap solution (15 g floor-scrubbing soap/liter)
- stock solution 200 mg Ca^{2+}/liter
- demineralized water
- stand, clamp
- buret
- funnel
- volumetric pipettes (10 mL and 25 mL)
- volumetric flasks 50 mL (at least 2)
- Erlenmeyer flask 100 mL + stopper

METHODS:

1. Determining the foam number of a sample:

- Using a volumetric pipette, add 20 mL of the sample to the clean and dry Erlenmeyer flask.
- Start adding standard soap solution from the buret, making sure to regularly shake the flask vigorously.
- When the foam layer maintains for about 30 seconds, determine the added volume of soap solution (= foam number).

2. Making a calibration curve:

– Using a volumetric pipette, take a 20 mL stock solution Ca^{2+} sample.
  Determine the foam number of the stock solution Ca^{2+}.
– Using the volumetric flasks, make dilutions of the stock solution Ca^{2+} in order to obtain solutions of 100 mg Ca^{2+}/L, 50 mg Ca^{2+}/L, 25 mg Ca^{2+}/L. Taking 20 mL samples of these dilutions, determine the foam number of each dilution.
– Finally, take a 20 mL demineralized water sample (containing 0 mg Ca^{2+}/L and determine the foam number.
– Using all these results and Excel, make a calibration curve (# mL soap solution/# mg Ca^{2+}/L). Make Excel functions give you the equation of this curve.

3. Determining the hardness of rainwater and tap water:

– Take a 20 mL – rainwater sample and determine the foam number.
  Repeat this procedure three times in order to obtain reliable results.
– Take a 20 mL – tap water sample and determine the foam number.
  Repeat this procedure three times in order to obtain reliable results.

RESULTS AND CALCULATIONS:

– Make a table with the results for the calibration curve.
  Using Excel, draw the calibration curve and give the equation for this curve.
– Using this equation and the mean result for the foam number of rainwater, calculate the rainwater hardness.
– Using the same equation and the mean result for the foam number of tap water, calculate the tap water hardness.

DISCUSSION AND REFLECTION:

– Compare the experimental values of rainwater and tap water to literature values (found on the Internet).
– State possible causes of deviation between the experimental values and literature values.

REPORT:

Use a computer (Word, Excel) and make a scientific report of this experiment.

DETERMINING THE AMOUNT OF ETHANOL IN AN UNKNOWN SOLUTION

Goals:

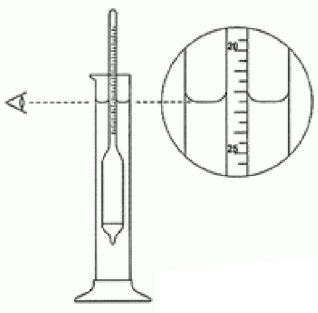
- **using Excel, make a calibration curve (density/amount of denaturated ethanol)**
- **determine the amount of denatured ethanol in an unknown solution (from the equation obtained from the Excel graph)**

Materials:

– denatured ethanol
– demin. water
– measuring cylinders (100 mL)
– transfer pipettes
– densimeters
– parafilm

METHOD:

– Make the following dilutions of denatured ethanol (in measuring cylinders):
10% - 20% - 30% - 40% - 50% - 60% - 70% - 80% - 90% of ethanol.
– Using a densimeter, determine the density of each dilution and write it down in a table.
– Using a densimeter, also determine the density of pure water and pure denatured ethanol.
– Finally, determine the density of an unknown dilution provided by your teacher.

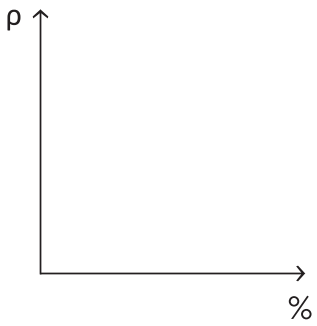


RESULTS:

– Complete the following table and add the experimental density data

Volume of ethanol (mL)	Volume of water (mL)	Amount of ethanol (%)	Density ρ (g/mL)
0	100,0	0	
10,0	90,0		
20,0			
30,0			
40,0			
50,0			
60,0			
70,0			
80,0			
90,0			
100,0	0,0	100	

– Using the collected data, make a calibration curve in Excel.



– Using Excel functions, add the equation which gives the relation between the percentage of ethanol and the density.
– Using this equation and the measured density, determine the percentage of ethanol in the unknown sample.

Calculation:

DISCUSSION:

– What kind of curve is a calibration curve?
– Compare the experimental value for the percentage of ethanol in the unknown sample to the exact percentage provided by your teacher. Is the experimental result satisfactory (relative deviation)?

DETERMINING THE AMOUNT OF PHOSPHORIC ACID IN COCA-COLA

REACTION:

$3\ NaOH + H_3PO_4 \rightarrow 3\ H_2O + 3\ Na^+ + PO_4^{3-}$

Materials:

