ON THE FIRST YEAR STUDENTS OF THE PHYSICS TEACHER TRAINING PROGRAMME AT EÖTVÖS UNIVERSITY

Cs. Wiener
Eötvös University, Department of Materials Physics, Budapest, Hungary,
kadar@metal.elte.hu

ABSTRACT

Eötvös Loránd University (ELTE) is the most prestigious university in Hungary in the field of teacher training. However, since there is no entrance exam, many physics students lack even an average level knowledge of high school physics. To overcome this problem new courses were introduced to the physics teacher training program, where high school physics is taught. Still, experience has shown that these courses are efficient only for approximately 40% of the students. The reason is that besides the absence of physics knowledge, students also have problems with mathematical knowledge, formal thinking and some basic skills, like reading comprehension, study skills, and note-taking skills.

INTRODUCTION

Most of the papers concerning physics teaching deal with teaching in high school or secondary grammar school. Since the introduction of the new university admission system in Hungary, questions of high school level teaching also appear on the undergraduate level.

One of the reasons is that physics students are admitted to the universities primarily based on the results of their high school final exams of two subjects of their choice from the following list: biology, chemistry, geography, informatics, mathematics, and physics. That is, students can be accepted at universities (including the most prestigious universities) without a significant background in physics. Moreover, the minimum score for admission is rather low for the physics-related courses, especially for the teacher training programme. In order to handle the situation, extra physics courses were introduced for students with incomplete high school physics knowledge. These extra courses were mandatory for approximately 70-80% of the admitted students.

In this paper some typical (high school level) problems are studied that were found hard-to-understand for at least 30 % of the students taking the extra physics courses. The observations are based on the monitoring of individual problem solution and midterm exams of approximately 20-40 students per semester for 6 semesters. Notice that the difficulties of the students arose not just when they first met the problems, but also when the problem types were already discussed in detail in class.

EXAMPLE 1. GRAPH-DRAWING, INTERPRETATION OF GRAPHS

Problem 1. A car is moving along the x-axis according to the graph of velocity versus time (Fig.1., left panel). Determine the position of the car as a function of time. The starting position is $x=0$ *m*.

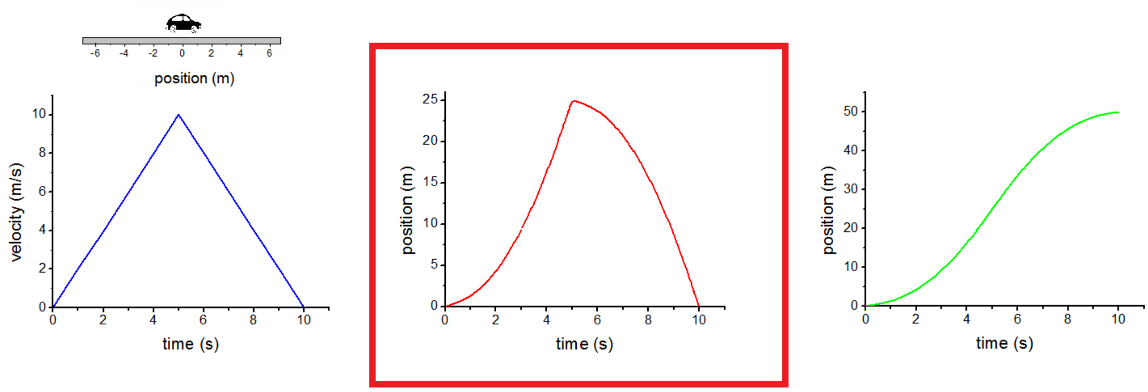

Fig.1. Motion in one dimension. Left panel: the velocity-time function given in Problem 1, middle panel: the typical incorrect answer, right panel: the correct solution

The middle panel of Fig.1. shows the typical incorrect answer. According to the (wrong) solution, after reaching the maximum velocity, the direction of the motion changes. The wrong answer originates from correlating the slope of the velocity-time function to the direction of the motion, i.e. if the slope of the function $v(t)$ is positive, the car goes in the positive direction, and in case of negative slope the direction of the motion is negative. However, it is obvious that the direction of the motion does not change, since the velocity is still positive.

In order to change this concept it is effective to link the negative velocity to an "activity-image", e. g. to back up. The discussion of problems of the following kind is also useful.

