FCHgo!

"Energy, Electricity and Hydrogen"

Thesaurus of suggested didactical experiments

Structure of experiments

The proposed experiments constitute a list, from which teachers, according to their local educational needs/ possibilities may construct own scenarios. We suggest that *chosen elements* from this list are inserted into the preferred by teachers lesson scenarios. Therefore, the list does not contain "must-have" experiments, but an open directory.

By the color we sign the level of difficulty and/or complexity and/or special safety requirements: green – simple (in our intent possible to experiment in the age 8-10 yrs), blue – intermediate (11-12 yrs), red – difficult (13-17 yrs), violet – expert (not only difficult, but principally expensive).

Main contents

We start from very simple experiments on mechanical energy that can be done on the elementary level. Then we discuss experiment in electrochemistry and electromagnetism (4 experiments on electrochemistry on elementary-school level are described separately, with worksheets). Alternative energies and fuel cell are discussed in details in separate documents, on the secondary level The experiments are organized to follow the "production" line of energy making a fuel-cell car move.

LIST OF EXPERIMENTS

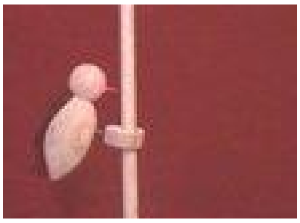
1. Energy, its forms and energy conversion

These experiments aim to show that the energy cannot be "produced" but only transformed from one type to another: mechanical energy, electricity, heat.

● **1.1. Jumping balls**: a heavier rubber ball (make a small cavity in the upper side) and a ping-pong ball.

This is the simplest experiment that (from our didactical experience with children) spontaneously induces the idea of energy: children exclaim "the heavier ball transmitted the energy to the upper one".
The exact calculation, assuming that the lower mass M is M>>m where *m* is the mass of the upper ball shows that the upper ball will be projected to the high $H = 9h$ where h is the height from which the two balls started.
1) Didactics: make the two ball fall from the same high and mark (we use a pupil as a height meter) the amplitude of the jump; then make the experiment with two balls twice (children concentrate spontaneously the attention on the upper ball) and the third time asking to observe the heavier ball. The explanation comes directly form children and immediately.

● 1.2. Wooden woodpecker



To be found in many regional editions: will slide down, step-by-step, but first it must be risen to the top of the "trunck".

Careful observation shows that the woodpecker stops from time to time before a next step. But when it stops, the spring is bent and pushes the woodpecker back to the trunk. It allows a next step of sliding down. During this sliding down, the potential energy transforms in steps to the kinetic one, than the kinetic into the elastic (potential) energy of the spring, and then a next portion of the potential (gravitational) energy is consumed. At the and of the trunk the whole initial potential energy is transformed into the heat.

Could the woodpecker climb up? Yes, if somebody delivers the energy, like in this climbing chimney cleaner (that requires a hand to pull the rope, that delivers, using the interplay between static and dynamic friction, portions of energy needed to climb step by step).

● 1.3. "Death" loop

This is a "classical" school experiment that is usually used to explain the existence of the centrifugal (non-inertial) force that acts on the ball (or a motorbike rider in the circle) in the uppermost part of the loop.

In practice, to solve the problem, the budget of energy must be used: assuming the radius of the loop R, in the highest point of the loop the potential energy is $2mgR$ and the kinetic energy must be at least $mv^2/2=mgR/2$ in order to deliver the centrifugal force mv^2/R balancing the gravity force mg. Therefore the initial potential energy must be $5mgR/2$. The lowest initial altitude (in the case the engine of motorbike stops unexpectedly) must be $5R/2$.

Literature: dydaktyka.fizyka.umk.pl/zabawki1/files/mech/mech-en.html

clean energy we understand the electric power stations (home, local, centralized) that do not require the use of nuclear nor gas/ coal fuels.

2. Electricity "production"

By "electricity" production we understand different ways to obtain the separation of electrostatic charges (like in the triboeletric effect) and/or electrical currents. We show few examples, out of many possible.

