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The Role of Mathematics and Physics as Essential Foundations for Future Armed Forces Officers

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Abstract

The aim of this paper is to get acquainted with the form of teaching physics at the Department of Mathematics and Physics, Faculty of Military Technology, University of Defence. A good knowledge of mathematics and physics is a prerequisite for coping with the demands placed on future officers of the armed forces. Further, the article presents conclusions that show that mentoring, updating textbooks to a form close to the current generation, and targeted practice of more demanding physics topics together with modernized classroom and laboratory equipment, including extensive use of e-learning, gradually leads to better learning results. This contribution also presents the analysis of students results and the form of teaching physics.

KEY WORDS: *sustainable education, cadet's motivation, knowledge of physics, student achievement*

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1. Introduction

Teaching physics is essential for the future understanding of students within their military specialties. Thus, the main purpose and importance of teaching physics is to use the acquired skills of students in their military specialties.
The Department of Mathematics and Physics (Faculty of Military Technology, University of Defence, Brno, Czech Republic) educates future officers in technical fields, as well as civilian experts for the national security system and the defence industry.

This paper aims to spark a discussion about how to teach physics in today's modern era at specific military universities. We describe how to help students in their understanding of physics with new, interesting, intuitive literature and what an essential role individually focused mentoring plays in the training of students. The military requires university graduates to be not only soldiers and commanders, but also educated professionals in their specialties.

Unlike civil universities, our students cannot choose some subjects independently, all subjects of the study programs are mandatory for them. Students take exams for individual subjects during the exam period, which usually lasts four weeks, on dates set by the examining teacher. Each student has one regular deadline and two remedial deadlines for successfully completing the exam. If he is not successful in these terms, then his studies at our school end.

Physics is taught in almost all specializations, especially in the military-technical field of mechanical and electrical engineering [1].

Students from various types of secondary schools come to our faculty. This means that students' knowledge of physics is very different. At the beginning of the study, we try to balance the level of knowledge of physics with an individual approach.

The subjects in the individual study programs are adapted to the fact that it is a military university. That is why the subjects Physical Education, English Language, Preparation in the Field are reinforced hourly. But even the subjects Mathematics and Physics, which belong to the theoretical basis of the study programs, are well subsidized per hour. Physics is taught in the form of lectures, computational and laboratory exercises.

We strive to innovate teaching methods by introducing modernized textbooks and new laboratory tasks while using information technologies [2]. Whether our efforts have positive results can be judged from the results of students in physics exams over the past several years.

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2. Form of physics teaching

Physics has been taught at the University of Defence in Brno (and their predecessors) for more than 70 years. In this long period, different degree programs were rotated according to the army's requirements. Currently at the Faculty of Military Technology, courses are accredited for master's, bachelor's, follow-up master's studies and doctoral studies. In this contribution we will focus on the master's study program in which future officers of the Czech Army are raised. As of the 2019/2020 academic year, the master's study program includes a total of 168 hours of physics instruction.

Physics is taught in the second and third semesters, a total of 84 hours of lectures, 44 hours of computational exercises and 40 hours of laboratory exercises. As an example we present the laboratory exercise “Measurement of thermal length expansion” that is important for engineering military specialization, especially for the construction of engineering structures or the exercise “Measurement of the specific charge of electron” that is crucial for military electrical engineering specialization in terms of understanding the effect of the magnetic field on the movement of charged particles in electronic devices. (see Fig. 1, Fig. 2 and Fig. 3).

