Priceless experiments, or better yet just for a dollar

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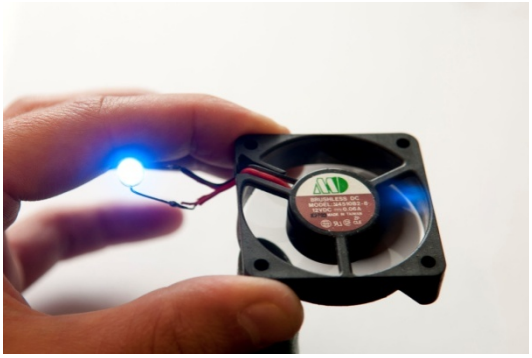
Probably almost every physics teacher knows how hard it is to get a new teaching aid or demonstration set to his physics cabinet. This statement keeps being repeated but it is already becoming a cliché. The teacher, who teaches students physics and really means it, then has no choice but to start making aids on his own, look around and gain the sense that not all things have to be discarded/thrown away. In this contribution I would like to show, or sometimes just remind, with which experiments teacher can enrich his or her lesson.

Laptop fan as an energy source

Old discarded fan, which has been used as an active cooling, was discarded because of intensified noisiness since the bearings were worn down. Such is the fate of most of fans to end up in waste, or in the best case in electronic waste. Nevertheless, it could serve the teacher and the students for a long time. When teaching direct current it can serve as an electric motor and also as a generator of the direct current.

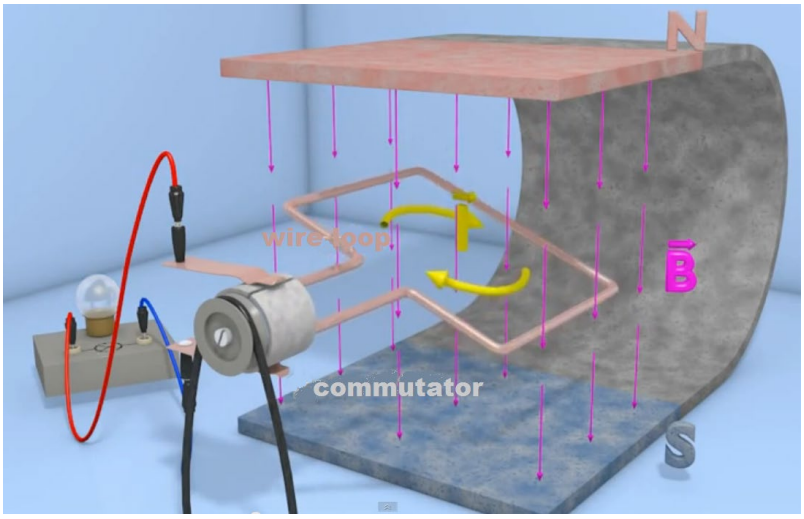
Method: First, we will try the fan's functionality out by connecting it to the direct voltage source. In most cases 4.5 V flat battery will be enough. Then we are going to try, if we are able to make the fan reach higher RPM by blowing on it. If we can do it, the bearings are in a condition that enables us to experiment. Keeping in mind the polarity, we will solder an LED to wires (it is better to use an LED with low input). Since LED is a semiconductor component, in which electrical current flows only in one direction. Then we only have to blow on the fan's vanes and watch how the LED will light on and how its brightness will change with rotational speed of the fan's vanes, or, more precisely, with the velocity of air blowing through them.

Pic. 1: LED soldered to the fan



Pic. 2: Fan as a source of electrical energy

Explanation: Dynamo is an electrical device, which converts mechanical energy of rotor into electrical energy in a form of direct electric current, which means that it is a direct electrical generator. Dynamo consists of a stator made up from magnet or electromagnet and of a rotor with windings and commutator. So its construction is similar to the construction of direct electric motor, which is used for the opposite purpose.



