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**Students' Misconceptions Concerning Waves
and Harmonic Motion**

INTRODUCTION

Pupils come to school with their own image of the world of physics. In particular, we are currently seeing a lot of "everyday notions" about physics in the area of mechanics. Misconceptions of pupils concerning mechanical notion were discovered by didacticians of physics and of psychology. Misconceptions concerning electrical, thermal and other notions were discovered, too.

The author have long been searching for similar investigations concerning harmonic notion. The only investigations of that type that she has come across are those of F. Siemsen [1]. They are the deep analyses of the investigations concerning waves and harmonic motion of a French psychologist [2], [3] carried out about 40 years ago. The latter was a psychologist from Piagets' group.

The author decided to investigate that area of physics, which is a 'blank' in the didactics of misconceptions* and "everyday notion" (preconception**). She investigated both pupils who had not yet started learning physics at school, and students who had already studied wave phenomena, and who ought to understand physical phenomena and physical notions. But there are still those notions, those phenomena, that were not understood by students. That is, understood in the scientific sense. Students still have the old 'everyday' ideas about those notions. This can be discovered through tests carried out on students six weeks after they

* Misconception exists as the result of teaching. There are misunderstood notions and phenomena. They can also be the results of the influence on preconceptions of physics teaching.

** Preconception -- ideas about the physical world, which pupils formulate from everyday experiences. They are developed from an egocentric point of view. They are good enough for pupils to explain particular phenomena in an intuitive way. They are often incoherent and inconsistent. They are biographically determined. They involve from either rational or irrational sources. They are -- (...) extremely resistant. Preconception about mechanics can be compared with the physics of Aristotle physics [4].

have studied the after-mentioned notions (giving them time to forget what they have learnt in class).

The investigation was carried out in three different age groups of students, pupils studying in two different education systems. These systems of education are different in terms of their aims and teaching methods. However, despite these differences, the understanding of various groups of students concerning the after-mentioned notions did not differ greatly. To illustrate the methodology of my investigation and its aims, the author would like to offer two examples concerning harmonic motion.

EXPERIMENTAL PART

The first part of the author's investigation was constructed as an "interview". The second part — a written test was formulated, based on interviews and a pilot test. Some of the items were multiple choice questions, required the participant to offer a drawing or explanation. Participants were chosen from 2 different age groups and from 2 different countries. From Germany, class X, 15-year-olds and from Poland (class VIII, 14-year-olds) were set a test 6 weeks after teaching the pupils about wave phenomena and harmonic motion. They could choose one or more than one answer.

The following is the first question: Draw a picture of different positions of the springs as they are moving and mark the midpoint* of those springs.

The author has grouped the responses to the question into four categories:

- A: There are three different positions, in the middle is a midpoint.
- B: There are three or more positions (Fig. 1A). The top position, or one of the top positions, is the midpoint.
- C: There are three or more positions (Fig. 1B). The lowest position, or one of the lowest positions, is the midpoint.
- D: Any answer.

The results revealed that the majority of students (88%) correctly solved the problem set. However, most of those correct responses came from the group of students who received 'special' teaching about waves and harmonic motion — the research group. The author formulated the aims and methods of this 'special' teaching using the results of the interviews. The general idea of this 'special' teaching was to project the close relation between waves and harmonic motion and to take into consideration the students' preconceptions (concerning, for example the midpoint notion). In both Polish and German text books there is the assumption that students can intuitively distinguish the correct scientific notions from common 'everyday' ideas concerning waves and harmonic motion. This is an incorrect assumption as 42% of students who had studied using German and Polish text books could not give the correct answer. The differences between the results of tests on Polish students and those carried out on German students are negligible.

* The investigations were carried out in Germany and in Poland. In both countries the notion "midpoint" implies "balance position".