Problem 2. Draw the velocity-time function of the following stories. Kati would like to go shopping. The shop is along a long and straight road.

a) First she rides on a bicycle. For 30 *s* she accelerates to 5 *m/s*, then rides at constant velocity for 15 minutes and when she notices the shop, she starts to decelerate for 20 *s*, then she stops.

b) Second she goes by car. It takes 2 minutes to accelerate to 20 *m/s*, then travels with constant velocity. Unfortunately she notices the shop too late, so after deceleration for 20 *s* she has to back up: she accelerates to 5 *m/s* for 1 s, then decelerates to zero to stop at the shop.

EXAMPLE 2. NEWTON'S LAW.

Problem 3. A hockey puck struck by a hockey stick is given an initial speed of 20 *m/s*. The puck slides 120 *m* on the ice, slowing down steadily until it comes to rest. Determine the coefficient of kinetic friction between the puck and the ice.

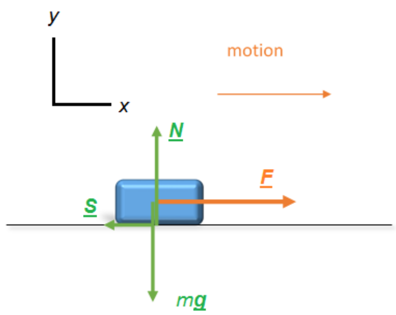

Fig.2. The free-body diagram of the motion of a hockey puck. The introduced force ***F*** indicates that the student uses Aristotle's concept of physics. (The vectors on the figure are a bit shifted for the sake of clarity.)

Since the puck moves to the right, many students think that there must be a force ***F***, which acts on the puck in the direction of the motion, and therefore they write Newton's law in the *x* direction in the following form:

$$F - S = ma, \qquad (1)$$

where *S* is the friction force. This means that these students think the force is related to the velocity of the object, i.e. they use Aristotle's concept of physics.

One possibility to avoid the introduction of non-existing forces is to emphasize that force is the consequence of interaction. Here the puck interacts only with the ice (the origin of forces ***S*** and ***N***) and with the Earth (*m**g***). Therefore force ***F*** is not a consequence of interaction (in an inertial frame), thus it does not exist, so Newton's second law gives

$$-S = ma. \qquad (2)$$

EXAMPLE 3. VECTORS, ABSTRACTION

Problem 4. A man pulls a 2 *kg* box on a frictionless incline with a horizontal force ***F*** ($F=20\ N$) upward. The acceleration of the box is 3.66 m/s^2. Determine the angle of the ramp with the horizontal.

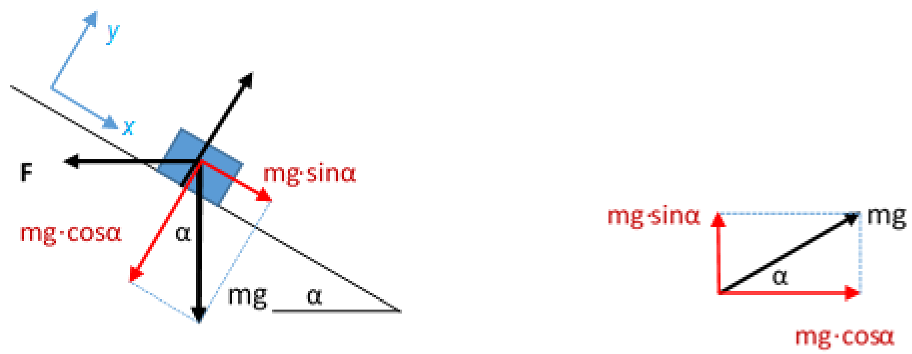

Fig.3. Left panel: The free-body diagram of a box pulled with horizontal force. Right panel: computing the components of the gravitational force in the "usual" coordinate system

The strategy to solve this problem is to compute the x- and y-components of the forces using trigonometry. (The x-axis is parallel and the y-axis is perpendicular to the slope.) By taking the sum of the x-components one can obtain the x-component of the resultant force, which is *ma*, according to Newton's second law. (Here *m* and *a* are the mass and the acceleration of the box, respectively.)