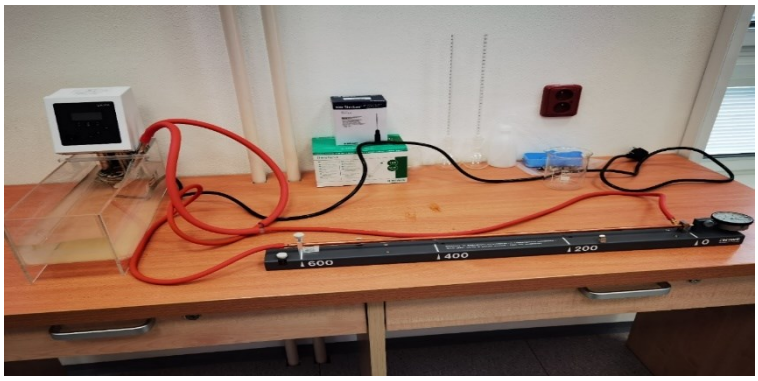


Fig. 1. Measurement of thermal length expansion

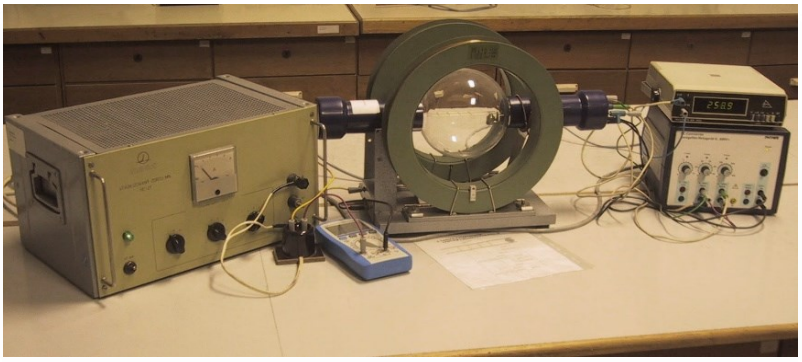


Fig. 2. Measurement of the specific charge of electron.

Fig. 3. Measurement with an optical spectrometer.

Physics lessons include, for example, the following topics: kinematics, dynamics, work, force, energy, gravitational field, special relativity, fluid mechanics, thermodynamics, electrostatic field, electric current, magnetic field, electromagnetic field, oscillations, waves, optics, quantum optics, quantum mechanics and nuclear physics.

As part of computer exercises, teaching takes place in groups of approximately 15 students. Physical examples from the mentioned topics are solved here. Approximately 10 students work in pairs on laboratory exercises. During the measurement, physical laws are verified here (Measurement of the specific heat capacity of the material, Temperature dependence of the thermistor), values of physical constants (Measurement of the specific charge of the electron, Determination of the value of gravitational acceleration), physical properties of materials (Measurement of the index of refraction of glass, Passage of gamma rays through various materials) and measurement results are processed on computers, including reporting. The classrooms and laboratories for teaching physics underwent a major renovation a few years ago, which included the purchase of new computer technology and new modern laboratory measuring instruments. We are currently preparing a new Physics textbook. During our many years of teaching practice in the field of physics, we often met, when introducing students to this exact science, with unpleasant reactions, such as: "Physics is only formulas and laws.", "What will I need it for in my life?" , "I never understood physics and I will never understand it.", "That physics is boring."

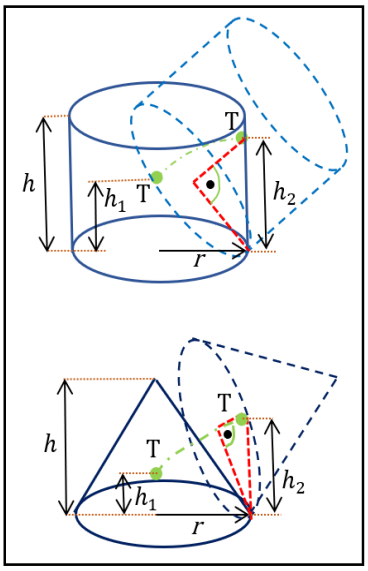
Příklad 5.4.1

Na vodorovné rovině stojí dvě homogenní tělesa: válec a rotační kužel vyrobené ze stejného materiálu. Obě tělesa mají stejné podstavy a stejné výšky. Které z nich má větší stabilitu? Poloměr podstavy $r = 0{,}5$ m a výška $h = 1$ m.

Řešení:

Pro hodnocení stability obou těles použijeme první kritérium. Vypočítáme, jak velkou práci je třeba vykonat pro uvedení těles do polohy vratké.

Těžiště válce při stabilní poloze je na jeho ose ve výšce $h_1 = \frac{h}{2}$. Pokud se válec dostane do po-



Obr. 5.11 *Určení stability válce a kužele.*

Fig. 4. Sample No. 1 of the upcoming physics textbook.

Úloha 5.3

K čemu slouží provazochodci dlouhá tyč, kterou drží při chůzi po laně v rukou?

Úloha 5.4

Když ponesete na zádech těžký baťoh, proč se budete při chůzi předklánět?

Úloha 5.5

Máte za úkol osekaný kmen stromu rozřezat na dvě poloviny, které budou mít stejnou hmotnost. Zavěsíte pomocí lana strom na jeřáb tak, aby se nacházel v rovnováze (osa kmene je rovnoběžná s vodorovnou podložkou) a v místě, kde se nachází lano, strom rozřežete. Budou mít obě poloviny stejnou hmotnost?

Fig. 5. Sample No. 2 of the upcoming physics textbook.