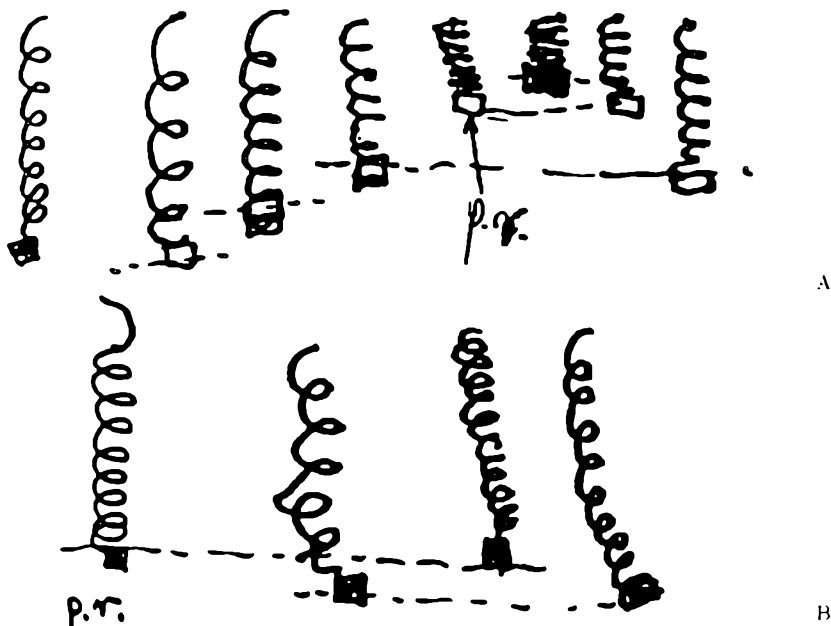


Fig. 1. The midpoint of the springs: A. There are three or more positions. The top position, or one of the top positions, is the midpoint. B. The lowest position, is the midpoint.

It is worthy of attention that some students gave answers B. For these students the midpoint was probably the point to which they had to stretch the spring. The initial position of the spring, before it started moving, was also the midpoint for them. It is also possible to associate it with the equilibrium of the ball in the groove, or between two railway tracks. In that case the potential energy for the stationary ball is the smallest. Especially when analyzing German text books, we notice that students may well have such an association.

Table 1. The results of tests on Polish and German students concerning the first question

QUESTION	German		Polish		German & Polish	
	research	control	research	control	research	control
A	83% (78)	62% (40)	93% (96)	55% (63)	88% (174)	58% (103)
B	4% (4)	10% (6)	3% (3)	21% (24)	4% (7)	17% (30)
C	4% (4)	9% (6)	2% (2)	7% (8)	4% (8)	8% (14)
D	7% (7)	19% (12)	2% (2)	17% (19)	5% (9)	17% (31)

The task concerning the midpoint was formulated using the results of an interview with younger pupils. They gave, amongst others, the following explanation:

"It is the same with the springs as with me, when I want to jump. I jump up from the ground: the ground is my midpoint position".

We asked a similar question concerning pendulums. But almost all pupils interviewed had no difficulties in giving a correct answer. This gives a methodical pointer, indicating the way we ought to introduce the concept of the midpoint of the pendulums (as it is easily understood with the aid of intuition), and only then introduce the concept of the spring (being more difficult to grasp for students). It is this method which the author have used in teaching about waves and harmonic motion.

The next task concerns the greatest velocity of the vibrating pendulum. Draw a picture of a vibrating pendulum. Mark on it different position of the moving pendulum and mark the position at which the pendulum was moving at the greatest velocity.

The author received the following answers:

1. The thread of the pendulum lengthens (Fig. 2). The pendulum moved at greatest velocity at the midpoint.
2. The greatest velocity is at the midpoint.
3. The pendulum reached its greatest velocity when in the position further away from the midpoint. The thread lengthens.
4. The pendulum reached its greatest velocity whilst moving from the midpoint to the position furthest away from the midpoint. The thread of the pendulum lengthens.
5. The pendulum reaches its greatest velocity when moving from one position which is furthest away from the midpoint to another position which is the same distance away from the midpoint.
6. The pendulum reaches its greatest velocity when it is between the midpoint and the position furthest away from the midpoint.
7. No answer or one which is incomprehensibly directly related to.

The above questions are not the German and Polish text books or to my own conceptions concerning teaching about waves phenomena and the harmonic motion. More than 40% of all respondents correctly answered the questions, although there were many students who expressed the opinion that: "the body reaches its greatest velocity between the maximum distance from midpoint and the midpoint".

When teaching at school, the author starts with the assumption that it is necessary to limit the quantity of new concepts presented to pupils and do not introduce the topic of the transformation of energy. It partly explains why as many as 59% (the author grouped together answers A and B) of students from the research group give the correct answer. But for the majority of those students (36% from the research group, 46% from the control group) the length of pendulum lengthened. In both German and Polish text books there is no explanation (or only a very superficial one) of the problem of the transformation energy.

Apart from incorrect marking of the point of greatest velocity, many students also made another mistake. For them the thread of the pendulum lengthened the

Table 2. The results of tests on Polish and German students concerning the second question

Q U E S T I O N	German		Polish		German & Polish	
	research	control	research	control	research	control
A	18% (17)	5% (3)	17% (17)	13% (15)	17% (34)	10% (18)
B	40% (38)	33% (21)	41% (44)	38% (42)	42% (82)	36% (63)
C	3% (3)	2% (1)	9% (9)	11% (12)	6% (12)	7% (13)
D	6% (6)	3% (1)	7% (7)	9% (10)	7% (13)	6% (11)
E	19% (18)	27% (17)	25% (26)	23% (26)	22% (44)	24% (43)
F	3% (3)	16% (10)	0% (0)	5% (6)	6% (3)	10% (16)
G	6% (6)	17% (11)	2% (2)	3% (3)	4% (80)	8% (14)

further it travelled from the midpoint. That answer was not arrived at by chance. In earlier investigations, (using the interview method), pupils were given pictures and they just had to choose the correct one. Many of them gave the answer shown in Fig. 2.