Approximately 35% of the students cannot determine the components of the forces in the tilted coordinates in Problem 4, though they can determine the components in the "usual" coordinate system (with horizontal and vertical axes) (Fig.3., right panel). Many students just memorize the x- and y-components of *mg* exerted on the object on a slope inclined at an angle α. These students typically lack the mathematical skills needed to solve an equation or an equation system, where the coefficients are not given constants, therefore missing the chance to understand how the result depends on the coefficients.

EXAMPLE 4. FRICTION FORCE

Problem 5. A block of mass *m=3 kg* is pulled by a string with a force *F=10 N* at angle *α* above the horizontal. Determine the coefficient of kinetic friction (μ), if the block/sled moves with constant velocity.

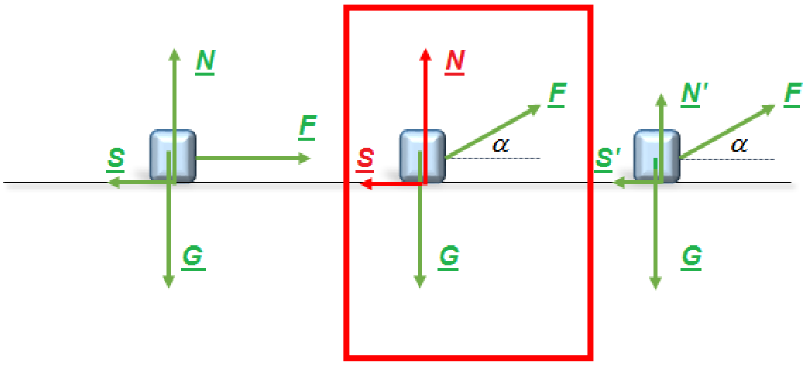

Fig.4. Changes in friction force and normal force as the angle of the pulling force is changing from zero (left panel) to *α* (right panel) and the typical incorrect answer (middle panel)

In the case of $\alpha = 0°$ almost everyone finds the correct solution. The two components (horizontal and vertical) of Newton's second law for the block/sled are:

$$F - \mu \cdot mg = m \cdot a = 0 \tag{3}$$

and

$$N - mg = 0. \tag{4}$$

However, many students use the same equations also in case of $\alpha > 0°$: $F \cdot \cos\alpha - \mu \cdot mg = m \cdot a = 0$ and $N - mg = 0$. These students think that changing the angle of the string does not have an effect on the friction force (and the normal force). As it is well known, the vertical component of the pulling force reduces the normal force to

$$N = mg - F \cdot \sin\alpha, \tag{5}$$

and therefore the friction force is

$$S = \mu \cdot (mg - F \cdot \sin\alpha). \tag{6}$$

Thus Eq. (3) must be changed to

$$F \cdot \cos\alpha - \mu \cdot (mg - F \cdot \sin\alpha) = m \cdot a = 0. \tag{7}$$

EXAMPLE 5.

Problem 6. A uniform horizontal beam of length 2 *m* and weight 300 *N* is attached to a wall by a pin connection that allows the beam to rotate. Its far end is supported by a cable that makes an angle of 30º with the horizontal. Find the magnitude of the tension in the cable. Indicate the forces acting on the beam.

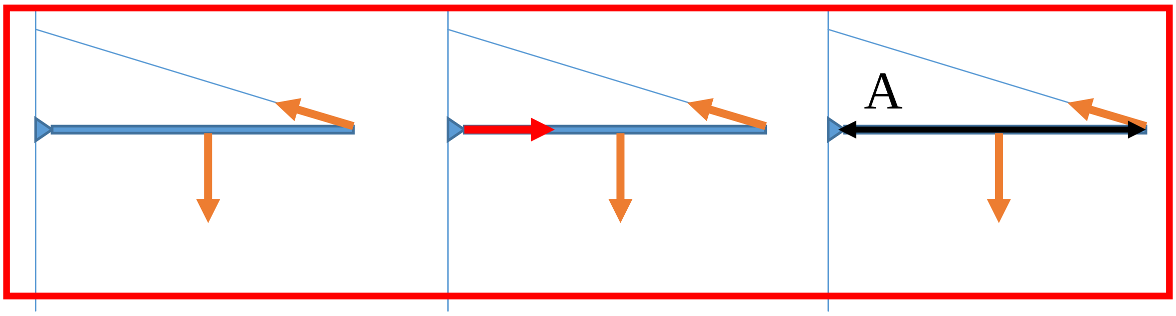

Fig.5. Problems emerging during the solution of Problem 5. Left panel: missing force, middle panel: misdirected force, right panel: wrong determination of the lever arm

More than 50 % of the students commit (at least) one of the following mistakes:

1) They forget about the force on the beam exerted by the wall, therefore on the free-body diagram only the gravitational force and the tension in the cable are identified. (Fig. 5, left panel).