● 2.1. "Electricity" by friction

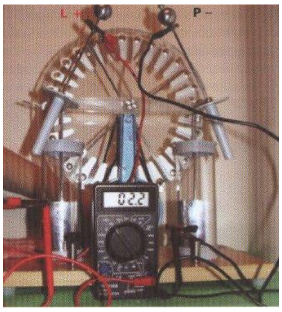
Electrostatic charges are easy to be shown: any piece of cloth and any piece of plastic (i.e. polymer) material should work. To detect one con, construct Volta's electrometer, using a glass, an aluminium foil and a toothpick.

Much more fun in the class we get if we use the electrically charged stick to detect if girl's hair are clean: girl's hair, especially natural blond, are usually thinner and longer, so it is easy to rise them by approaching with the charged stick. Not to make any harassment, we use our own (hairy) hand as an alternative detector of electrical charges on the plastic stick.

● 2.2. Triboelectric effect - intermediate

Experiments with fur (or silk, plastic bag) pieces and glass/ Sulphur/ ebonite, plexiglass bars are present in every school. School textbooks usually say that glass is positively charged, while plastics have negative charge. This is not essential didactically. What would be useful is to show that both the ebonite bar and the piece of cloth gain *net* electric charges, like in the example with the silk scarf pulled out from a woolen coat.

●● 2.3. Electrostatic generators



It is useful as a *social competence* in experiments with the electrostatic charges to show sparks from electrostatic machines. According to the narrative didactics, before making the experiment we inform pupils that a spark 1 cm long corresponds to the voltage of 30 kV. We separate the electrodes by 3 cm, saying that if a spark occurs, the voltage created will be 100 keV.

To make this value understandable for small children, we ask about the meaning of <u>kilo</u>-meter, and we make them check what is the voltage of their phone cells: “you understand now, that your phone close to this machine would be destroyed, do not you?”

A simple voltmeter can be used to establish which electrode of the machine is positive and which negative, but the voltmeter must be connected to the machine *before* we start turning the disks. Due to the current flow through the voltmeter, the voltage read is low, not hundredths of kV but single volts.

Wimhurst machine is a simple and robust equipment. It must be kept free from dust, dry and the combs collecting the charge must not touch the rings.

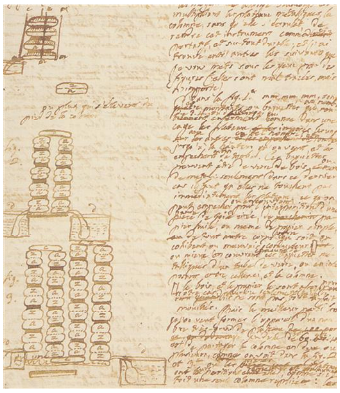
3. Volta’s piles

Original Volta’s pile “glasses-like” (*a bicchieri*); photo from Como museum, concession by Comune di Como.

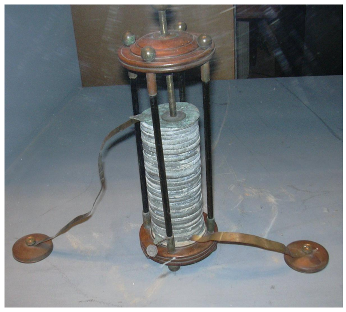
Volta’s (or Galvani, as you like) pile, despite of more than two hundreds years (AD 1797) from its construction, is still the unique way of storing/ supplying the electric current in phones and portable computers. Lead batteries are in every car. And, in spite of the time elapsed, we are still far from quantitative understanding of its functioning.

In a series of experiments, even if simple also quantitative, we show how to construct Volta’s piles from “almost” nothing.

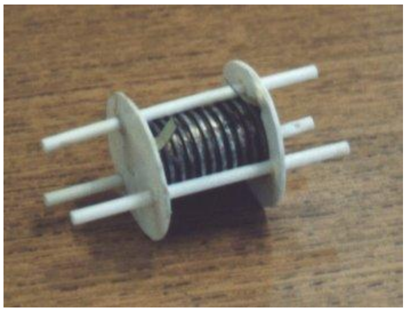
3.1. First Volta's pile



The first Volta's pile, described in his letter to xx in March 1798 was a pile (this is the origin of the name) of tin (Sn) and silver (Ag) coins. Every second pair was separated with a piece of cloth wetted by salty water.