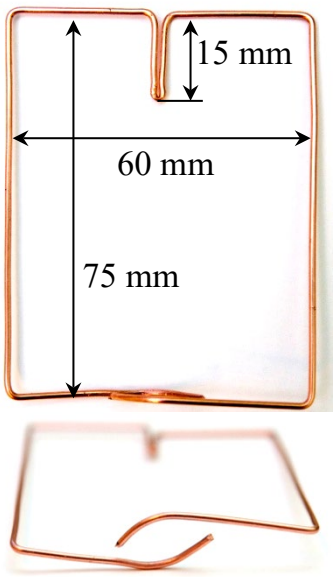
Pic. 3: Scheme of the dynamo with permanent magnet [1]

Dynamo is based on the principle of electromagnetic induction. In case when the plane of the rotating wire loop is slightly rotated parallelly to the direction of magnetic field lines, the value of electric current flowing in the loop is maximal. Conversely, no current will flow if the plane of the loop is perpendicular to the direction of magnetic field lines. At this moment the commutator, consisting of two semi-circles isolated from each other, reverses polarity. Value of the current changes from zero to maximum two times per one whole revolution.

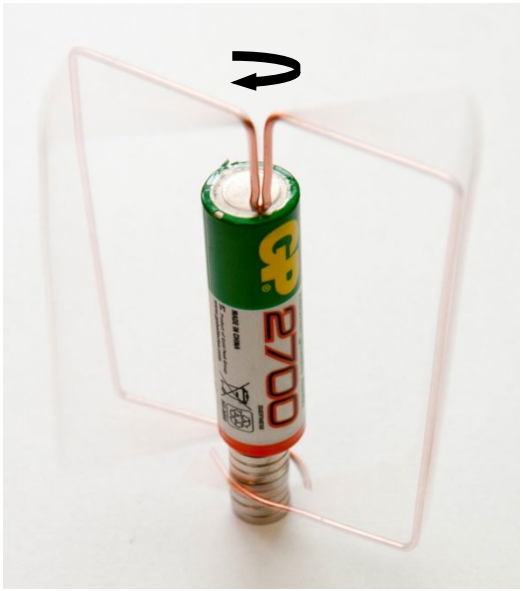
Direct current electric motor – easier way does not exist

Behaviour of a conductor in a magnetic field can be demonstrated by a small direct current electric motor. Inventor of this impressive experiment is none other than Michael Faraday himself, British chemist and physicist.

Method: To make this aid we are going to need around 30 cm of copper wire with the diameter of 1-1.5 mm, a neodymium magnet and an AA battery. We bend the copper wire as it is shown in picture 4. Then we put the neodymium magnet to the battery's positive terminal and place the wire loop on the battery's negative terminal so that the lower part, which forms commutators, lightly touched the magnet. If contact pressure between the magnet and commutators was high, friction between them would be also high and generated force would not be great enough to spin the loop. Some time experimenting is required but it is well worth it.