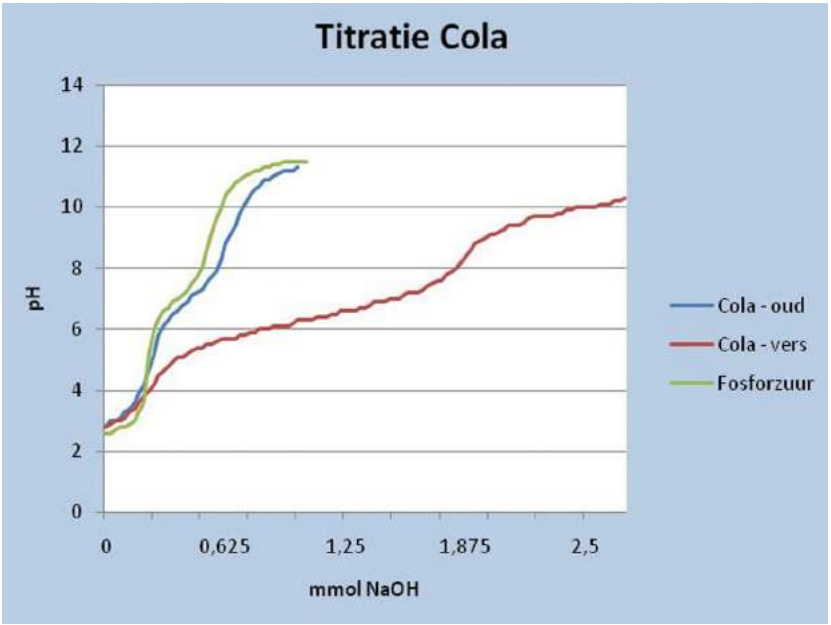
– phosphoric acid (85%)
– Coca-Cola
– Coca-Cola Light
– Coca-Cola Life
– NaOH (0,05 M)
– demineralised water
– pH-meter
– balance
– 3 beakers (100 mL)
– 3 burets
– stirring rod
– electrical stirrer
– Excel file (provided)

METHOD:

– Weigh approximately 50 g Cola in a beaker.
– Write down the exact mass you have weighed:
– Measure the acidity of the sample.
– Put the pH you measured in the Excel file.
– Add 1 ml of the NaOH solution, stir well and measure the pH. Put the result in the Excel file.
– Repeat the step above until the pH reaches 11–12.

RESULT:

The graph you obtain should be similar to the graph below.



DISRUPTION OF A CHEMICAL EQUILIBRIUM

Goal:

- **Examining the influence of different factors (concentration, dilution, temperature) on a chemical equilibrium reaction.**

Research question:

What is the influence of the concentration of the reagent and the concentration of the reaction products on a chemical equilibrium reaction?

Materials:

– 0,01 M $FeCl_3$
– 0,01 M KSCN
– 0,05 M $AgNO_3$
– saturated solution of $FeCl_3$ (920 g/L)
– saturated solution of KSCN (2170 g/L)
– demineralised water
– plastic map
– beaker with hot water
– pasteur pipettes

PERFORMANCE:

1. Put the test page below in a plastic map.
2. Bring one drop of the 0,01 M $FeCl_3$ solution and one drop of the 0,01 M KSCN solution in the squares numbered 1 to 6.
3. Add a drop of the solution mentioned on the right side of each square. Mix the drops in each square carefully. Observe the colour changes in each square and take a picture of the test page.

   Hint: In order to heat the solution in square 6, suck all of the solution in this square with a Pasteur pipette. Turn the pipette upside down so the solution goes to the bulb side of the pipette. Hold the bulb side in hot water for approximately 3 minutes. Then put the solution in square 6 again.
4. Explain the colour changes using the law of Le Chatelier–Van't Hoff.
5. After taking a picture, clean the plastic map with a tissue and a damp cloth.

TEST PAGE:

0,01 M $FeCl_3$ + 0,01 M KSCN solution	1	
0,01 M $FeCl_3$ + 0,01 M KSCN solution	2	+ saturated $FeCl_3$ solution
0,01 M $FeCl_3$ + 0,01 M KSCN solution	3	+ saturated KSCN solution
0,01 M $FeCl_3$ + 0,01 M KSCN solution	4	+ 0,05 M $AgNO_3$ solution
0,01 M $FeCl_3$ + 0,01 M KSCN solution	5	+ demin. water (several drops)
0,01 M $FeCl_3$ + 0,01 M KSCN solution	6	+ heat

EXTRACTING SUGAR FROM SUGAR BEETS

METHOD:

– Clean the beet: remove as much mud as possible. Peel the beet using a knife.

– Rasp the beet. Put the rasped beet in a beaker and pour water in the beaker until the beet is completely covered with water.

– Heat the beaker. Make sure the temperature does not get too high, the liquid should not boil! Approximately 80°C is perfect!

– Stop the heating after 5 minutes.

– Filter the solution. Wear gloves in order not to get burnt!

– Allow the filtrate to evaporate (you can slowly heat a little bit of the filtrate in a porcelain bowl until the liquid gets more viscous).

IDENTIFICATION OF SYNTHETIC POLYMERS

Introduction:

There are various kinds of (synthetic) polymers that are used in a wide variety of applications in everyday life (packing materials, pipes, glue, isolation material, etc.). Sometimes it is not so easy to tell which kind of plastic we have in our hands, but there are some simple tests to identify the most common pastics. Using these tests, you can try to determine different kind of plastic.

Thermoplast test:

Heat an iron nail in the blue part of a Bunsen burner flame.
Touch the plastic with the hot nail. This test is positive when the plastic weakens.

Beilstein test:

Heat a copper wire in the blue part of a Bunsen burner flame.
Touch the plastic with the copper wire for a few seconds and immediately put the wire in the Bunsen burner flame again. This test is positive when a green gloss appears in the flame.

Floating capacity:

Wash the plastic thoroughly with soap. Push the plastic to the bottom of a beaker filled with water mixed with a few drops of soap. This test is positive when the plastic rises in the beaker to float on the water.

