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An Alternative Physics Textbook for Secondary Schools

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Abstract. This article refers to a concept of alternative physics textbook for secondary schools in the Czech Republic. The author works on an alternative text of mechanics. This article starts with a short summary of reasons for producing the alternative textbook and then presents the main premises the new text should be based on. Some of them are documented on concretely chosen examples from the chapter Motion in a straight line. Author's experiences in his new approach are presented as well. The suggestion of the first four chapters of the textbook has been already finished and it is available on the author's www-site [6].

Introduction

Physics belongs to the most unpopular subjects at secondary schools in the Czech Republic [1]. People working in physics believe that physics is very interesting and useful science but most of students would disagree. By my opinion, it is partly caused by the physics textbooks, especially when teachers use them as the only source for preparing lessons. Nevertheless, there are no alternative physics textbooks for secondary schools nowadays.

Teaching physics at Czech secondary schools is based on the textbook Physics for secondary schools [2] that consists of eight parts (Mechanics, Molecular and Thermal physics, Mechanical vibrations and waves, Electricity and magnetism, Optics, Special relativity, Physics of micro world, Astrophysics). All these textbooks have been edited several times but with only small changes, even if post-reviews [4] of the textbooks called attention to a lot of mistakes. Authors of the textbooks often use a kind of "pseudo-scientific" language, complicated sentences and problematic formulations. This style leads to memorising physics by students without understanding it. Moreover, there is a lack of real problems and examples from the world around us in there and I can see no effort to engross students in interesting problems, questions, etc. The textbooks look very dully in comparison with French or English or American ones. Even the university textbook Haliday D., Resnick R., Walker J.: Physics [5] is written in much more interesting style. Foreign textbooks might be inspirational for us since changes in teaching physics on secondary schools are expected in the future due to implementing framework educational programmes and state-graduating exam.

Main ideas of alternative textbook

The main goal of my thesis is to put forward an alternative text of Mechanics. For reasons written above, my suggestion is based on these main premises:

(a) The content of the textbook should be similar to the standards of the state-graduating exam. It should focus on understanding the basic physical principles and, of course, the scientific thinking.
(b) Each topic should be completed with a lot of solved, graphically separated problems. Most of them should be related to the real situations from everyday life.
(c) The textbook should contain some facts and applications interesting for students.
(d) Each chapter should contain a lot of questions and problems for individual student's work. (The book should also serve as a practise book.)
(e) The graphic style of the textbook should be attractive, i.e. with photos, pictures, graphs and diagrams.

Motion in a straight line

Clearly, it is impossible to publish here the whole text of some chapter or paragraph of the textbook. Thus, let me present at least some concrete illustrative passages (typed here in the frames) from the chapter Motion in a straight line that are completed with comments. More details can be found on my www-site [6]. It is clear from the title of the chapter that I prefer the following process of teaching kinematics: first, introduction of motion in a straight line and then, generalization to the three-dimensional motion.

(a) The chapter starts with a short list of main targets:

Goal

1. You will gain understanding of the fundamental quantities of motion: position, velocity, and acceleration.
2. You will learn reading and understanding graphs describing motion.
3. You will learn about uniform motion and motion with constant acceleration in a straight line.
4. You will learn a systematic approach to solve practical problems concerning the motion in a straight line.

(b) The main quantities – position and velocity are explained using the example of a moving car (Figure 1). I would like to show the importance of appropriately chosen pictures, which are useful for student's understanding and remembering the important facts. Figure 1 belongs to the explanation of position and average velocity, Figure 2 belongs to the concept of speed and Figure 3 belongs to the part concerning instantaneous velocity. I want to teach students to distinguish between vector and scalar quantities. Therefore, I define the average velocity as a vector quantity

$$\boldsymbol{v}_\mathbf{p}\ \text{(vector)} = \frac{\Delta \mathbf{x}}{\Delta t} = \frac{\text{displacement}}{\text{time}} .$$

Than I continue with average speed as a scalar quantity. Finally, I define the instantaneous velocity.

