Practical projects in physics education

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This contribution describes the structure of some projects that are suitable for high school education. They have been compiled at the website of a "Physics Club" that took place at the Faculty of Mathematics and Physics of Charles University (MFF UK) in Prague between the years 2001 and 2004. A project based on the Magdeburg hemispheres and its usage for bringing physics lessons alive is discussed as an example. The Physics Club was organized by the Department of Physics Education of MFF UK as an activity for students from different high schools who were interested in physics and experimenting.

Project motivated by the Physics Club at the MFF UK

In what manner do objects placed in a real fluid move? What can be found inside a floppy or optical disk drive? How can the elasticity of wood be measured with skewers? Why is the surface of liquid elastic? How much heat is leaking from our homes? How can one fabricate spatial photographs or videos? On what principle does the food in a microwave oven get heated?

These and other similar problems were among the practically conceived projects that were solved by high school students during the Physics Club that took place in the years 2001 – 2004 at MFF UK in Prague. Descriptions of selected projects and other experiments are available on the web at [1].

Additional information about the orientation and goals of the Physics Club is summarized in [2], for example.

Each project is described on a single web page which is appended with various notes, solutions of related exercises and problems, instructions on verifying or heuristic experiments, suggestions for teachers, further references and so on. Each project is introduced by one or more motivational problems or practical exercises. These problems and exercises are then solved with an effort to involve as many practical experiments as possible. Most of these experiments can be done with very simple tools. The text is generally accompanied by pictures, photographs or a short video.

These projects took place at the Physics Club and most of them were also used in classic grammar school physics lessons. Thus, the projects or parts of them can serve as suggestions for work at various seminars or as additional content for regular physics education. Anyone who wants to get to know something more about the world around them can use the materials as well, or they can serve as a source of inspiration for the preparation of some practically oriented reports.

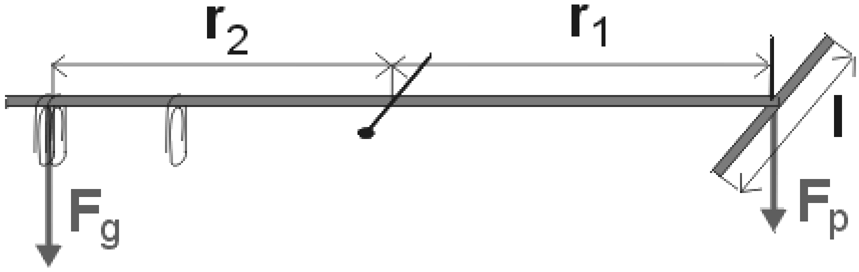
We should state that these projects do not claim to be a total nor absolutely comprehensive explanation of the topics. Neither are they the only possible way of presentation and solution of those problems. They just present some of the many possible approaches that can be further developed and improved.

One particular example – Surface tension at play

This project begins with a simple question: How does it happen that some insects can walk on a water surface and a human cannot? The reader is challenged, after a short introduction, to lay small metal objects such as a razor blade, a paper clip or a 50 heller coin (a small Czech coin struck from aluminium) on the surface of some water. These objects are made of materials with higher densities than water and therefore they should sink. A short explanation of the fact that they remain on the surface and a glance into a text book gives us the basic idea of intermolecular forces and the surface layer. The introductory section ends with two problems: What pulls two coins lying on the water surface together? And how can we move a coin lying on the water surface from one side of the bowl to the other without touching it?

These simple introductory experiments are usually gratefully accepted by the students if they are allowed to try the experiments out themselves – as the beginning of a unit about fluids, for instance.

The project goes on with a discussion of the question: How large an object can the surface carry and what factors does it depend on? After a more detailed study of the shape of the surface layer we conclude that the force which holds the object on the surface depends on both the length of the object's rim that is in contact with the liquid and the type of liquid. These facts are illustrated by several examples. A hyperlink leads to another web page that contains the description of two methods for measuring surface tension. These descriptions can serve as instructions for laboratory exercises. The first method is a modification of the well known droplet method and uses a digital camera to determine the dimensions of the droplet. In the other method, we measure the force which is needed to pull the object upwards from the surface using a simple balance scale made of a wooden skewer, a few pins, and several paper clips.



This leads to another problem which was described by L. Dvořák in [3]. The calculated value of the force arising from surface tension that makes a 50 heller coin float is about half of the coin's weight. How is it then possible that it does not sink?

At the bottom of the page there are hyperlinks to possible solutions of the introductory problems (attraction between two coins and moving of a coin on the surface without touch). The last exercise goes back to the initial question and determines the theoretical size of feet that would allow a person to walk on a water surface.

The project is concluded with a few notes for teachers and some references.

