Students' Misconceptions in Mechanics and their Manifestation in a Survey

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Abstract

Regardless that students have been taught physics or not, they have their own visions, which influence their physical thinking. These visions can facilitate the teacher´s work, but they can also make it difficult. There is a well-defined, specific form of reflective thinking when students seem to have the right visions and do not easily accept the scientific knowledge to replace them. This is the case of students´ misconceptions.

Our goal is to characterize misconceptions in mechanics, present some misconceptions, and construct a questionnaire to test them. We also deal with classification of misconceptions and appropriate strategies to fight against them.

What are the misconceptions ?

Student´s misconception is that kind of school belief that contradicts the scientific evidence. Probably it is an inevitable part of the teaching process. It cannot be handled as a simple mistake because it seems to be based on real facts. Therefore it is resistant to any efforts of correction [1].

Misconceptions often contradict the key knowledge of physics; therefore they basically obstruct the process of gaining meaningful knowledge.

We should be aware of the fact that misconceptions are related to actual and qualitative understanding of physical situations. The students´ misconceptions play a remarkable role in teaching physics. We can fight them only if we are aware of their features. Galilei knew about that when writing the Dialogues, and he purposefully aimed at resolving misconceptions.

Some specific misconceptions at any age

Our research of misconceptions has been restricted to problems of mechanics. Therefore, the list of some specific examples is limited only to this area. Some of the following examples are frequently presented in tests and during the teaching process:

- Vehicles overtaking each-other are at the same speed when next to each other.
- When the acceleration of two vehicles is equal, their velocities are equal, too.
- The heavier the objects the higher its speed, when it falls to the ground.
- The velocity is directly proportional to the active power of the body. If the body is not forced, the speed is zero.
- Passive objects, for example a table, cannot be the source of a force.
- Forces in the action-reaction law act on the same body. The equality of forces in the action-reaction law is condition of the balance of the body.

In addition to those listed, there are sometimes quite surprising misconceptions in men´s thinking, such as the external driving force can be exerted only by living creatures.

The ways of mapping misconceptions

The primary source of knowledge of misconceptions is the teacher´s experience. Experienced teachers may have complex knowledge of it, while some of the new teachers do not even assume that students can have misconceptions [1]. Teachers should consciously map misconceptions in advance, especially before teaching some of the topics individually. This can be done through questionnaires, tests, interviews, or a combination of all. The audio recordings of the interviews may be analyzed in detail. The advantage of the tests is their easy statistical interpretability, their disadvantage is that they can hide, in fact, the degree of how well students understand the lecture.

By preliminary testing the misconceptions we arranged a list of 15 questions from the tests of Hesteness´ previous studies [2]. Results by preliminary test have been made so far in cooperation with 15 students from grade 9 and 16 students from grade 11 (15 and 17 years old) [3]. The entire test was planned to be used in other groups, too. In the complete test (29 questions) we tested 62 students from grade 9, 30 stu-

dents from grade 11 and 22 BsC students (after secondary school graduation) by use of the internet. To illustrate the test, we are going to present some questions from it. These are multiple choice questions with only one correct answer. Students were also told about this.

Some questions from the test of Hestenes

- In this figure, which trajectory shows the cannon ball´s path (see Fig. 1.) most accurately?