Coins currently used in EU (and another type used in Poland) are based on copper and copper-nickel alloys, so they are practically *useless* (to make Volta's pile). Here, below, a photo of the pile made from old Polish coins, that were from aluminum and from copper/nickel. As you see, the coins get corroded after some time: these are chemical reaction ("corrosion") that drive the electrical current.



3.1a. Volta's tongue "volt-meter"

Obviously, Volta did not measure the "voltage" in volts neither by a voltmeter. He used his own tong. This is not a very hygienic experiment, but worth mentioning.

Volta noticed an "sour" taste when he positioned a pair of coins, Sn/Ag on his tongue, with Sn on the tongue's tip. We know now that it was an acid taste since Sn^+ ions go into the solution (i.e. into Volta's saliva).

It is easy to repeat this experiment with eurocent coins: a half of the 5 cents coin is wrapped into Al foil. Now the coin can be easily placed on the tongue (remember to extend it outside your mouth, like Einstein in his famous photo).

● 3.2 Lemon battery

The core of Volta's invention was the use of two different metals with a liquid (called electrolyte) between them. In the first version of a pile of coins (Ag/Sn), the electrolyte was salty water, in the second version with glasses (Cu/ Zn) the electrolyte was the diluted sulfuric acid. But the electrolyte can be any water-based solution – human hand, a cucumber or a lemon.

►Needed:

- simple digital voltmeter, with cables and "crocodiles"
- two pieces of metal (Al or Fe, Cu or brass, in the form of nails or triangles)
- different fruits

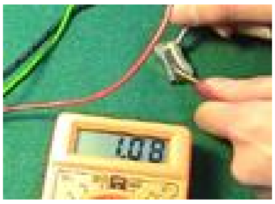
Ask pupils to bring from home any vegetable.
- Divide pupils into groups of 3-4 and give an empty sheet of paper to every group.
- Explain how to switch on the voltmeter, chose the "2V" range, and ask pupils to check if the voltmeter shows zero when two wires are short-cut (make them write the value read)

- Ask pupils to measure (and record) the voltage in different fruits when the free ends of voltmeter wires are inserted

- If more metals are available make them repeat measurement with different metals (and fruits).
- If time is enough, make them measure the voltage putting nails (triangles) at different distances.
- Make every group report orally the results obtained.

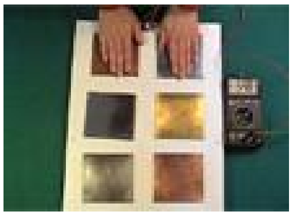
In the lemon battery experiment pupils spontaneously divide role: one inserts nail into the apple, another one reads the voltmeter, the third one makes notes.

3.3. Many types of Volta's piles



As said above, combinations of different metals, for positive electrodes Cu, Ag, Au, for negative Zn, Al, Fe give galvanic voltages, of the order of half a volt. In the photo below the 1 V voltage is obtained from an aluminum pencil sharpener: the knife is in stainless steel, so its potential is positive as compared to Al. (The paper put in-between the Al and the knife has been wetted by salty water.)

3.3a. IQ meter



To make more systematic studies of the electrochemical voltages, it is useful to collect different metals: lead, aluminum, copper, brass, iron, stainless steel, and then measure voltages with different combinations. Pupils' hands can act as electrolytes, closing the electrical loops: attach the two wires from the voltmeter to two metals, and simply touch two metals with two hands.

