GIREP & EPEC 2015
July 6 – 10

Uniwersytet Wrocławski

INTERNATIONAL CONFERENCE GIREP EPEC 2015
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Europhysics Conference
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Collection of Solved Problems in Physicc: Online Learning Source Encourages Students' Active Learning

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Abstract
The article reports the on-line learning source – the collection of solved problems in physics. The well elaborated tool is giving the students opportunity to learn problem solving by themselves in an efficient way. The collection is developed at the Department of Physics Education at Charles University in Prague, nevertheless the international collaboration with the Department of the Education of Physics at Nicolaus Copernicus University in Torun was established. Whereas the Czech institute provides management of the database, creates new problems in Czech and translates them into English, the Polish institute translates the problems into Polish and creates experiments linked with these problems. The Polish institute also printed booklet of chosen problems in mechanics.

Keywords
Physics education, solving problems, online learning.

Introduction

Solving quantitative problems is one of the favorite exercises in teaching physics. It requires *key* competences: mathematical fluency, knowing physics and understanding the written text ("OECD", 2014). Teaching should develop in students the ability to solve problems. Students would acquire the skills that will enable them a systematic and continuous search of knowledge, as well as developing a logical, critical and creative way of thinking. One of the goals of science (and physics) education is teaching students to solve problems (Harskamp & Ding, 2006).

The common collections of unsolved or briefly solved problems are not very suitable for self-study to not so skilled students. Moreover, reading solved problems is a very ineffective way of learning. There is also usually a lack of time to solve enough problems in the class.

Collection of solved problems in Physics

The collection of solved problems prepared at Charles University (Koupilová & Mandíková, 2015) goes beyond the traditional role of numerical exercises in Physics. The form of the electronic database of problems with structured solution is designed specially to substitute tutor's help and to encourage students to solve the problems or at least some of their parts independently. It uses various hints, notes with laws and formulas and plots.

The difficulty of understanding the written text is easier thanks to the step-by-step hints and explanations, written in a simple language. The numerical insecurity of a student is overcome by several, alternative and complementary problems, forming a sequence with a rising difficulty (Passing of a Train I and II, tasks no. 386 and 387). Finally, essentials of physics are underlined by coming back, on different levels, to the same problem: equilibrium position of pendulum in different systems (tasks no. 937 and 481), ballistic pendulum (*I* and *II*, tasks no. 146 and 147).

How the collection looks like
Typical structure of a task contains compulsory sections (title, assignment, at least one section of solution and the answer) and recommended sections (hints, analysis, comments, links to similar tasks, see Figure 1).

In analysis section a strategy of solution and physical principles used within the solution of the problem are highlighted; no formulas are used here to persuade students to think more about the physical context of the problem than about the mathematics involved. The main difficulties that students face in solving problems relate to a low degree of development of certain skills that are essential in any process of problem solving, for example, linking their prior knowledge to the new problem situation, conducting a qualitative analysis of the situation, developing a solution strategy or carrying out appropriate calculations (Becerra-Labra et al., 2012). Thus, in

solution section a special attention is paid to a step by step description, including every logical operation and formulas' operation, list of known and sought-after data, unit conversions and numerical calculations.