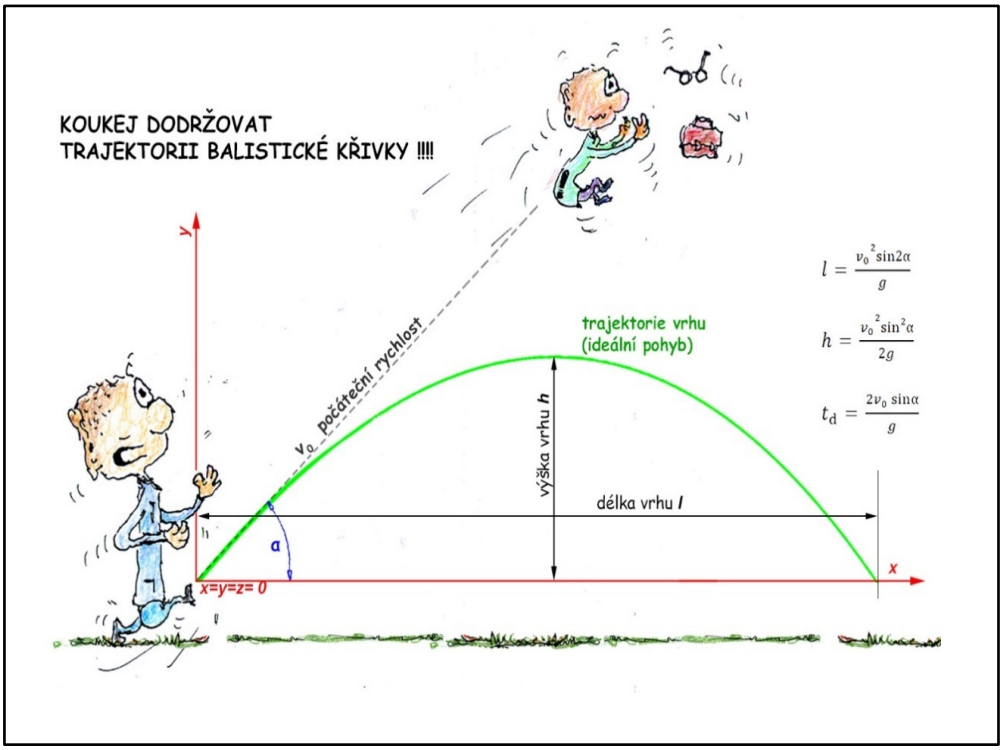


Fig. 6. Sample No. 3 of the upcoming physics textbook.

Therefore, our effort, in this publication, was to bring physics closer to students so that it becomes more interesting and fun for them. Tasks from practice, including their solutions and examples solved in detail, should contribute to this. The textbook also contains qualitative questions on which students can check their correct understanding of basic physical principles, as well as funny illustrations to complement the technical text (see Fig. 4, Fig.5 and Fig 6). This textbook corresponds to the new study texts for computational exercises and laboratory exercises. The physics exam at the end of both semesters is written and consists of six theoretical questions and four examples to be solved. A student can get a maximum of one hundred points from the paper. A student who gets at least fifty points will pass the exam. During the semester, students are continuously tested on their knowledge of physics in computational exercises. Based on the results of these continuous tests, it is therefore possible to react in time and, depending on the circumstances, to focus on specific topics in physics teaching. Ongoing tests also allow special mentoring sessions to take place if required.

3. Mentoring method and analysis of students results

Students from different types of high schools are coming to our faculty. This means that their knowledge of physics differs fundamentally when they enter college. The period of covid caused long-term closure of schools, teaching was only on-line, which brought a lot of subsequent problems related to students' readiness for university studies. Students do not have a good knowledge of secondary schools and did not receive good study habits. Students and teachers are struggling with all this, especially in the first two semesters of study at the university. Not only for these reasons was introduced mentoring at our faculty.

Due to the fact that students from different types of secondary schools come to the University of Defence and their knowledge of mathematics, physics, and other subjects varies greatly, the Faculty of Military Technology has also introduced the so-called guided preparation of students (mentoring). Students with a low number of mathematics and physics classes in secondary school, for example, had a difficult time completing tasks at the beginning of their studies, and gradually this often led to their resignation from studies.

The goal of mentoring is to provide students with support, especially at the beginning of their studies, so that they do not lose contact with teaching, manage to supplement the knowledge they did not acquire in secondary school, and so they do not feel that they will not be able to handle a certain subject. Mentoring also has a motivating effect on students where with the help of continuously completed tasks, they gain greater self-confidence in subjects and a desire to study.

The mentoring of students consists in the guided preparation of students through mentors and pedagogical leaders according to the preferred study specialization, through consulting services, and teachers of departments providing instruction. Over the course of the academic year, mentors continuously monitor and evaluate the fulfillment of students' study obligations, organize and manage their study preparation, manage the compilation of the exam schedule during the

exam period, continuously check the status of the fulfillment of study obligations during the exam period, and also keep an overview of students' participation in mentoring. Mentors also meet with students regularly to get feedback, which allows them to individually adjust the care for individual students.