If metals are arranged into two vertical columns and each piece is connected (below the wooden plate) to the entrance of the voltmeter, measurements are quite fast. Put the voltmeter range into meV: depending on the combinations (left – right column) the voltages are of the hundreds of meV. This is enough for physics but if you want to introduce some fun, arrange pairs of metals into raws that the voltmeter indicates negative values. Call it "intelligence meter" and ask you school director to touch the meter: "Well, usually IQ should be above 100, but sometimes, when you are particularly tired, it can happen to be negative…"

More (in Polish): http://dydaktyka.fizyka.umk.pl/zabawki/files/articles/zrodla/zrodla.html

3.4 Human battery

This simple and funny experiment is a surprise, even if we know principles of operation of Volta's pile. The same couples of Zn/ Cu plates that are used in Volta's pile in glasses (see photo in point 3). What is important for the surprise effect is the construction of the narration. First pupils/ students must identify the voltage in batteries of their cell phones. Then we ask: "and what happens when the battery is exhausted? An you need urgently to send an e-mail? Let's try!"

The experiment uses "bi-metals" like in Volta's original pile with the acid and glasses: zinc (or iron) and copper plates connected by a wire. Students form a chain, connected by the bi-metals hold in hands (be careful that they touch plates, not the wires). The whole chain is closed by a voltmeter. Some 0.7 V is expected from each pair, so five pairs are (in theory) sufficient to supply the voltage to the cell phone. In theory, because this is the sufficient voltage, but not a sufficient current (in amperes).

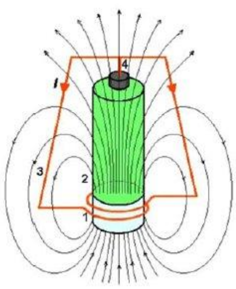
FCHGo lesson at IX Liceum, Gdynia, 12.03.2019.

4. Electrical engines

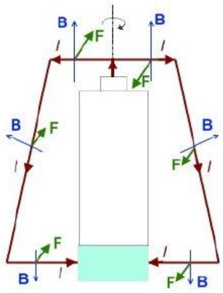
Electrical engines are essential part of any hybrid/ electrical/ fuel cell cars. They are so quiet, that a legislative proposal is under discussion in EU if electrical cars should artificially produce some noise in order to warn pedestrians. The Lorentz's force, acting in the magnetic field on moving electrical charges (i.e. wires with electrical current) is the physical basis for all electrical engines.

●● 4.1. Two-loop engine

The simplest two-loop engine is composed of a piece of wire (1mm diameter), a stick battery and neodymium magnet. The plastic isolation (present on the wire) must be removed from the loop in the lower part touching the magnet in order to assure the current flow.



The engine works thanks to localized configuration of the magnetic field around the magnet, see the figure. Inverting the magnet (upside-down) or inverting the battery changes the direction of turning (let pupils try it.). To start the engine, make the lower loop touch the magnet for a second; once started, the dangling of the engine will make the loop touch the magnet continuously: the engine will accelerate.



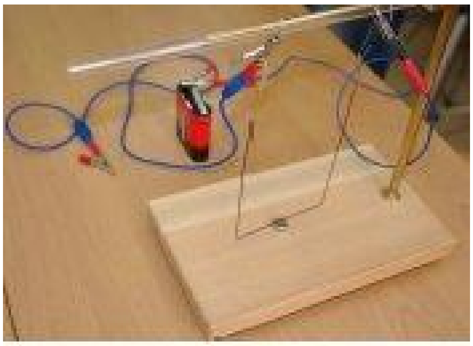
It is very instructive to let the engine turn for a while (say 15 s) and to show that the battery is getting hot: the current flows through the wire and also through the battery. It gets hot due to the internal resistance of the battery. Be careful not to exceed few seconds as the battery can get very hot. The source of the current in the battery are *electrochemical reactions*, i.e. the "chemical" energy: the same as in a fuel hydrogen cell.

● 4.2. One-loop engine

A simpler one loop engine requires a neodymium magnet, a stick battery, a big nail and a piece of flexible wire. Keep the wire attached to the upper pole of the battery and to the magnet (see photo). The sharp end of the nail works as a mechanical bearing, reducing the friction. The battery must be Cd-Ni (1.5 V), as Zn is not magnetic and the nail would not attach to it.

The mail is needed to obtain the needed configuration of the magnetic flux through the wire loop: not both but only one magnetic pole contributes to this flux.