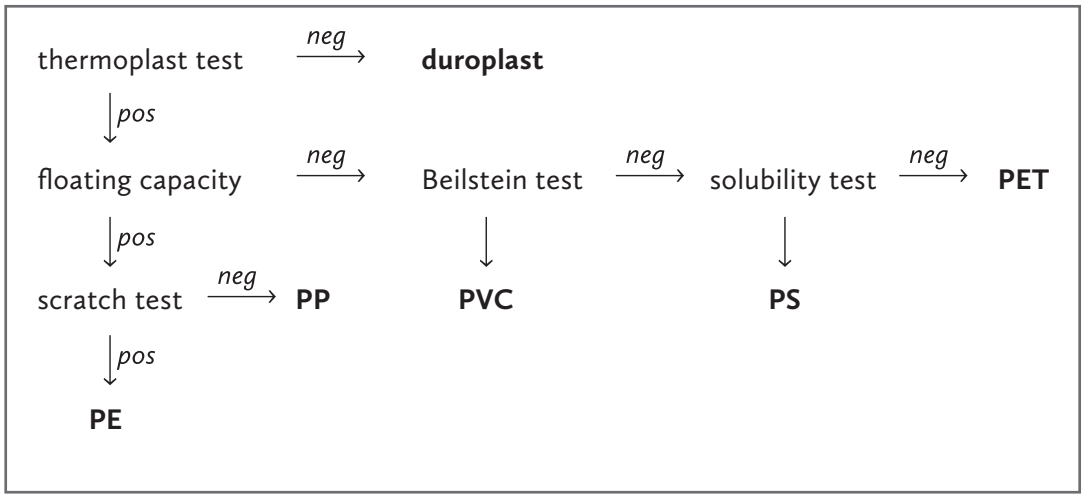
Scratch test:

Scratch the plastic with your finger nail. This test is positive when you can feel the scratch afterward.

Solubility test:

Put the plastic in a beaker filled with acetone. This test is positive when the plastic becomes sticky.

INTERPRETING THE TEST RESULTS:



PREPARATION:

Materials:

– iron nail
– copper wire
– pincers
– 250-mL beakers
– soap
– water
– acetone
– Bunsen burner
– matches
– different kind of plastics (packages, containers, foils, pipes, bottles, etc.)

METHOD:

– Subsequently submit all of the samples to the identification tests as described in the introduction.
– Write the results (pos/neg) in the following table.
– Determine the kind of plastic you have examined using the interpreting scheme mentioned in the introduction.

RESULTS:

Sample↓ Test→	Thermoplast	Beilstein	Floating	Scratch	Solubility	IDENTIFICATION

STEREOMODELS IN ORGANIC CHEMISTRY

Orientating/Research question:

How to present organic molecules in 3D?

PREPARING/MATERIALS:

– molecular model kit
– camera

Complete the following table representing the colours of different atoms in the molecular model kit.

Element	**Colour of the atom model**
Carbon	
Hydrogen	
Oxygen	
Nitrogen	
Halogen	

PERFORMANCE AND OBSERVATION:

Build the following molecule models and take a picture of each built model.
Add these photos including the IUPAC name of each isomere to the report.

1. Chain isomers of C_5H_{12}
2. Functional group isomers of C_3H_6O
3. Location isomers of C_3H_8O
4. Functional group isomers of C_2H_6O
5. Location isomers of C_4H_8
6. Optical isomers of a molecule containing 4 carbon atoms, 9 hydrogen atoms and 1 chlorine atom.
7. Cis-trans isomers of molecules containing 4 carbon atoms and 8 hydrogen atoms.

PHYSICS

SINT-CALASANZINSTITUUT

In Front of the Atomium (Brussels, March 2015)

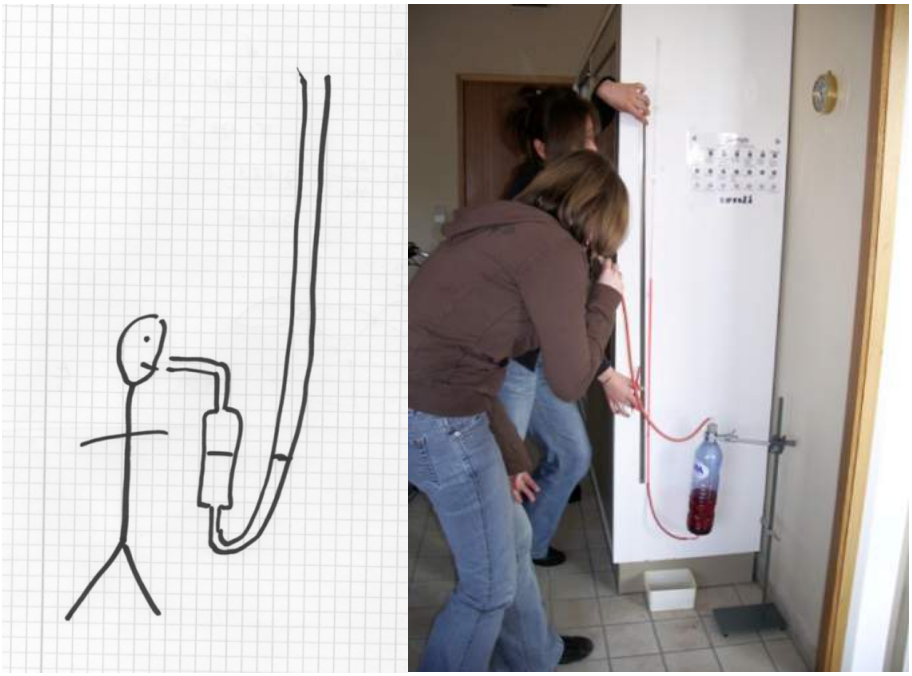
BLOWING UP YOURSELF

Can you blow up yourself?

Actually, the question is “Can you inflate an air mattress while someone is lying on it?”
Of course you can give it a try it, but we are going to do some experiments to answer this question.

1. Measure the lung pressure so that you make an experiment with a manometer.

Make a drawing of this experiment.



2. Measure the pressure of air in an air mattress while someone is lying on it.

3. Compare.

4. Conclude.

5. Verify your conclusion with an experiment. Is it working?

DENSITY OF OBJECTS WITH A REGULAR SHAPE

Introduction:

Research question:

What is the relationship between the mass and the volume of a substance?

HYPOTHESIS:

PROCEDURE:

Materials:

– PVC cylinders
– PE cylinders
– balance
– ruler

Procedure:

– Obtain 3 PE cylinders (black).
– Determine the mass of the cylinders and record your results in the table below.
– Determine the volume of the cylinders. Measure the relevant dimensions and record the reading in the table below. Also write down the formula used to calculate the volume of a cylinder.
– Complete the last column of the table and calculate the average of these values.
– Repeat the steps above for 3 PVC cylinders (grey).