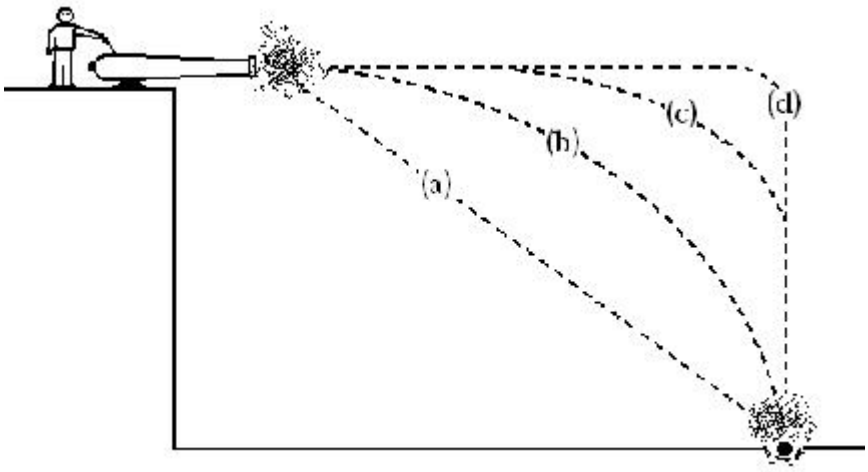

Figure 1. The cannon ball´s path

- A box is being pulled at a 4 m/s constant speed on the floor. What conclusion can be drawn from the forces on the box?
  - (a) If the force is doubled, the speed of the box grows to 8 m/s.
  - (b) In order to pull the box at a constant speed, a bigger force has to be exerted than it weighs itself.
  - (c) The driving force and the friction force operating on the box have to be equal.
  - (d) To ensure that the box moves at a constant speed, a greater force must be exerted on it than the friction force itself.
  - (e) A single force acting on the box is the driving force, external forces such as friction are not "real" forces, they are able only to obstruct the movement.

- The students are sitting in the same type of swirl-chair (see Fig. 2.). Which statement is true?

Figure 2. Students in the swirl-chair

(a) None of the students exerts force on the other.
(b) Student A exerts force on student B, but B does not affect A.
(c) Both of them exert force on each other, but B exerts a greater force.
(d) Both students exert force on each other, but A exerts a greater force.
(e) Both students exert exactly the same force on each other.

Main results of the complete Hestenes test from our 9 grade students:

- 50% of students agree that a truck exerts a grater force on the car by collision.
- 85% of students agree that a decreasing upward force exerts force on the vertically thrown ball.
- 79% of students agree that by neglecting friction the attraction force of the rope is greater than the gravitational, when the velocity of the elevator is constant.
- 87% of the students agree that the force of the kick is exerted on the golf ball during the entire flight time (8% correct).
- 55% of the students think that the ball falls from the airplane to the ground according to Fig. 3. (24% correct).

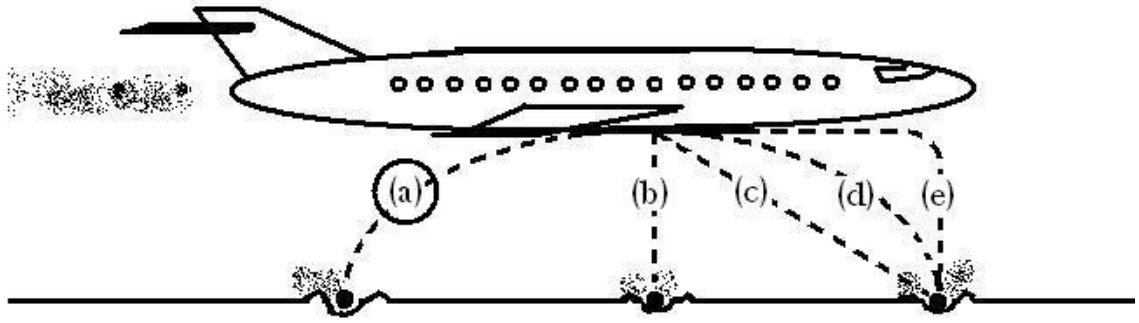

Figure 3. The fall of the ball from the airplane

Main results of the complete test from our 11 grade students

- 80% of students agree that a decreasing upward force exerts on the vertically thrown ball (13% correct).
- 43% of students agree that the puck, which is pulled at point B at right angles, is moving to point C as in Fig. 4. (40% correct).