All students are required to attend guided study preparation in the first semester of their studies. In the following semester, those students who had a grade point average of less than 2.00 in the first semester and who were classified with grade E, as well as all those who do not meet the minimum requirements from the interim tests, participate in mentoring. Those students who have met the conditions and no longer need to participate in mentoring, have self-study sessions during guided preparation.

The guided preparation of students makes it possible to balance the differences between students, especially at the beginning of their studies, but it is also essential for its further course. It motivates students to prepare regularly and participates in minimizing the dropout rate of students due to not being able to cope with their study obligations.

To sum it up, mentoring represents regular meetings of students and teachers. Teachers practice repetition of high school skills and focus primarily on those areas in which students have the greatest difficulty. With which students have the biggest problems. In addition to repetition of high school physics, mentoring also focuses on new topics on the ongoing teaching at the university.

Is mentoring useful for students? To find out, we collected data on students' results in physics exams from the last few years, when lessons are run according to the latest study programs. We analyzed these study results with a focus on the influence of an individual approach to students [3-9], the gradual introduction of innovative methods into teaching with the use of new laboratory equipment, the modernization of study materials and the use of information technology.

Table 1.
Average evaluation of students in semester exams.

Academic year	Second semester	Third semester
2019/2020	2.37	2.20
2020/2021	1.75	1.52
2021/2022	1.82	1.70
2022/2023	2.16	1.70

Table 1 shows the average physics ratings of master's students over the last few years. The assessment of the students shows that in the third semester of study (second semester of physics teaching), the results are regularly better, which is mainly associated with the better habits of the students they acquired in the previous semester. After the introduction of mentoring, average student outcomes improved. In the following years the results stagnated, which is linked to a period of covid when teaching was predominantly online. Table 1 does not include the significant fact that the number of students who took the physics exam on the first or second term decreased.

In the first year of study, there is a high dropout rate of students. The reasons are various. The most common is that the student applied to the school with certain ideas about studying at a military college, but the reality disappoints him. Another reason is that he does not successfully pass the exam in the subjects of the first year of study, which are mainly mathematics, physical education and physics.

Table 2.
Student dropout rate due to physics exam failure.

Academic year	Second semester	Third semester
2019/2020	5	1
2020/2021	0	0
2021/2022	1	1
2022/2023	2	2

For us physics teachers, the goal is to have as few students as possible who end their studies because they did not pass the physics exam. Table 2 shows the number of students who dropped out because they failed the physics exam. It can be seen that the given numbers correspond to the numbers in Table 1.

Both tables confirm that after the introduction of mentoring in the 2019/20 school year, when students are given increased care, academic results and dropout rates gradually improved. It is possible to compare the differences between the entry knowledge of students who graduate from different secondary schools. It goes without saying that a prerequisite for the success of mentoring is the effort of the students themselves to improve their knowledge.

Analysis of the results of physics exams over the past few years also shows a positive effect on student results in relation to their division into smaller groups in laboratory and computational exercises. An individual approach to students also plays an important role, especially at the beginning of studying physics.

4. Conclusions

In recent years, the Department of Mathematics and Physics underwent a major reconstruction of the equipment used for teaching physics. The building, which houses the Department of Mathematics and Physics, was reconstructed both externally and internally. In the laboratory exercises, many laboratory tasks were replaced with new equipment and new computer technology was installed in the classrooms. Study texts for students are gradually being exchanged, and significant progress has also been made in the field of electronic study materials. The group of academic workers - physicists - is gradually getting younger.

Students have the option of choosing to study physics in English as well. For teaching in the English language, students also have the corresponding study materials at their disposal.

The aim of the mentioned text was to point out that the introduction of mentoring and care for students from the beginning of teaching physics, which begins in the second semester of study, leads to improved study results, facilitates acclimatization of students in a new study environment and teaches them to study at university. A big role in our effort to bring physics closer to students and to interest them is played by new study literature, both in printed and electronic form. We try to make the form of the teaching texts close to the current generation of young people, to engage them with a non-traditional approach. We know from feedback from students that they positively evaluate the modernization of our laboratories, where they stop working with old measuring devices and start using modern computer technology to process measured values. The results for the last five years, based on the analysis of the students' performances in the semester exams, confirm their gradual improvement in studying physics.

Our aim is that improving the individual approach to students, innovation of study literature and modernization of classrooms and laboratories at the Department of Mathematics and Physics will contribute to increasing the interest of young people in studying at the University of Defense.

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