Some other projects and experiments related to the activities of the Physics Club at the MFF UK in Prague are described in [4] and [5].

The project of Magdeburg hemispheres

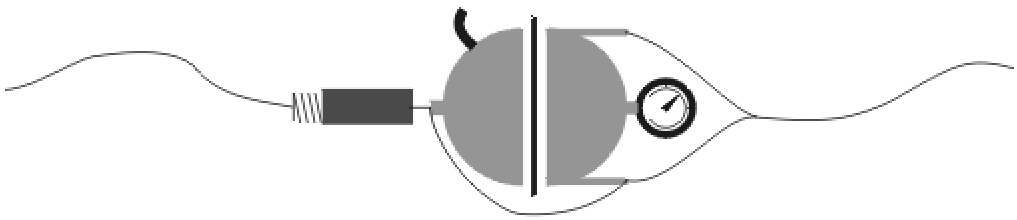
The project of making Magdeburg hemispheres and using them in physics lessons arose in the context of a statewide competition for the best video recording of a physical experiment, organized by The British Council and the Observatory of Prostějov in 2004/2005. The main author Václav Ridl, a student of the second class of the Grammar School in Polička, led his project to the final of the competition and won the first prize.

The Magdeburg hemispheres are a well known tool that demonstrates the effects of atmospheric pressure. The air is pumped out from inside two hemispheres with mating rims. To pull the hemispheres apart, a force greater than the air pressure that pushes the hemispheres together is needed. The value of this force depends on the area bounded by the joint between the hemispheres, so it depends on their diameter.

The usual school model of the Magdeburg hemispheres has a diameter of about 8 cm and can be pulled apart by hand. The hemispheres in this project are made of a spherical Camping Gas container with a diameter of about 28 cm and ten people on each side are needed to pull them apart when the air has been pumped out from within.

To make the apparatus, the following procedure was used. The bottle was cut into two hemispheres. Their rims were then smoothed on a lathe. A ring of thick rubber was put between the hemispheres to improve the seal. One hemisphere was provided with a vacuum gauge from an old milking machine so that the pressure between the hemispheres could be measured. The air is sucked out from inside the hemispheres through a thick-wall rubber tube that is attached to another valve that was screwed into the other hemisphere. The air intake is stopped if we simply fold and clip the tube.

A rope is attached to each of the hemispheres and another short rope connects the two hemispheres together so that they do not fly too far away after they are pulled apart. A spring scale made of a plastic pipe and a car suspension spring is attached between one of the ropes and the hemispheres. The spring scale was calibrated with heavy dumbbells and it can measure forces to a maximum of about 3000 N.



The advantage of this device is that its demonstration involves all the students in the class. We pump the air out of the hemispheres and close the inlet. Then students come one by one to the ropes and try to pull the hemispheres apart. We can read both the pressure inside the hemispheres from the vacuum gauge and the pulling force that is needed to pull the hemispheres apart. Then we can compare these values to the theoretical calculation of the force

$$F = \Delta p \cdot S$$

where Δp stands for the difference of the atmospheric pressure and the pressure inside the hemispheres and

$$S = \pi \cdot r^2$$

is the area of the cross section of the joint between the hemispheres with the radius r.

The students can calculate the expected value of the force that holds the hemispheres together in advance and then verify their calculation and the theoretical equation.

The experiment with Magdeburg hemispheres is very attractive for the students and its demonstration can also be used to teach the history of air pressure research or as a theoretical exercise verified by a measurement (optionally with a discussion on possible difference between the theory and the experiment).

References

[1] http://fyzweb.cuni.cz/dilna/krouzky/vybrane/vybrane.htm (alternatively can be navigated from http://kdf.mff.cuni.cz)

[2] Jílek M.: *Kroužek fyziky pro středoškolské studenty*. In: Sborník konference Veletrh nápadů učitelů fyziky 7. Ed.: Svoboda E., Dvořák L. Prometheus Praha 2002. s. 164 – 167.

[3] Dvořák L., Jílek M.: *Pokusy nejen pro letní tábory*. In: Sborník ze semináře „…aby fyzika žáky bavila…". Ed.: Kolářová R., Pinkavová Z. Univerzita Palackého v Olomouci 2003. s. 141 – 147.

[4] Jílek M.: *Fyzika jako zážitek*. In: Sborník konference Veletrh nápadů učitelů fyziky 8. Ed.: Šerý M. Jihočeská univerzita v Českých Budějovicích 2003. s. 104 – 109.

[5] Jílek M.: *Několik nápadů nejen z kroužků fyziky*. In: Sborník konference Veletrh nápadů učitelů fyziky 9 – svazek druhý. Paido Brno 2004. s. 50 – 54.