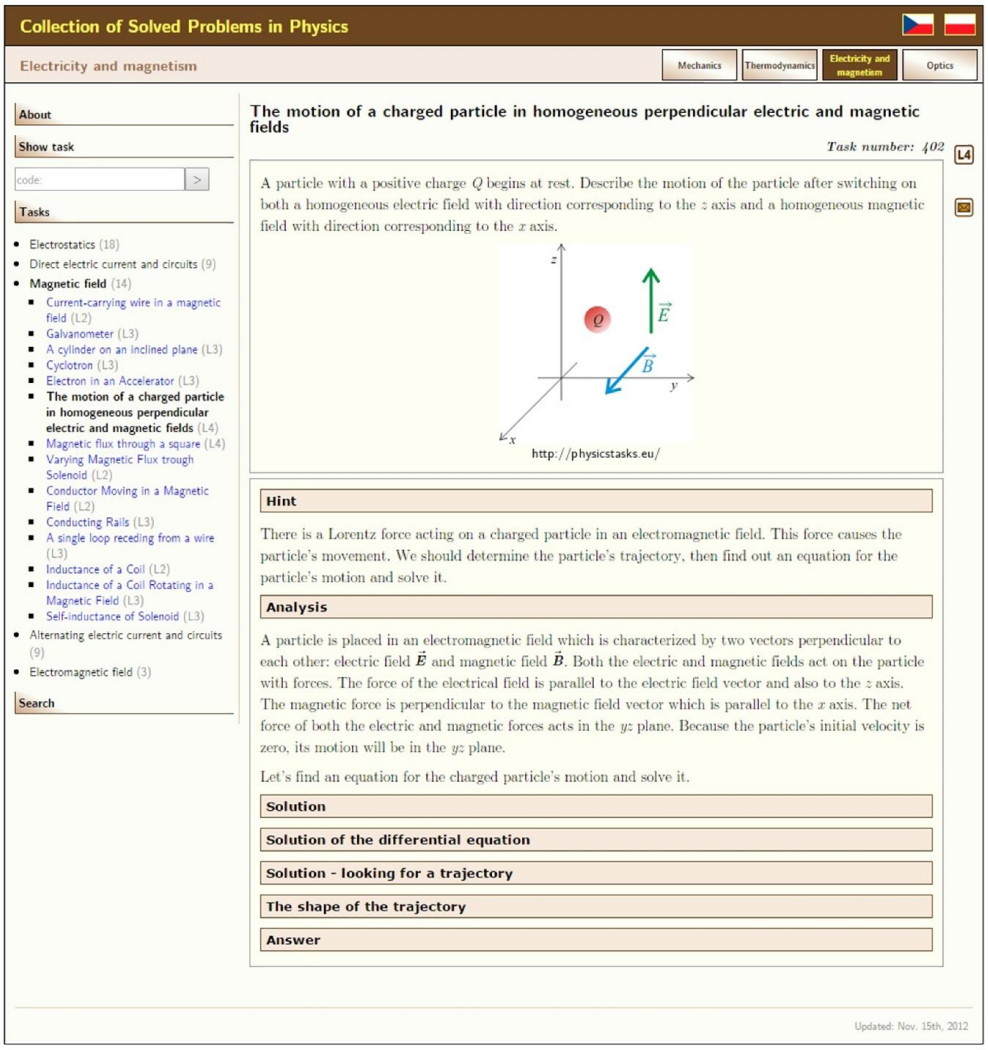

Figure 1. The screenshot of a typical problem

Users of the collection

We have had usually over 1000 visitors per day in January 2014 – June 2015 period. The number of visitors precisely distinguishes school days, weekends and holidays. The geographical distribution of the visitors is figured on Figure 2.

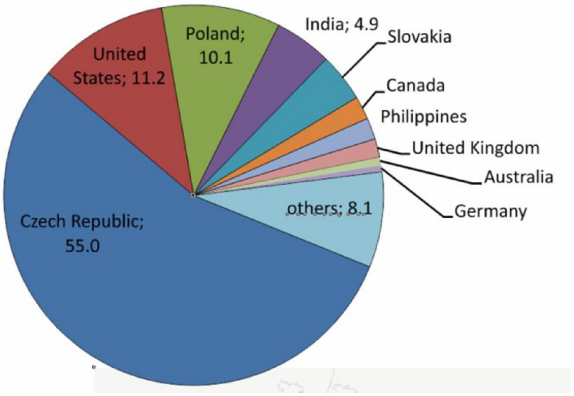

Figure 2. Geographical distribution of visitors

Current content
Current content of the web database includes nearly a thousand physics and about 400 math problems in Czech. Besides them, translations of approximately 100 physical problems in Polish and 120 in English (Table 1) are available.

Table 1. Rough numbers of published problems in individual subjects.

Topics			Tasks
Czech	Physics	Mechanics	220
		Electricity and Magnetim	260
		Thermodynamics	140
		Optics	50
		Physics of microworld	90
		Theoretical mechanics	50
		Mathematical methods	80
	Math	Mathematical analysis	190
		Linear algebra	160
		Algebra	15
English		Mechanics	50
		Thermodynamics	20
		Electricity and Magnetim	50
Polish		Mechanics	30
		Thermodynamics	36
		Electricity and Magnetim	20
		Physics of microworld	12

Booklet of problems in mechanics
The Department of the Education of Physics (ZDF) of Nicolaus Copernicus University in Torun published online the Polish translation of nearly one hundred tasks (see Table 1). Apart from this, a booklet with selected problems in mechanics has been prepared as the educational material for Polish students and teachers distributed during ZDF seminars. First edition was printed in 300 copies in 2013. It was assessed as an excellent tool for students' self-study, that's why we decided to extend its content (some problems for more advanced learners were added) and it was printed in 2014 at the NCU publishing house (Koupilova et al., 2014). The booklet is available only in Polish.

Linking physics problems with experiments

Physics problems can be usefully supplemented with experiments showing the same physical phenomenon, or vice versa. This interconnection of problems and experiments can serve not only as a motivation for students, but it is also useful for better understanding of physics concepts. For this reason, ZDF prepared set of physics experiments linked with problems.

An example of work linking problems with experiments is a problem of a spinning reel with a tape wound on it. Such an experiment used to be shown during lectures on mechanics by one of our colleagues (Hieronim). While unrolling the tape, the direction of the movement of the reel depends on the angle that the tape forms with the horizontal direction – see the movie on our webpage (Służewski & Karwasz, 2015).