● 4.3. Lorentz's force



In the two-loop engine one has to consider the amplitudes of the pairs of forces and their directions. A textbook experiment on the force acting on the current in the magnetic field is free from these difficulties. To perform it, we need a low-voltage current supplier (or a 4.5 V battery, see figure), a piece of the copper wire (take put the isolation on its ends) and a neodymium magnet.

►Experiments to be done *qualitatively* are the same as in two-loop engine:

- invert the current direction
- invert the poles of the magnet.

In order to determine the direction of the force, we need first to define the direction of the magnetic field around the magnet (poles are on the basis of the cylinder). One way to do this is to hang the magnet (with an iron paper clip attached) on a thin thread: the magnet will assume the position N-S, like the compass needle: the pole which indicates the south direction is N (the direction of the magnetic field lines has been agreed to go from N to S pole).

A second way is to make roll down the magnet on a slightly inclined wooden slope. According to different geographical directions the magnet will make different trajectories; until its path is correctly E-W (or W-E).

●● 4.4. Hand electricity power station *(pila a manovella)*

This a key experiment, linking the questions of electricity and the energy.

1) The most common teaching is that in order to generate the "electricity" we must deliver the energy to the device.
2) But using this device we may make also semi-quantitative measurements. "Let's make some quantitative measurements. I push the level 5 times than we wait for how many seconds the rotor moves" [usually 5-6 second, one can repeat this experiment. Then, we take out the lamp which is inside and repeat the experiment. Now the rotor moves some 12 seconds. "You understand? This is conservation of energy. When the lamp is in the circuit than the energy generated goes to the heat (and light), and obviously to the friction of bearings. Without lamp the energy losses are smaller – only the friction."

There are many models of similar generators. This one, bought at Science Museum in London is particularly interesting as it allows to identify the internal elements, in particular the wire and the (gray) magnet.

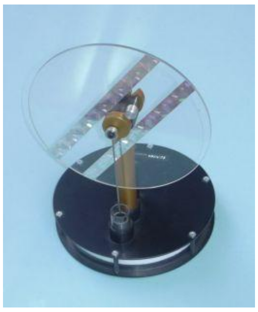
This, alternative model is also interesting as it shows that not only rotation but also the translational movement can generate the electricity (it is accumulated in a condenser). Again, one can count for how many seconds the lamp is illuminated, after e certain number of "strokes".

A complementary experiment, that even pupils can perform independently is a plastic tube (like for telephone cables) with a solenoid wrapped around and a LED closing the loop. A neodymium magnet falling inside make the LED flash. A variation can be done letting two magnets fall, separated by a piece of iron (a thick nail). Making a video it is possible to notice in which moment the LED flashes.

6. Heat and work

The concept of energy flows and re-flows is the basic notion in the didactical concept of FHCGo (see the didactical material by prof. H. Fuchs). Thermal engines are good exemples of the inflows of heat, work and outflow of residual heat.

We show two Stirling engines that work with quite “residual” heat: at can be put on the hot cup of water or cooled by ice cubes.



dydaktyka.fizyka.umk.pl/zabawki1/files/termo/silnik-en.html

A simple experiment can be done as supplementary to the measurements of solar constant (see PowerPoint experiment no. 1). A can (here aluminum can from an old calorimeter, but also a can from coffee) is painted by a black paint on one side. It gets illuminated by an old W lamp (one can use also a resistance electrical heater). We check how the temperature of can rises when it is illuminated from one or other side (start from a can cooled in tap water, dry it before experiment).

The upper side of the palm is also quite a good detector of the heat that is brought by an IR radiation. Ask every pupil to check it personally.