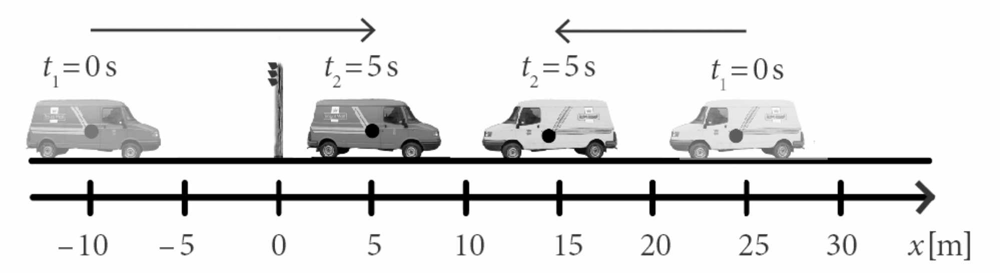


Figure 1: The position of these cars is determined from a point of reference. You can see the positions of the cars and their change in the time interval Δt=5s.

Figure 2: The speedometer in a car registers the speed of the car. You cannot see the direction of the car's movement on it.

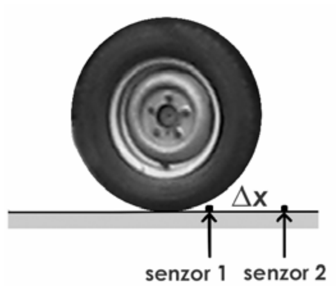


Figure 3: How to measure the velocity of the car in a point? We can put two sensors on the road in a short distance Δx and measure the time Δt it takes to get through the distance. In fact, we will obtain an average velocity in this very short time interval.

(c) The other important goal is to understand the graphs describing motion. Let me illustrate working with graphs in the following example of an elevator motion (Figure 4).

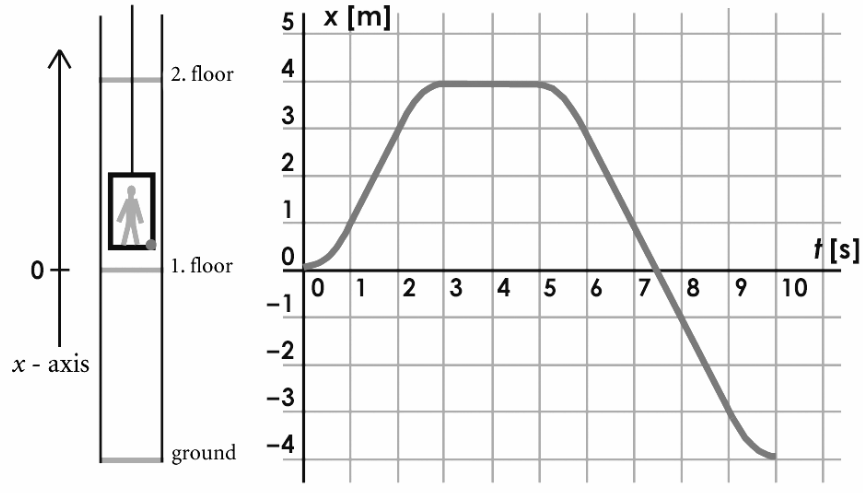


Figure 4: The position-time graph shows how the position of the elevator changes in time. (We observe the position of the point on the floor.) It moved to the second floor, than stopped for two seconds and then moved down to the ground floor and stopped again.

Then in the textbook you will find an analysis of the position-time graph, which is followed by the velocity-time and acceleration-time graphs (Figure 5).