2) They notice the force exerted by the wall, but they think its direction is the same as the direction of the beam (horizontal, in this case) (Fig. 5, middle panel).

3) During the calculation of the torque, the lever arm is taken as the distance between A and the point of application of the force, where A corresponds to the axis of rotation, perpendicular to the plane.

The first five examples suggest that the introduction of extra courses for approximately 70-80% of the students is unavoidable, since without these courses students cannot make up for their shortage in high school physics and mathematics. However, there are other types of problems as well. The average result of a test concerning definitions and formulae is about 60% if the test was announced before and 10% if it was not. It appears likely that this is caused by (besides the ever-present laziness and disinterest) the lack of studying skills. It is worth noticing that these results were obtained by students who chose to study physics. Solutions of midterm tests suggest that several students misinterpret or do not understand the problems, which may be caused by the low level of reading comprehension.

EXAMPLE 6. ABSTRACTION

Problem 7. An object weighing 100 *N* hangs tied to two cables that are fastened to the ceiling, as in Fig. 6, left panel. The cables make angles of 37º and 53º with the horizontal. Find the tension in the cables.

Problem 8. Four charges ($Q_1=Q_2=Q_3=-1\ C$, $Q=1C$) are placed according to Fig. 6, right panel. The distances from charge Q is 1 *m*, 2 *m* and 1.5 *m*, respectively. Is charge Q in equilibrium?

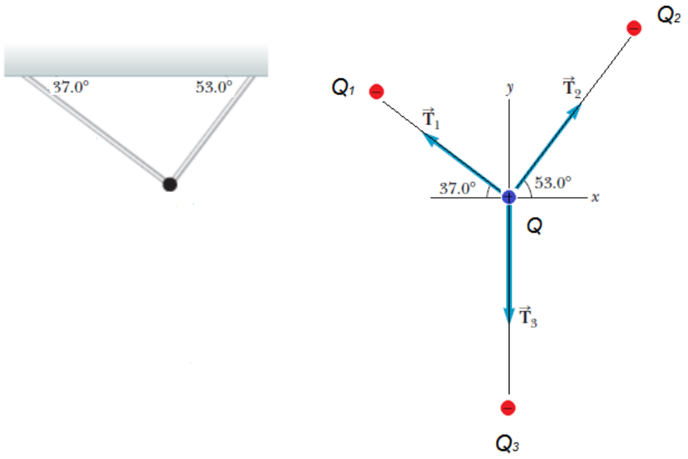

Fig.6. Left panel: object suspended by cables (Problem 7). Right panel: arrangement of charges (Problem 8)

The solution of equilibrium problems in mechanics is usually easy for the students if they do not have to use the concept of torque. But this is not the case if the topic is no longer mechanics. While 80% of the students solve Problem 7, only 20% of the students can solve Problem 8, though the two problems have the same free-body diagram. Most students can calculate the forces between the charges, but they think that the Coulomb's force is a force only in its name, so they do not use the strategies they used to solve Problem 7. Even after a detailed discussion of the problem still 40 % of the students are incapable of solving a problem of this kind.

Problems 3 and 6 suggest that capability of solving problems does not depend on just the physics and mathematics knowledge, but also on the cognitive structures of the students. It seems likely that a high percentage of the students are not operating in the domain of formal thinking, as was found in [1]. For students whose cognitive structures have not reached the formal thinking stage the extra courses are not sufficient, individual methods are needed.

CONCLUSIONS

Physics students are accepted at Hungarian universities without a significant background in physics. To handle this situation, high school level physics courses were introduced that are mandatory for approximately 70-80% of the students. We have shown several examples for problems arising in these courses that are caused by various reasons besides the lack of physics knowledge, such as problems in mathematics, reading comprehension, study skills. It also seems likely that the cognitive structures of many students have not reached the appropriate level.

ACKNOWLEDGMENTS

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REFERENCES

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