7. “Alternative” energies

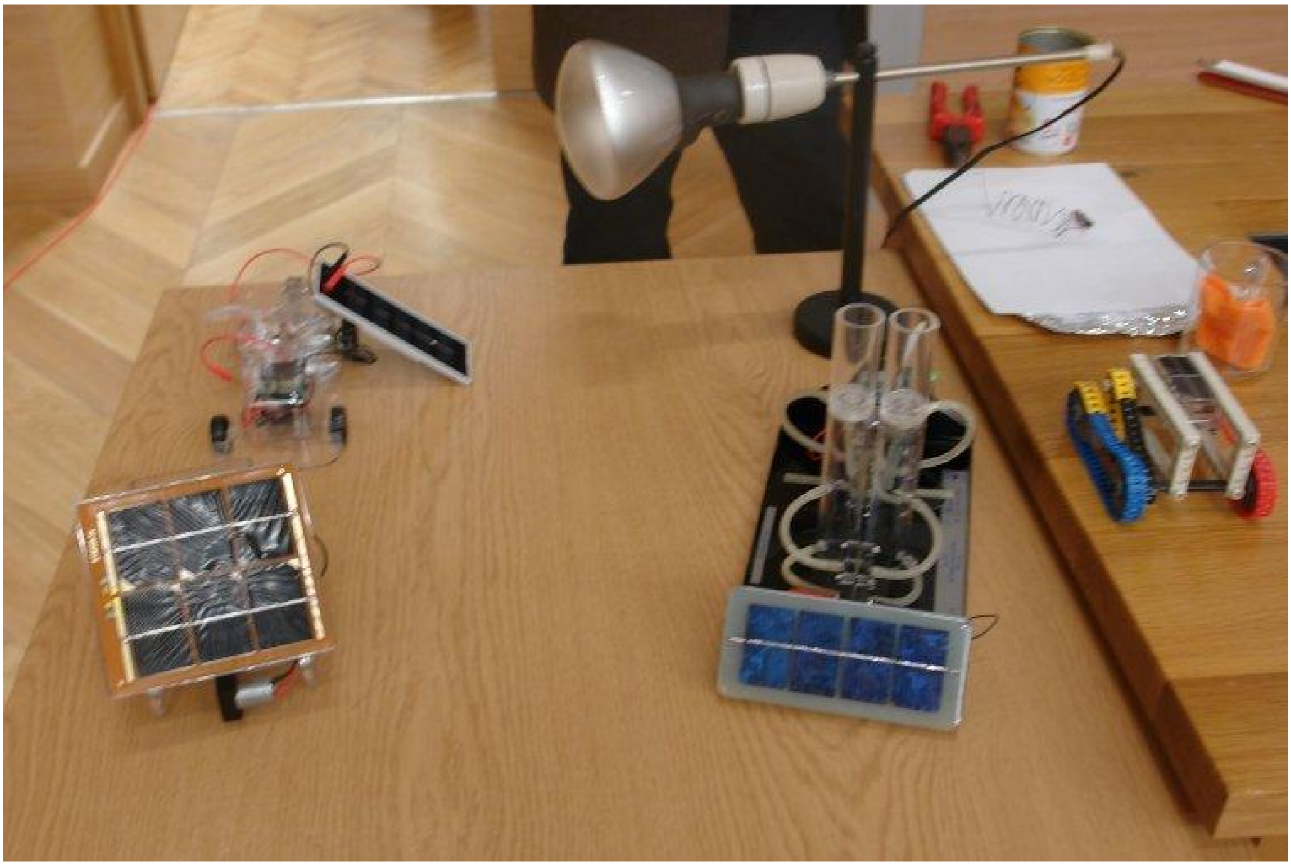
By alternative energies we understand the electric power stations (home, local, centralized) that do not require the use of nuclear nor gas/ coal fuels.

Sets of experiments on different forms of alternative energies controlled by remote sensors are proposed by Pasco (see the “Biblio” file).

Number of simple experiments can be shows and/or collected by pupils. 

8. Fuel cells

Separate Power Point presentations (Exp_3 and Exp_4) describe two possible simple experiments. More complex experiments would require the systems like that of Phywe (see “Biblio” Power Point).



to be continued…

see more at:
http://dydaktyka.fizyka.umk.pl/nowa_strona/?q=node/857
http://dydaktyka.fizyka.umk.pl/zabawki1/
http://dydaktyka.fizyka.umk.pl/nowa_strona/?q=node/854

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