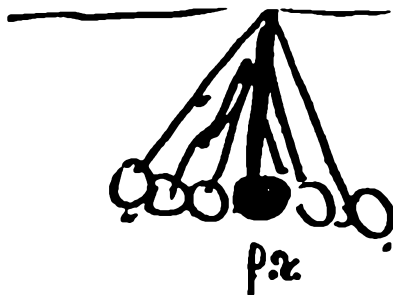


Fig. 2. The thread of the pendulum lengthens. The pendulum moved at greatest velocity at the midpoint

We are driven to ask the question "Why did they give that answer?". According to J. Piaget [5] the pupils, being partly at the level of concrete operation and of formal operation (i.e. pupils aged 14-15 and 16-17) think in a very concrete way. They concentrate very hard on one single process — in this case, the moving of the pendulum and on trying to find out when it reaches its greatest velocity. They are not able to simultaneously notice other aspects in that case. They notice only the final effect of the movement of the pendulum and do not think about the medial positions between O and B and C. Only the extreme is important for the pupils. It may be that in class X (i.e. in German pupils aged 15) there are pupils who are still on the level of concrete operations. This suggestion can be confirmed in comparing the results of the German and the Polish groups. More Polish students, than German students, noticed (incorrectly) that the pendulum lengthened. The Polish students were one year younger and so more of them were on the level of concrete operation than those in the German group.

One can also find another explanation for this misconception. For some students the ball of the pendulum moves like the shadow of the ball in the shadow

projection. Shadow projections were introduced in physics lessons. But the author also interviewed the pupils who had not learnt physics. They gave the same answer. School is not the only source of students' misunderstanding in that case. Students bring those preconceptions with them from their everyday lives in the outside world.

CONCLUSIONS

There were more questions of that type. Basing on the analysis of the results of the various questions, one can construct a model of the way pupils and students think about wave phenomena and harmonic motion. We can try to understand how the connections between single notions arise. We can try to imagine how the pupils thought processes work; what changes occur when the students assimilate the next bit of information; what effect this new information has on the formation of misconceptions; which misconceptions are resistant against new information imparted by the teacher.

The author starts with the assumption that pupils beginning to study waves and vibrations already have their own pictures in their minds concerning these phenomena. But the author does not know the precise meaning of those pictures.

The investigations have helped her to construct a model of pupils and students' thinking. This model consists of some of the views pupils have offered the author during her investigations and the model answers some of the questions. Here are some elements of this model.

Some pupils starting to learn physics for the first time, bring with them the following ideas about wave phenomena and harmonic motion: a wave is a series of disturbances of a substance, they spread together with the substance; vibrations are seen as a movement with a constant velocity. There are also some pupils for whom the velocity of a vibration body is not constant. According to them the velocity changes periodically, being greatest at the maximum distance from the midpoint, or between the maximum distance and the midpoint. Some pupils consider that there is a "current" between the vibrations of larynxes. There is no connection between waves and vibrations. The pendulum lengthens the further away it is from the midpoint. According to some pupils, the midpoint of the vertical spring is in the highest or in the lowest positions. Students do not have an intuitive understanding of the resonance notion.

Two separate waves when each is heading in the direction of the other, do not interfere. They reflect. When we provide the vibration spring with a new portion of energy, this will only result in a change in frequency (not amplitude).

Taking into consideration mis- and preconceptions, allows for more successful teaching.

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Some Tensile and Bending Characteristics of Wheat Stalks

INTRODUCTION

During almost all technological processes agricultural products are exposed to different mechanical loads which are accompanied by deformation. This must be either sufficiently great (for cutting, pressing etc.) or sufficiently slight in order to avoid damage (harvesting of vegetables and fruits). Consequently, the mechanical strength of products here plays an important role. A large variety of agricultural products, their complex biological structure, constant changes in mechanical and physical properties render it difficult or impossible to find general rules determining the behavior of these materials effected by loading [1]. For instance, mechanical properties of the same potato or wheat variety depend on the vegetation stage, weather and soil conditions, on their storage duration, temperature and moisture during measurement. Thus, designers of agricultural machines may have used, so far, results of experimental studies which have been often performed at random.

The paper presents the results of studies on the mechanical properties of wheat stalks during tension and bending including the effect of fertilization and stage of plant vegetation. This paper is part of a large-scale research project focusing on mechanical properties of cereal stalks [2,3].

METHODS OF INVESTIGATIONS

Studies were carried out on stalks of Polish Jara wheat (*Triticum aestivum* L. var. *Lutescens cv Jara*). The wheat was cultivated on experimental plots with differentiated nitrogen fertilization: 50, 100 and 150 kg of pure component per ha, respectively. Doses most frequently used are 80-100 kg/ha. Potassium and phosphatic fertilization was constant. Each fifty stalks were collected during milk,