In accord with calculations, see (Koupilova et al., 2014), the effect is based on the interaction between two forces – the one pulling the reel (to the right on Figure 3a) and the static friction force (acting to the left in this case). These two forces (actually moments of these forces) can be added in such a way that sometimes the spool accelerates to the right, sometimes to the left, depending on the angle of application of the force to pull (see the movie: Służewski & Karwasz, 2015).

Although the theoretical description of a similar problem is one of textbook "classics" (Mazzoldi, 1998), a real experiment attracts much more web visitors than the solved problem itself. Further, precise measurements using computer-controlled force sensors illustrate several other aspects, like slipping, errors in digital approximations or simplifications in calculations (see Figure 3c).

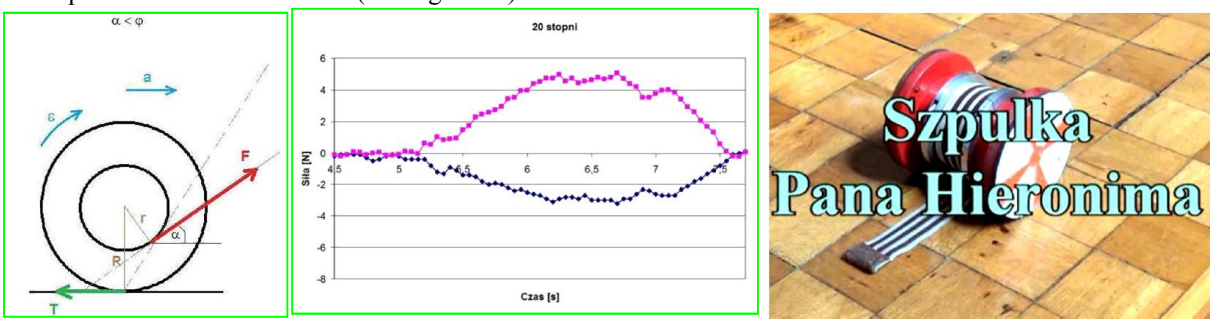

Figure 3. From simplified picture of the situation in the Problem Collection (left panel) to a real demonstration (middle) and computer-aided experiment (right). The direction of movement of a rolling bobbin depends on the angle of the pulling force. Adopted from Służewski & Karwasz (2015).

We have also analysed both theoretically and experimentally the problem of static and kinetic friction on inclined plane on the same webpage (Służewski & Karwasz, 2015), which is crucial for explaining a similar case of "a cat pulling a ball of wool". Depending on the point of application of the pulling force, the static friction force changes its value. Moreover, if the thread is hooked above the axis (at least at the level of $R/2$, where R is the radius of the ball), the friction force changes direction (see Becerra-Labra, et al., 2012; Mazzoldi, 1998). The friction during rolling is a static friction and it acts always *against* a possible direction of the slip.

Conclusion

The database of problems with structured solution, either in electronic or printed version, is designed specially to substitute tutor's help and to encourage students to solve the problems independently. Solved problems in physics are only a starting point into illustrating different aspects of the real world. We plan to add new problems and new topics to the on-line database and to continue in translation of problems into English and Polish. We have also prepared a set of experiments that are linked with the already prepared problems.

References

Becerra-Labra, C., Gras-Marti, A. and Torregrosa, J.M. (2012). Effects of a Problem-based Structure of Physics Contents on Conceptual Learning and the Ability to Solve Problems. *International Journal of Science Education*, **34** (8), 1235-1253.

Harskamp, E. and Ding, N. (2006). Structured collaboration versus individual learning in solving physics problems. *International Journal of Science Education*, **28** (14), 1669–1688.

Karwasz, G. (2015). Hyper-constructivism in teaching Physics: defining social competences, *GIREP 2015 Proceedings.*

Koupilová, Z., Mandíková, D. (2015). *Collection of Solved Problems in Physics*. Retrieved May 11, 2016, from: http://physicstasks.eu

Koupilova, Z., Mandikova, D., Rochowicz, K. and Karwasz, G. (2014). *Sbirka zadań z fizyki*, Wydawnictwo UMK.

Mazzoldi, P., Saggion, A. and Voci, C. (1998). *Problemi di fisica generale*, Padova.

OECD (2014). In The Organisation for Economic Co-operation and Development: Testing student and university performance globally: OECD's AHELO, Retrieved May 11, 2016, from: http://www.oecd.org/edu/skills-beyond-school/testingstudentanduniversityperformancegloballyoecdsahelo.htm

Służewski, K., Karwasz, G. (2015). *Hieronim's roll*, Retrieved May 11, 2016, from: http://dydaktyka.fizyka.umk.pl/nowa_strona/?q=node/472

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