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Understanding Misconceptions in Physics (translation from Indonesian)

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Introduction

Physics, as a natural science in engineering, is not supposed to be difficult to learn and understand, because its content is easily found in daily life and follows a common logic. However, as our facts suggest, physics has become a subject that is considered difficult, so that the students and their teachers often "agree" to seek out a compromise to be optimized in the formal education process, that is, how to make an approach that merely allows most students to pass the exams.

There have been many educators, particularly those who work with physical sciences and mathematics, finding that we have a challenge known as misconception in our way to understand physical phenomena.[1] The misconception occurs not only among the students,[2] but also among the graduates, including those from physics majors. In the effort of improving teaching methods, this challenge is very important to explore and study further.

Types of misconception

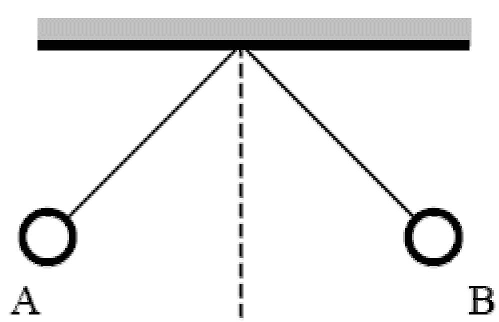
Misconception is a phenomenon where someone fails to bring the theory he or she learnt into practice due to his or her incomplete and misleading conception. In general, we can put the misconception into two categories:

1. Misconception of conditions: failures in application due to insufficient recognition of the assumptions and conditions underlying a concept.
2. Misconception of intuitions: failures in application due to a breakdown between experiential intuition and theoretical concepts.

These two categories of misconception can appear together and influence each other. Being handicapped with one has a tendency to suffer from the other.

Misconception of conditions

Theoretical concepts cannot be grasped by just reviewing their final mathematical equations. Appreciating the variables, which represent physical entities in an equation that provides the physical relation and behavior of those variables, is not enough. The important ideas, yet commonly forgotten, are the conditioning assumptions that run at the background, based on which the equation is derived in the first place. These assumptions dictate us what environment has to be met before we may apply the equation. The following is an example where this category of misconception occurs.



Example 1

Two elastic balls A and B, as shown in the figure above, are attached to strings of equal length hanging from the roof. The mass of B is twice as big as that of A. Then they are freely released from an equal initial height. Frictions are negligible.

In an examination given to the freshmen in engineering departments,[3] where the author was teaching one of the six parallel classes, the test results indicated surprisingly high rate of misconception. There were 10% of the students applied a "weird" concept that was meant to be the law of conservation of energy (LCE). They wrote:

$$U_A + K_A = U_B + K_B$$

where U and K are the gravitational potential energy and the kinetic energy of the mass, respectively. Looking at the subscripts, we immediately know that the students failed to recognize that in LCE we have to apply the law on the *same mass* in *different positions*. Though the equation above looks like LCE, it means nothing at all.

Similar thing also happened in the application of the conservation of momentum (LCM). When the students discussed about the collision between A and B, they wrote:

$$m_A v_A + m_B v_B = m_A v_A' + m_B v_B'$$

where v is the speed gained by the mass, and primed values denote the final state. In general, they correctly indicated that the unprimed state on the left-hand side is the state before the collision and the primed state on the right-hand side is that after the collision. Unfortunately, there were many students who gave $v_A = v_B = 0$, i.e., the speed of the masses when they were freely released from the height, far before the collision occurs! They failed to recognize that the two speeds involved in LCM are the speeds of the mass *just before* and *just after* the collision.

Another example for this type of misconception is the application of Newton's third law. Many people recognize this law through a short formula, yet incomplete: action = - reaction. When asked: "Are the normal force and the weight (gravitational force) working on a mass on a smooth plane action-reaction pair meant by the third law?" they usually undoubtedly say "yes". Actually we know that those two forces are not the interaction pair. The misconception fails to recognize that the interaction force pair must work on two *different* bodies.

Misconception of intuitions

This type of misconception may or may not be accidental. The students' interpretation in Example 1 above that A and B collide with $v_A = v_B = 0$ is an accidental misconception of intuition, because it originates from the misconception of condition described above. The students failed to use their intuition to recognize that with $v_A = v_B = 0$ they were dealing with a situation that does not make sense, that is, it is impossible for a collision to occur if the colliding parties are both at rest.

The word of "making sense" is the key to probe the misconception of intuitions. The ability to integrate personal experience, observation, and learning are very important in this case. Efforts such as demonstrations and lab practicum are supposed to minimize this type of misconception.

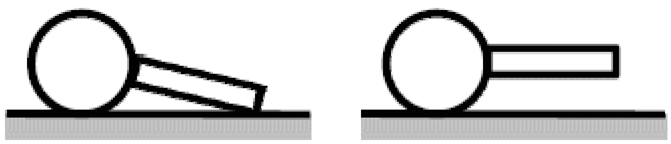
In the examination given in Example 1 through a question “where will the balls collide?” only 28% of the students answered correctly (at the lowest point of the trajectory). There were 37% of the students who gave the collision point on the trajectory closer to A, because they believed that larger mass must fall faster, while 7% gave the opposite answer. The rest did not answer the question with various reasons.

This kind of misconception is not accidental. The intuition that heavier bodies fall down faster is quite dominant.

Another example for this type of misconception comes from another test[4] given by the author. This time, the level of the misconception is very serious.

<u>*Example 2*</u>

A body consisting of a sphere and a stick attached to it is to be put on a table. Draw all of the forces acting on the body due to its interaction with the table.



correct position wrong position

Before sketching the forces the students needed to make a figure showing the position of this body. Surprisingly, a significant number of the students (22.5%) made a wrong figure (the one on the right in the figure above). This “strange” position of the body did not bother those engineering students, incredible!

For those students, the relation between conception and reality broke down. When it is the case, there was no point to discuss further about the force diagram. There was a more urgent problem to fix: their misconception.

If one wants a more “ridiculous” example, there was a question in a survey test of “how could you measure the volume of your body?” in the beginning of the semester. Based on the knowledge carried from the high schools about Archimede’s principle, the students were supposed to use the knowledge to answer the questions. It turned out that there were quite a number of students giving answers similar to this: “Multiply your body height by its length and width”.

Solutions

The misconceptions described above can be overcome using different approaches, depending on the properties of the misconception type. The first type, which is caused by the lack of recognition on the underlying conditions, is easier to fix. Physical concepts must be given along with their complete and correct conditions or assumptions. The students’ tendency to memorize the mathematical formulas has to be prevented using a more comprehensive qualitative approach. The physical phenomenon is described by the formula, but is not the formula itself. The formula is useless without correct physical interpretations and the conditions on which the derivation is based.

The second type that has to do with physical intuition needs greater efforts to overcome. We need reliable and integrated lab practicum designs, representative demonstrations, opportunities for direct observations, not only in the college level, but also go down to the very early stage of education. The integration of personal experience with theoretical concepts must start as early as possible. Teachers' and parents' creativity play an important role in this very case. Once the students have these physical intuitions, it would be easier for them to learn physics. On the other hand, one with failures to have physical intuition after high school graduation would mean a tremendous hard work for him or her to learn physics. In short, do have correct physical intuitions, and then make the correct conditioning; this will open your ways widely in understanding Mother Nature.

References

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