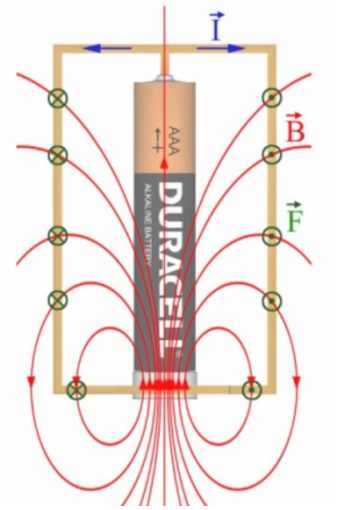


Pic. 4: Proportions of the loop

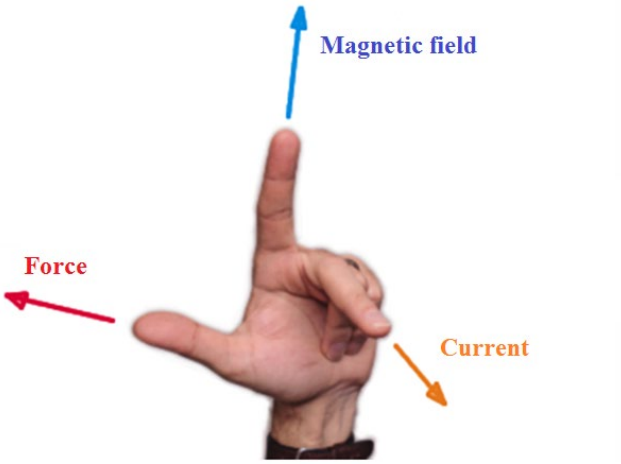


Pic. 5: Assembled electric motor

Explanation: Principle of direct current motor is based on the fact that a current-carrying conductor placed in a magnetic field experiences a magnetic force. We also use the fact that electric current can flow in the surface of a neodymium magnet. Magnet serves in two ways: it creates magnetic field with induction *B* and at the same time it conductively connects poles of the battery. When we place the loop on the battery and the commutators touch the magnet, electric current *I* will start to flow in the loop (in accordance with the arrangement, current flows from the positive pole to the negative one, see pic. 6). Using the good old Fleming's left-hand rule, we will determine the direction of magnetic force and rotational direction of the loop (pic. 7). The result is the loop's rotation.



Pic. 6: Acting physical quantities [2]

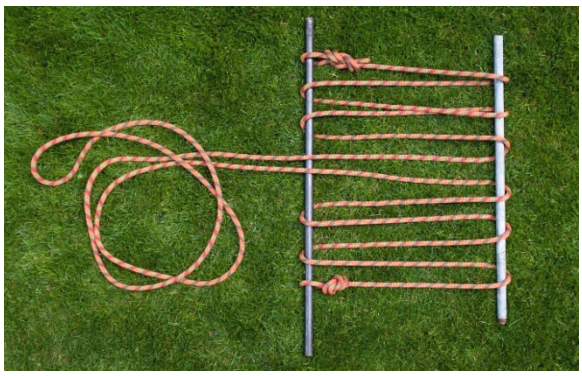


Pic. 7: Fleming's left-hand rule

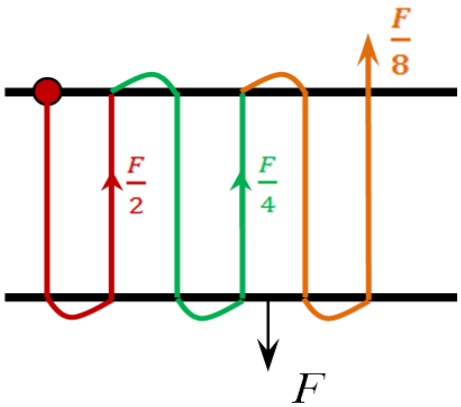
Block and tackle

History of simple machines is thousands of years old. As far back as more than 2000 of years ago king of Syracuse ordered Archimedes to show what simple machines can do. The Greek scientist constructed a rope and pulley system and pulled a boat to the coast all by himself. No wonder then that one man can win over the strength of several men in a tug-of-war, but not just in any one. For the experiment we need to make a model of the moveable pulley system, i.e. block and tackle.

Method: We are going to need a longer climbing rope (or possibly a tow rope), two broom shafts or even better two metal pipes or wooden dowels with the length of ca. 1 metre. We will tightly tie both ends of the rope to the pipe. When we thread the rope in the way shown in picture 8, we will get the system of movable pulleys. Then you just need two volunteers to catch a hold of every pipe. The pair then tries to get the pipes away from each other, but they will not succeed because even a relatively small force at the free end of the rope is enough to not let the pair win and to draw them to each other.



Pic. 8: Arrangement of the rope between the pipes



Pic. 9: Force distribution between the pipes

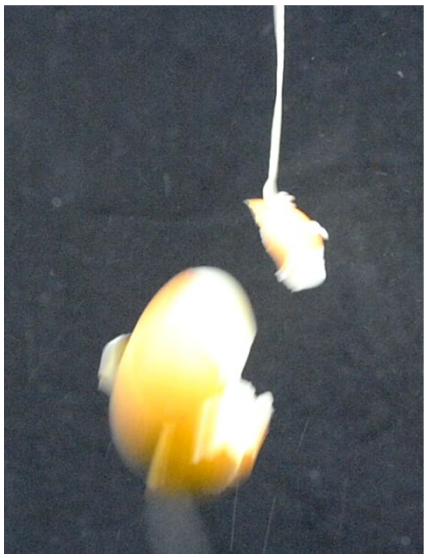
Explanation: As it is evident from the picture that we have a pair of movable pulley systems. There are two systems so that the two pipes are, if possible, parallel to each

other during pulling. Let us focus on only one system of movable pulleys. In picture 9 we can see particular forces acting on the rope between the pipes. We consider the model without friction between the rope and pipes though. In actual fact, the friction is high and that is why a climbing rope along with polished pipes' surface is an optimal solution. If we assume no friction, the force necessary to draw the pipes closer is equal to one eighth of the tow force.