MEASUREMENTS AND CALCULATIONS:

Pay attention to the units and significant figures!

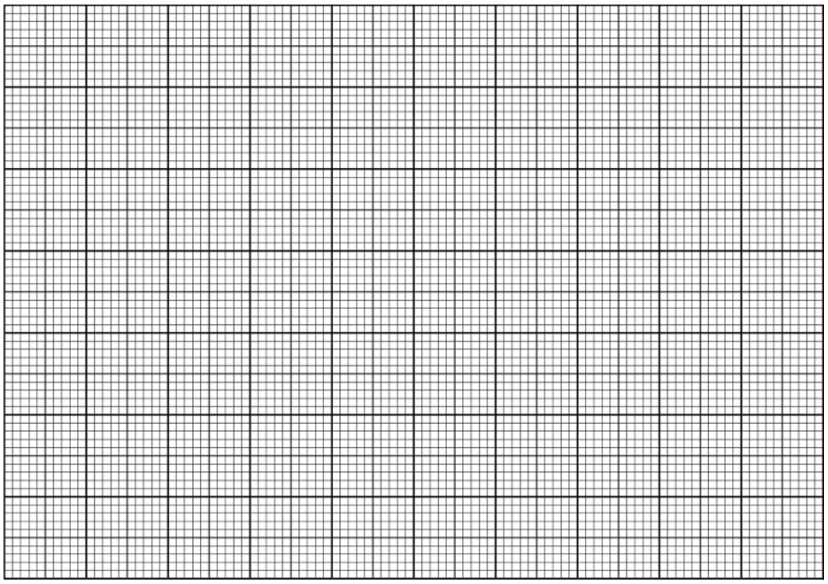
Substance PE				
m (.....)	r (.....)	h (.....)	V = ... (formula) V (.....)	m/V (...../.....)
			Average	
Substance PVC				
			Average	

Plot the results for the mass and the volume for both substances.
Clearly indicate which graph goes with which substance.

Do not forget to take into account the mass that accords with a volume of 0 m^3.

a. Which physical quantity should be plotted on the horizontal axis?

b. Which physical quantity should be plotted on the vertical axis?



c. What kind of graph is obtained?

d. Which relationship between the mass and the volume can thus be determined from the graph?

e. Which other method can be used to verify this relationship? Hint: use the table.

Conclusion (answer to the research question):

The ratio of mass to volume is always .....
This ratio is called the **density**. The symbol of this physical quantity is ρ.

Formula: ρ = unit of ρ =

The density is ..... for each substance.

REFLECTION:

Do your conclusions match with your expectations (hypothesis)?

Answer the following questions:

– For the **same volume** of PE and PVC, the mass of **PE/PVC** (indicate the correct answer) will be the greatest.

– For the **same mass** of PE and PVC, the volume of **PE/PVC** (indicate the correct answer) will be the greatest.

DETERMINATION OF THE LENS EQUATION

Introduction:

We have already learned how to construct the image of an object through convex lenses.
In this experiment, we will investigate how to calculate at what distance from the lens the image of the object will appear.

Research question:

Which equation expresses the quantitative relationship between the object distance (o), the image distance (i) and the focal length (f):

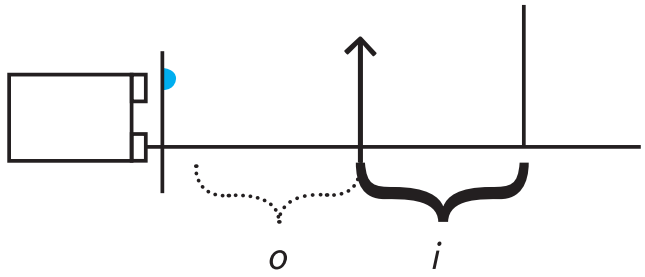
a. $\frac{1}{o} + \frac{1}{i} = \frac{1}{f}$ b. $\frac{1}{f} + \frac{1}{o} = \frac{1}{i}$ c. $\frac{1}{i} + \frac{1}{f} = \frac{1}{o}$

PROCEDURE:

Materials:

– battery
– chip with LEDs
– convex lens with f = +15 cm
– white screen
– metric tape

Procedure:



– Prepare the experimental set-up as shown in the figure.
– Light up all 3 LEDs and hold them behind the lens at a certain distance (o).
– All the time the **distance o** between the LED's and the lens should be larger than the focal **length f**.
– Move the white screen on the other side of the lens until a sharp image of the LEDs is formed.
– Measure the distance (i) between the lens and the screen.
– Fill in the table.

MEASUREMENTS AND CALCULATIONS:

Measurements:

f = +15 cm		$1/f$ = ... (.....)	
o (cm)	i (cm)	$1/o$ (.....)	$1/i$ (.....)

Conclusion (answer the research question):

From the first two columns from the table it can be concluded that when the distance of the object increases, the distance of the image .....

REFLECTION:

Evaluate your work.

What went well/wrong?

Why is it not possible to determine the relationship between o and i when o < f?

DETERMINATION OF THE POWER OF A DIP TUBE

Introduction:

Electricity is produced in electrical power plants. Specialized companies deliver this electrical energy to houses and other buildings. Consumers have to pay these companies according to the amount of electrical energy they use. In order to measure the amount of electricity and make up the bill, the company provides every consumer with a kWh-counter.

A kWh-counter shows the consumed amount of electrical energy with a number. The smallest number shown is mostly 0,1 kWh. That is no problem when measuring large amounts of electrical energy used throughout a year, but in the lab 0,1 kWh is far too big.

In order to be able to measure smaller amounts of electrical energy, we have to use the turning disc at the bottom of the counter. The kWh-counter shows how many turns of the disc equal 1 kWh. By counting the number of times, the coloured point on the disc moves by, we can count the number of turns the disc makes.