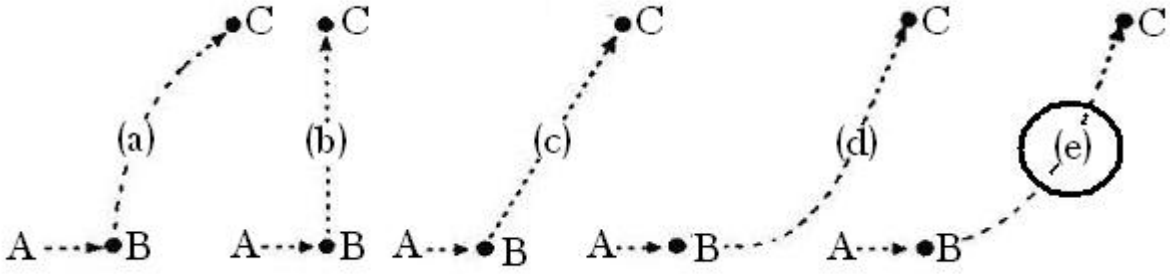

Figure 4. The movement of the pulled puck

- 66% of the students don´t see in a collision of truck and car the law of action-reaction.
- 57% of students agree that by neglecting friction the pulling force of the rope is greater than the gravitational force, when the velocity of elevator is constant.
- 73% of students agree that the force of the kick is exerted on the golf ball during the entire flight time (20% correct).
- students think that the ball falls from the airplane to the ground as follows: 11 times (a), 5 times (b), 3 times (c) and 10 times (d) - see Fig. 3.

The main results from the complete test from BsC students

- 77% of students agree that the force of the kick is exerted on the golf ball during the entire flight time (18% correct).
- 86% of students agree that the same applies to a puck.
- 82% of students agree that (neglecting air resistance) a decreasing upward force exerts force on the vertically thrown ball.
- 45% of students agree that in case of students in the swirl-chair the active person exerts a greater force on the other one.

The classification of misconceptions

The misconceptions can be classified according to different criteria. They could belong to the sphere of kinematics and dynamics. They can be also grouped according to their origin, according to the action that made them develop, or according to their source of information. The source of such information can be television, friends, adults, readings, or their own observations and experiences. Literature can also offer misconceptions related to the laboratory, or the classroom [4].

There is an opportunity of useful grouping if we try to find the wrong principle hidden in the background. Such an idea as, e.g. a body is at a standstill in its natural state and a certain force is needed to maintain its motion is the sign of Aristotle's thinking. It does not contain the law of inertia. This is related to the idea that the abandoned bodies move due to the inner driving force (impetus), and the movement goes on until the internal power is exhausted.

The listed cases could be further classified according to whether the formation of the misconceptions had external reasons or these were internal reasons related to students´ thinking or activities [1].

The origins of the formation of misconceptions

The students' misconceptions can have a variety of sources and trace back to both external and internal causes. [1] Besides the external factors, the students´ own activity and experience play the most important role. In many cases, students may notice that motion ceases if force causing the movement is lost. Taking into account this experience makes the refutation of misconceptions much more difficult.

The majority of teachers assume that these misconceptions can be explained especially by external reasons rather than by cognitive deficits of the students. Indeed, not only less gifted students may have misconceptions. Do not forget that there are difficult internal basic concepts of physics, too, such as mass or electric charge. We must take into consideration that a physical concept such as the conservation of energy and the momentum conservation laws, is often complex and preliminary knowledge is needed [5]. The teacher usually takes into account the existence of previous knowledge, but it sometimes happens that there is a lack of this knowledge [6]. In this case, we can use any method of teaching, students will not understand the subject of instruction.

Misconceptions occur in the thinking of people of all ages although their number decreases with higher grade students. In the higher grades, students are able to learn more and more complex models. This is certainly due to their mental development. However, the survey made among engineering students has shown that students achieved a result of only 20 percent in the misconception occurrence test. Furthermore, they could not reach more than 50 percent even after they had already attended a special course about misconceptions [7].