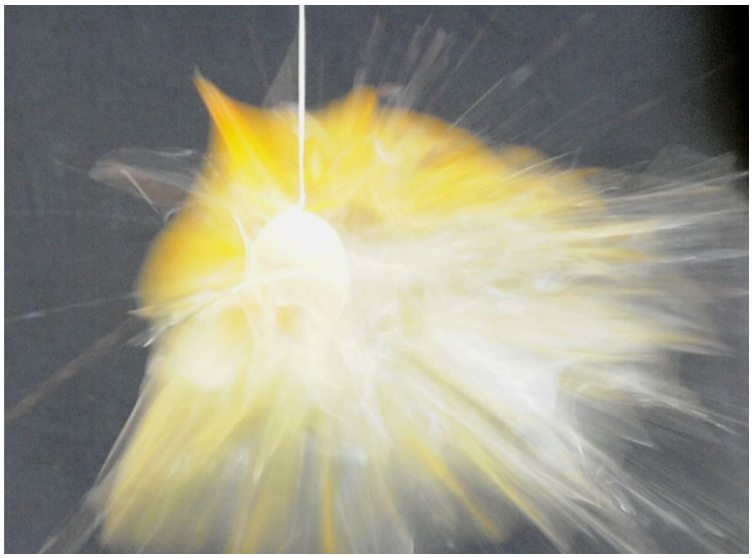
Pascal's law and an egg

Pascal's law can be demonstrated by several ways. The most popular experiment is a plastic bottle with holes, out of which water will start gushing equally, if we squeeze the bottle hard enough. However, let us describe a more impressive and thrilling experiment, which demonstrates the validity of Pascal's law for liquids and which can be performed in the way students will never forget (verified by experience).

Method: Proceeding with caution, the experiment can be performed even in a classroom, but it is better to realize it outside at a safe suitable place. We will need one raw and one hard-boiled egg. We will attach a long string to each egg by a hot glue gun, so that we can hang them up (best on a tree). With great caution we shoot the boiled egg first, and then the raw one with a pellet from an air gun. Notice, how different the moments were when pellet hit the boiled egg and when it hit the raw egg. Teacher must always keep in mind that after shooting through an egg pellet can ricochet off the wall or ground and struck the observers. You can prevent this situation by placing a trap behind the egg, or an egg carton, eventually by shooting outside against the slope.



Pic. 10: Boiled egg



Pic. 11: Raw egg

Explanation: In case of shooting the boiled egg, it will be shot through and split into two big pieces. Pressure caused by the pellet is only local and occurs in the place of the pellet's passaging. It shows that because of crystalline structure of solid materials, pressure is not transmitted as in liquid or gas. In case of shooting a raw egg, something else occurs. Pressure caused by the pellet penetrating through the egg is being transmitted in the liquid content of the egg and it is pushing the whole surface of the eggshell (pressure at each point of the eggshell is equal). The pressure is so high that the whole egg explodes in all directions. We can notice that the content of the egg spreads perpendicularly to the original eggshell's surface. Pascal's law has been confirmed.

Abstract

Contribution describes interesting physical experiments, whose costs of realisation is minimal and does not exceed 1 dollar. It emphasizes simplicity, clarity and attractiveness of these experiments as well. Instructions for implementation of experiments for students and teachers and explanation of their physical principle are also a part of contribution.

Key words: electric motor, direct current, dynamo, pulley, Pascal's law

References

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[2] How to make a Homopolar motor. In: *Youtube* [online]. 15. 08. 2014 [vid. 2013-03-14]. BeforeAndAfterTV channel. Available on: https://www.youtube.com/watch?v=xbCN3EnYfWU