Using the kWh-counter, we will determine the power used by a dip tube.

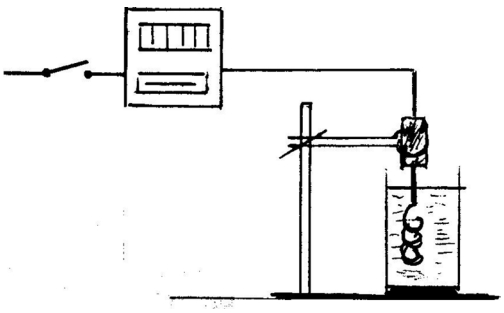
PROCEDURE:

Materials:

- kWh-counter
- chronometer
- beaker with water
- dip tube

Procedure:

- Calibration of the kWh-counter:
  - Read the number of turns of the disc equalling 1 kWh displayed on the kWh-counter.
  - Calculate the amount of consumed electrical energy equalling 1 turn of the disc.
- Determination of the electrical power of the dip tube:
  - Put the dip tube in a beaker with water.
  - Connect the dip tube to the socket on the kWh-counter board.
  - Connect the kWh-counter to the main electricity network.
  - Using a chronometer, measure the time needed by the disc on the kWh-meter to complete 10 full turns.
  - Calculate the power of the dip tube.



MEASUREMENTS AND CALCULATIONS:

1) Calibration of the kWh-counter

..... turns = 1 kWh

Calculate the amount of energy equalling 1 turn of the disc (switch from kWh to J)

..... turns = ... J

Conclusion: 1 turn = ... J

2) Determination of electrical power of the dip tube

Time needed for 10 full turns of the disc:

Used amount of electrical energy: 10 turns = ... J

Calculate the electrical power of the dip tube, starting with the formula you will use for this calculation.

REFLECTION:

Answer the following questions:

- On each electrical device, you can find several properties, such as electrical power. What is the electrical power mentioned on the dip tube?

- How big is the relative deviation of the experimentally determined electrical power compared to the power mentioned on the dip tube? Use the formula:

  Relative deviation = ... %

- Calculate how much it costs to use the dip tube.
  - Using 1 kWh costs approximately 0,08 €. Of course, the price depends on the country you live in and on the company delivering electrical energy.
  - Assuming you are using the dip tube for 1 hour; how big the consumed amount of electrical energy would be.
  - How much would you have to pay for using the dip tube for 1 hour?

DETERMINATION OF THE UNIVERSAL GAS CONSTANT

Introduction:

The ideal gas law gives the relation between the pressure, volume, temperature, and the number of moles of gas:

$$p\,V = n\,R\,T$$

R is called the universal gas constant. Its value, 8,31 J/mol×K, is the same for each ideal gas.

In this lab, you will measure various properties (volume, pressure and temperature) of a sample of hydrogen gas in order to experimentally determine the value of R. The single displacement reaction between a known mass of magnesium and hydrochloric acid will be used to generate the hydrogen gas:

$$Mg(s) + 2\,HCl(aq) \rightarrow MgCl_2(aq) + H_2(g)$$

The hydrogen gas will be collected over a diluted HCl solution in an inverted graduated cylinder (see the picture below).

The volume of hydrogen gas can be directly read. Since the gas is collected over a water bath, it will also contain an amount of water vapour that exerts a certain pressure. The pressure of the hydrogen gas can be calculated by subtracting the vapour pressure of water from the atmospheric pressure:

$$p_{H2} = p_{atm} - p_{H2O}$$

(Note: to ensure that the atmospheric pressure is equal to the pressure of hydrogen gas and water vapour, the water level inside and outside the graduated cylinder must be the same.)

The vapour pressure of water can be read from a table (see the table below).

PROCEDURE:

Materials:

– stand + clamp
– beaker (600 mL)
– rubber stopper with a hole
– thermometer
– graduated cylinder (10 mL)
– copper wire
– piece of magnesium ribbon
– 3 M HCl solution

Safety: HCl is corrosive! Wear gloves and safety glasses. Rinse any spills immediately.

PROCEDURE:

– Obtain a stand and clamp.

– Fill the beaker with water and place it near the stand.

– Obtain a short piece of magnesium ribbon (no longer than 1 cm!). Write down the length.

– Obtain about 10 cm of copper wire. Wrap the magnesium ribbon around the end of the copper wire. Make sure enough copper wire is left to hang over the edge of the graduated cylinder.

– Fill the graduated cylinder with 2 mL of 3 M HCl.

– Then add water to the graduated cylinder until it is completely full.

– Hang the magnesium ribbon in the graduated cylinder near the top.

– Immediately insert the rubber stopper and, while covering the hole, quickly invert the cylinder into the beaker filled with water. Clamp cylinder in the upside down position. Make sure the stopper stays below the water level in the beaker.

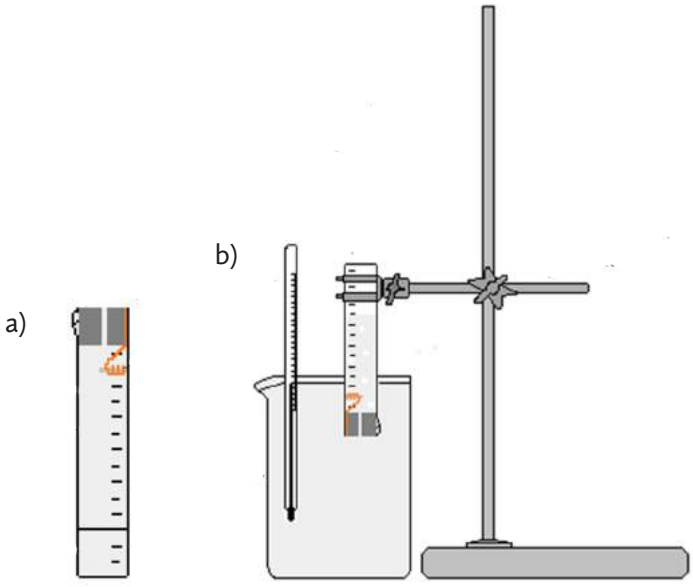
– The reaction will occur as soon as the acid diffuses down the cylinder and makes contact with the magnesium ribbon. The hydrogen gas formed will displace the water from the cylinder.