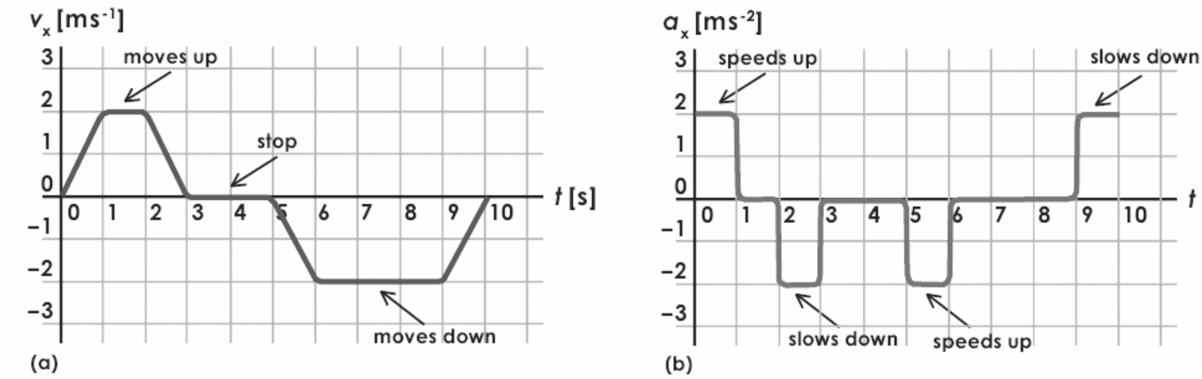


Figure 5: The velocity-time and acceleration-time graphs show the motion of elevator.

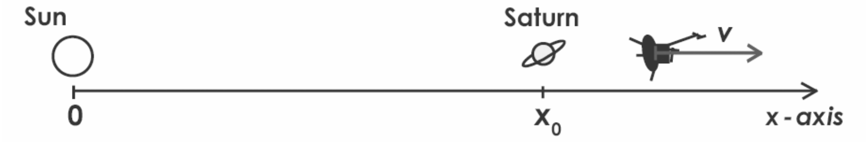
(d) The last illustration I present here is from the paragraph Uniform motion. As I have already stated that there should be a great amount of solved problems in the text and most of them should be related to the real problems. This is, of course, very difficult because most of real problems do not have easy solutions (especially, at the secondary school level). If it is possible to omit the complicating factors and formulate the problem easier, we will get a problem that may be both interesting and solvable for students. In addition, we can train critical thinking of students by asking them, why the solution is not 100% realistic or which facts were ignored. The following problem refers to the Voyager spacecraft.

Problem

In 1981 the spacecraft Voyager II passed the planet Saturn. Its distance from the Sun is 1430 million km. Suppose that Voyager moves in a straight line from the Sun with constant speed 10 kms^{-1}. Calculate the position of Voyager after 5 years, in the year 1986.

Solution

At first we should make a schema and choose the *x*-axis.



We can use the equation for the uniform motion $x(t) = x_0 + v_x t$. Initial position is $x_0 = 1430.10^6$ km and velocity $v_x = 10$ kms^{-1} and we want to calculate the position at time $t = 5$ years = 5.365.24.60.60 s = 16.10^7 s.
We will get
$x(t) = x_0 + v_x t = (1430.10^6 \text{ km}) + (10 \text{ kms}^{-1}).(16.10^7 \text{ s}) = 3030.10^6$ km.
This is the approximate distance of the planet Uranus, which Voyager really approached in 1986.

There is also a short text about the Voyager mission completed with a picture of the spacecraft in the textbook:

Did you know?

The spacecrafts Voyager I and Voyager II launched in 1977 and bring us many pieces of information about planets they have visited – Jupiter, Saturn, Uranus and Neptune. Voyager I is the most distant human-made object in the Universe from 1998. It appears to have reached the edge of the Solar system in 2005 and still continues to the interstellar space until the year 2020 when its power source expires.

Conclusion

I have completed the first four chapters of the textbook: The world of physical quantities, Motion in a straight line, Motion in three dimensions, The laws of motion. The actual version of those chapters can be found on my web-site [6].

Several concepts have already been used in my lessons. Let me summarise the main experiences:

(a) When I based my lessons on my texts, students could not use the standard textbook [2] and therefore they had no text for study. This was very difficult for many students, especially in the first year of their secondary studies.

(b) Many students had also problems with their mathematical skills. Unfortunately, there was a lack of time to deal with this problem in the class with two physics lessons per week.

(c) It seems to me that student's appreciation of physics is much better when I use the alternative approach in comparison with lessons based on classical textbooks. I believe, this is caused mostly by using interesting problems concerning to real situations and everyday live.

In the future, I am going to test the new text from both teachers' and students' point of view.

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