Correction methods

The study of misconceptions in classical mechanics is largely related to everyday experience. Misconceptions, which were developed through many years and are seemingly logically supported, have to be often transformed. Existing knowledge is more difficult to be changed than to teach new ones. But it can be successfully done if we compare the bias with experimental facts. Experimenting is a key issue for the development and credibility of physics as a science. Students have to be taken to the laboratory, where they can have qualitative experience. We have to help them to explain their prejudices and their preconceptions may be confronted with the laboratory experience. The best thing is, if this process takes place before the teaching process is starting [7], [8]. It is always useful to clarify all the qualitative questions before the first numerical analysis [5].

We have to raise awareness that the basic concepts and principles of physics are often difficult or complex. It is important to pay great attention to their explanation and understanding. It requires such teaching methods that promote the correct understanding. Students' thinking and their own pace should be taken into account. The fine details will be lost in a frontal lecture; it allows a perception of only a little individual feedback. The tailor-made teaching is more effective, but rarely implemented in school settings. Individual speed of learning can be provided relatively well by computer programs [6].

Suitable software can support students to gain experience. They can imitate, for example, that the students are driving while they can draw speed and distance graphs of the way. But there is also software that can compare students´ answers to a database of misconceptions, and on the basis of it, it organizes the further work of students [9].

Parallel advances in science

In students' learning process similar stages can be observed to those of the development of science [10]. Parallels can be observed in the durability of students´ misconceptions and the durability of misconceptions in the physics as a science. In case of little knowledge, such ideas can be formed in both fields, which are under certain circumstances seemingly valid, but do not reflect the true face of phenomena. We can find such examples in the history of physics, that is why the history of physics is worth studing. For example, Galileo and Newton played an important role so that Aristotle's approach of thinking has been superseded by the physical one. But there are many still-debated questions in modern physics as well.

Misconceptions arising during the study of quantum mechanics, of course, are very far from everyday experience, their existence could rather be explained by incomplete knowledge of the experimental results or by the wrong interpretation. For instance, the problem of measurements referring to the polarized states of splitting photon pairs, when the results of the experiments are explained by momentary signal transmission or covert parameters. It is also possible that the used analogy is only apparent, but in fact, it is not permitted. Such misconceptions are even more difficult to be explained [11]. The well-designed and executed experiments play a decisive role in their refutation.

Incentives for attention

Only a few teachers deal with the reason of the raising of misconceptions and the ways of handling them, only a few of them devote enough attention to these during the planning phase of the teaching process. Teachers suppose they can easily cope with misconceptions. Unfortunately, it is frequent that only the subsequent surveys show that the teachers´ efforts are useless, and it can develop a tension between the teacher's expectations and the students' results. University students of physics may have misconceptions, too, and thus they are mostly unaware of them. The fact that the misconceptions occur even among practising teachers, are also shown in multi-country surveys [7]. In these cases, the teacher can contribute to the creation of misconceptions in children's minds. An on-line forum can help in an effective exchange of experiences where teachers are anonymous and can discuss their problems more openly [12].

There is a very extensive literature on misconceptions, but the results are not sufficiently implemented into the teaching process [1], [12]. However, it is important to teach the scientific view in a broader context.

It is worth connecting the misconceptions research with the theory of cognition and other spheres of education [13]. Misconceptions occur not only in physics, but in other disciplines as well [14].

Summary

By testing the mechanical misconceptions we can observe that the students start up from seemingly true but actually wrong ideas in many cases instead of having the laws of dynamics as a starting point. We can state that students are often not aware if some force attracts or not and do not respect the law of inertia and the law of action-reaction. From the nature of misconceptions and the students' typical answers results in the most important method of correcting misconceptions, in making experiments. This is an important method of effective, deep and convincing teaching of the basic concepts of physics.

Acknowledgements

I am very grateful and I owe thanks to Prof. Péter Tasnádi, for helping me with the working up of the chosen topic.

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