– The reaction should take several minutes. (Meanwhile make some calculations!)
As soon as all the magnesium has reacted, move the cylinder up or down so that the water level in the cylinder equals the water level in the beaker.

– Read the volume of gas from the graduated cylinder.

– Measure the water temperature.

Experimental set-up:



MEASUREMENTS AND CALCULATIONS:

Measurements:

Length of the magnesium ribbon: .....

Water temperature: .....

p_{atm}: ..... (assigned by the teacher)

p_{H2O} depends on the water temperature and can be read from the table below.
p_{H2O}:

Temperature (°C)	p_{H2O} (kPa)	Temperature (°C)	p_{H2O} (kPa)
16	1.8	23	2.8
18	2.1	24	3.0
19	2.2	25	3.2
20	2.3	26	3.4
21	2.5	27	3.6
22	2.6	28	3.8

Volume of gas in the graduated cylinder: .....

Calculations:

Calculation of n_{H2}

1. The mass of 10 mm magnesium ribbon equals 0,1 g. Calculate the mass of your piece:

2. Determine the moles of magnesium reacted. (Molar mass of magnesium = 24,3 g/mol)

3. Determine the mole quantity of hydrogen gas formed.

Calculation p_{H2}

4. Calculate p_{H2}

Calculation R

5. Calculate R

REFLECTION:

Evaluate your work.

What went well/wrong?

Does the experimental value for R differ significantly from the theoretical value?

What do you suggest to obtain a more accurate result?

GAS PRESSURE IN A BICYCLE TIRE

Measure the pressure of the gas in a bicycle tire.

A bike exerts a pressure on the ground. The rim does not drop on the ground because the gas exerts an equal pressure on the bike. We can determine the pressure of the gas in the tire by measuring the pressure which the tire exerts on the ground.

1. Determine the support surface of the tire on the ground.

You can do this by marking the tire with a red chalk and making a print of it. You need to cut out its print and weigh it. You do the same with a surface of 100 cm^2, cut it out of the same paper as before. By using the proportional rule you can determine the surface S.

2. Determine the force which the tire exerts on the ground.

Place the bike with the back tire on the scales. Determine the mass and now you can determine the force that the tire exerts on the ground.

$F = m \times g$ $F =$

3. Determine the pressure now.

$p = F/S$ $p =$

HALF LIFE OF M&MIUM

PURPOSE:

In this experiment, you will simulate the radioactive decay of atoms. M&m's will be used to represent the atoms. You will make a graph of the collected data and interpret it.

PROCEDURE:

– Gather 50 m&m's in a plastic bag. Do not eat them!

– Close the plastic bag and shake it for about 5 seconds.

– Gently pour out the m&m's on the table.

– Count the number of m&m's with the **"m" facing up (= un-decayed atoms)** and the number of m&m's with the **"m" facing down (= decayed atoms)**.

– Record the numbers in your data table.

– Put only the un-decayed atoms back into the bag and reseal the bag. Shake it again for 5 seconds.

– Count and record the time and the number of un-decayed and decayed atoms like before. Continue the steps until all atoms are decayed or until you reach 30 seconds.

– Repeat the experiment another two times and calculate the average of your values.

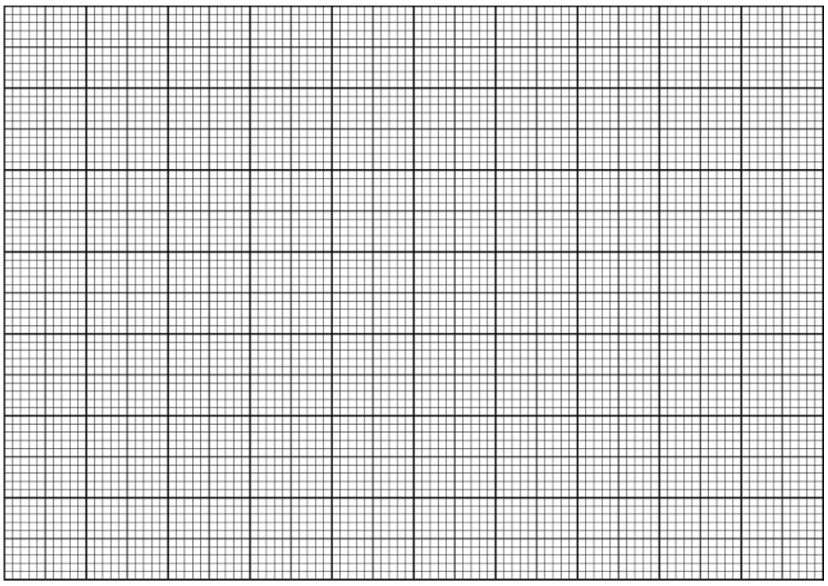
– Make a graph of the **average number of un-decayed atoms as a function of time**.

– Solve question 1.

RESULTS:

Time (s)	Total number of **un-decayed atoms**				Total number of **decayed atoms**			
	Exp. 1	Exp. 2	Exp. 3	**Average**	Exp. 1	Exp. 2	Exp. 3	**Average**
0								
5								

GRAPH:



Questions:

1. How much time is needed for half of the m&mium to decay?

t = ... = $\mathbf{t}_{\text{1/2 of m\&mium}}$

Definition: the half-life $t_{1/2}$ of a radioactive element is

.....

.....

(answer: the time it takes for half of its atoms to decay into something else)

Remark: Radioactive decay is a random process. It is impossible to predict when one particle will decay.

2. How many out of 50 m&m's would remain after 15 seconds?

3. Can the amount of radioactivity disappear completely? YES/NO

4. If you repeat the experiment with 100 instead of 50 m&m's, will this change the half-life? YES/NO

The half-life $\mathbf{t}_{1/2}$ is a measure for the rate by which a radioactive substance decays.
The half-life $\mathbf{t}_{1/2}$ depends only on

..... (answer: the nature of the substance),

and not on .....

(answer: the amount of the substance)

EXAMPLES OF HALF-LIVES:

^{15}O	124 seconds
^{123}I	13 hours
^{131}I	8 days
^{60}Co	5,3 years
^{137}Cs	30 years
^{226}Ra	1600 years
^{14}C	5730 years
^{235}Ur	704 million years
^{238}Ur	4,5 billion years

HYDROSTATIC PRESSURE

Activities	Contents
1. Definition of hydrostatic pressure Teacher performs experiment 1. Students observe. Observations and conclusion are noted. Students try to explain why pressure increases with depth.	**Experiment 1:** Water is poured into a plastic bottle with several holes at different heights. **Observation:** Water streams out from all of the holes, but the lowest stream is travelling the longest horizontal distance. **Conclusion:** The intensity of the water jet increases with depth. **Explanation:** A liquid can be divided into imaginary layers. Because of its weight, each layer exerts a force onto the next layer. Thus, the force and therefore the pressure increase with depth.
Teacher performs experiment 2. Students observe. Observations are noted.	**Experiment 2:** In a graduated cylinder filled with water, the hydrostatic pressure is measured at three different spots on the same depth with a pressure sensor connected to a computer. **Observation:** The pressure remains the same.
Teacher performs experiment 3. Students observe. Observations are noted. **Question:** – At a certain depth, there is an equal volume above both liquids. But the pressure at a certain depth in the salt water appears to be the highest. Why? (Because the mass of the volume of salt water is higher.) – Which physical quantity is defined by mass per unit volume? (Density) **Question (repetition):** – What causes hydrostatic pressure? – Which factors influence the size of hydrostatic pressure?	**Experiment 3:** Experiment 2 is repeated with salt water. **Observation:** The pressure remains the same, but it is higher compared to the pressure in normal water at the same depth. **Explanation:** Each substance has a different density, so pressures vary depending on the substance. • • • • • • • • • • **SUMMARY:** The hydrostatic pressure is the pressure exerted by the weight of a liquid onto the bottom and walls of a vessel and onto objects within the liquid. The hydrostatic pressure increases with depth and depends on the nature of the substance.

2. Size of the hydrostatic pressure

A student performs the experiment. Before performing the experiment, other students are asked to make an assumption about what will happen when the tube is placed in the water. Students formulate their observation.

Based on the experiment, the formula of hydrostatic pressure is derived.

Each time, students are asked to give the next step. Extra questions by the teacher can lead the students to the correct answer (in grey):

- What is the formula for pressure in general?
- Hydrostatic pressure is caused by the weight of a liquid. How can one calculate the weight? Formula?
- How can we include mass density into the formula?
- What is the formula for the volume of a cylinder?

At last, students fill in the names and units of the physical quantities in the formula.

Experiment 3:
A hollow glass tube is sealed with a plastic plate and placed into a beaker filled with water. Water is bit by bit added to the tube.

Observation: The plate 'sticks' to the tube. The plate loosens when there is an equal liquid level inside and outside the tube.

Conclusion: When the plastic plate releases from the tube, the hydrostatic pressure on the plate exerted by the liquid in the beaker equals the pressure exerted by the liquid in the tube.

Derivation of the formula:

$p = F / A$

↓ ($F =$) $m \times g$

$p = (m \times g) / A$

↓ ($m =$) $\rho \times V$

$p = (\rho \times V \times g) / A$

↓ ($V = V = r^2 \times \pi \times h$
$A =$) $A = r^2 \times \pi$

$p = (\rho \times r^2 \times \pi \times h \times g) / (r^2 \times \pi)$

↓ simplify

$p =$ ..... $P = \rho \times g \times h$

$p_{hydr} =$; unit =

$p =$; unit =

$g =$; value + unit =

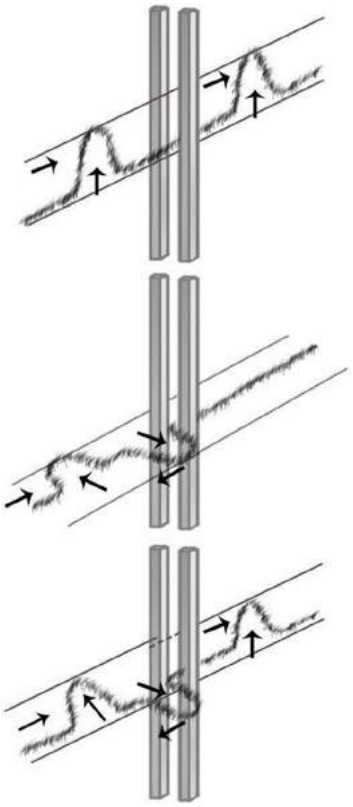
$h =$; unit =

POLARISATION OF LIGHT

How do you twist light? And why would anyone want to do so?

Introduction:

Twisting light might sound like a funny idea. But if engineers had not found a way to twist it in a controlled way, the displays in your mobile phone, laptop and maybe even your TV would have remained black.



In the experiments below, you will actually twist light. You will see how this can produce surprising effects and beautiful colours. Moreover, you will learn how giving light a twist is used to build displays and to control the quality of food and pharmaceutical products.

Before you start, you will need to understand what polarisation is and how a polarizer works. Light waves oscillate in a certain orientation. More precisely, light waves oscillate in a plane perpendicular to the direction in which it travels. Most light sources, such as the sun and almost all lamps, produce light that is called non-polarised. This means that different parts of the light oscillate randomly in different orientations. On the other hand, light is called (linearly) polarised when all waves oscillate in the same direction.

A polariser is a filter – that only lets pass through the waves – that oscillate in a certain direction. Light waves that oscillate perpendicular to the orientation of the polariser are absorbed. Diagonally oscillating waves can be vectorially decomposed into one part oscillating in the orientation of the polariser (passes through the filter) and one part perpendicular to it (is absorbed). As a result, all light waves passing through the polariser oscillate in the same direction.

EXPERIMENTS:

- Hold up a **polariser** with your hand and have a closer look at it.
  Why does it look like a grey filter?
  Can you find out in which direction the light waves oscillate that pass through this polariser?

- Now explore the world around you – **seen through a polariser**. Things look almost the same, but if you observe carefully, you will discover some interesting differences. For instance, rotate the polariser while you look at the blue sky, the display of your phone and at a reflection on glass or other shiny surfaces.
  What do you notice? Put down some short notes of your observations and try to find an explanation for the effects you see.

- Now take a **second polariser** and look through both polarisers while you rotate one of them.
  What do you observe and how do you explain what you see?

- Hold one polariser ca. 1 cm in front of the other, so that the area where the two overlap looks black. Then get a **third polariser** and rotate it between the two.
  Explain what you see with a drawing.

Replace the polariser in the middle with something made of **transparent plastic**, e.g. a bag or a ruler. Also try the same experiment with glass and other transparent materials.
There is a lot to be discovered with this simple experiment – be attentive to details and jot down your observations.

So, you know now how to twist light. And what is that good for?
Do you have any ideas for a practical application of twisting light?

You have seen that the light from a **liquid crystal display** (LCD) – like the one on your mobile phone – is polarised. Actually, this display technology is closely linked to the experiments you just conducted. Make a guess about how it works!

Feel free to do some more experiments, to take a closer look at an LCD (e.g. with a magnifying glass), and discuss your ideas with your classmates. Now summarize your ideas either in a short description or in a drawing.

WARM LIGHT

A light source should generate light, not heat.

It is not easy to transform electricity into light. A portion of the energy will always be 'lost' as heat, limiting the efficiency of the light source. It is not just light that can generate heat, however. Heat can generate light too and it can help us to understand what light is.

With this worksheet, you will learn more about the relationship between heat and making light.

1. How do you recognize an efficient light source?

There is a simple "hands-on" technique to find out if a light source is efficient: if it gets warm and it is not a heater, then energy is wasted.

Please examine the following list and rate the light sources. If you need to check before writing down your answers, please be careful. The objects may be very hot.

	Hot					**Cold**
Candle						
Light emitting diode (LED)						
Incandescent light bulb						
Halogen light bulbs						
Compact fluorescent light bulb						
Fluorescent light tubes (check tube ends)						
Firefly						
Plasma TV-screen						
Sun						

– Discuss your results with your classmates and then compare them to the data your teacher gives you.

By the way, the same trick also works to test the energy efficiency of other technical devices, such as the charger for mobile phones, electric toothbrushes, computers, cars, etc.

2. Have you ever heard people talking about 'warm' light, or 'cold' light?

In most cases, when these terms are used, the references are not to the heat produced by the light source, but rather to the colour of the light.

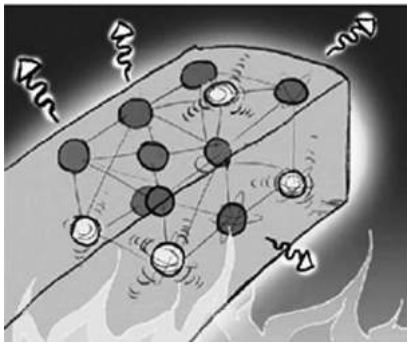
– **Red and orange are usually associated with warmth, while bluish light is considered to be 'cold'.**

But what does the colour of the light tell us about the temperature of the light source? Is a piece of metal that glows red warmer or colder than a piece of metal that glows yellow or even bluish white? Look at a piece of metal that is heated over a Bunsen burner or a metallic wire heated by an electric current. Please describe how the colour changes while the metal heats up.

– Based on your observation, is the common understanding of 'warm' and 'cold' light *physically* correct?

3. You were probably not surprised to see the metal **glowing**.
   But why does the metal start to emit light when it is heated up?

   Why does the colour change? Although this effect has been observed by humans for thousands of years, it was only a little over 100 years ago that Max Planck provided a satisfactory explanation for it. By heating metal we add **energy** to it. The more we heat it, the more the metal atoms vibrate in their positions in the latticework. To get rid of their excess energy – i.e. to cool down – atoms emit small packages of energy in the form of light. Such packages are called **photons**. How much energy a photon has, depends solely on the frequency of the light.



4. **Why does a photon with higher frequency have more energy than a photon with lower frequency? Or it is the other way around?**

   You can answer this question by carefully examining the change in the emitted light while the metal is cooling down. A diffraction grating will help you to separate the different frequencies of light. Please hold the diffraction grating close to your eyes so that the left part of the frame covers the glowing metal. The blue light has the highest frequency (and shortest wavelength) while red light – at the other end of the optical spectrum – has the lowest frequency (and longest wavelength).

   Carefully observe what happens to the spectrum while the metal cools down, until it stops glowing.
   Please note your observations.

   What can you conclude from your observations? Is there more energy in photons with a higher or with a lower frequency? Can you provide evidence to support your conclusion?

5. **Use the diffraction grating to study the spectra of an incandescent light source and the LEDs on the LED module.**

   What difference in the spectra do you note? How do they compare to the spectra of the hot metal?

   Obviously, the photons emitted by the red, green and blue LEDs have different energies. Touch the LEDs – can you notice any difference in temperature?

   What do you conclude from your observations about the way in which light is generated by the various different light sources?

NOTES