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# Identifying senior high school students' misconception on the momentum and impulse concepts uses three-tier diagnostic test

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**Abstract**

The level of understanding of students' learning in studying physics material deserves attention so that things do not happen that are not in accordance with the realm of concepts set by experts. The concept of physics is indeed fun to learn but it is enough to make students feel difficult when learning every material concept. The cause is the abstract concept of physics and its complicated mathematical calculations, especially in the matter of momentum and impulses. Although several studies state that misconceptions in studying physics concepts can be overcome, they do not last long and will definitely happen again. Therefore, this study aims to identify misconceptions among high school students regarding the concept of momentum and impulse. The research method used is descriptive quantitative. The participants in this study were 37 students who were obtained using a purposive sampling technique. The instrument used is the Three-tier diagnostic test which is formulated based on the indicators contained in the school curriculum used. The research data were obtained from the results of an analysis of the answers and patterns of students' answers on the three-tier diagnostic test items. The results of the study showed that it was identified that more than fifty percent of students had misconceptions.

**Keywords:** Misconception, Momentum and Impulse, Three Tier Diagnostic Test

## 1. Introduction

Physics is a branch of science that has the characteristics of abstract and concrete concepts, namely the relationship between natural phenomena and daily activities. Researchers in science education stated that in learning physics it is not only discussing collections of phenomena and their principles, but more emphasis is placed on exploration activities, analyzing each phenomenon and its principles that they find themselves (Anggraeni 2017). As a result of the characteristics of abstract and concrete physics concepts, the level of understanding of students is still low because they experience some difficulties during the learning process. The reason is due to an imbalance between mastery of concepts and the ability to solve physics problems and their application in everyday life.

Based on student learning outcomes in physics subjects, they still have not reached the minimum criterion score that has been set in the school. The learning outcomes of each student are different because the level of student ability in learning, especially when digesting the material presented by the teacher, shows that the level of student understanding is still weak, even in almost every subject in school, especially physics. Learning difficulties are one of the factors that can later result in failure or at least become a distraction that can hinder student learning progress, especially in learning every physics concept itself (Shalihah, Mulhayatiah, and Alatas 2016). When the physics concepts being studied are not understood properly and accurately by students, it will have an impact on conceptual understanding at a higher level and a wider range of material and tend to experience deviations or wrong concepts. The concept of physics that is distorted or experiencing deviations is known as a misconception. Van den Berg said that this misconception always refers to the incompatibility of the concept with the scientific understanding or explanation accepted by experts (Tayubi 2005). Several previous studies said that misconceptions occur almost all over the world, regardless of age, ability, gender, and socio-cultural environment. No matter how good the talents possessed by a group of students, they will still experience misconceptions regardless of background (Dalaklioğlu, Demirci, and Şekercioğlu 2015). Sources of misunderstanding of concepts can come from students' initial interpretations that are wrong. On the other hand, if the level of understanding of students and teachers is very good, it will become the basis for absorbing material concepts at the next level.

Misconceptions in the field of physics occur in almost every concept, however, the misconceptions that often occur in physics subjects are in the field of mechanics, and are at the top of other fields of physics (Kuczmann 2017). Momentum and impulse are a branch of physics from mechanics and is one of the materials that is quite difficult to understand. This is so because the scope of material on momentum and impulse does not only discuss calculations and mathematical formulas, each phenomenon discussed is very closely related to events that occur in everyday life. This means that in studying momentum and impulse material students must not only understand the mathematical and theoretical context, but also pay attention to the flow of the process in studying each material concept. The most important thing is that students really understand and are able to analyze every symptom and phenomenon that occurs in everyday life regarding momentum and impulse (Samsudin et al. 2015).

Based on previous research in identifying to reveal student misconceptions is to do a test. The test is used to find out conceptual errors (misconceptions) that occur in students when they have studied a material concept. There are several types of tests that can be used, one of which is a three-tier diagnostic test (there-tier test). The three-tier diagnostic test is an example of a test that can be used to identify misconceptions that occur in students. The results of this test will later become the basis for how appropriate and suitable treatment should be for the weaknesses possessed by students in understanding physics concepts. Three-tier diagnostic test is more efficient on a broad scale and can overcome student limitations (Cetin-Dindar and Geban 2011). Based on this, this study aims to identify students' misconceptions in learning the concept of physics material by using a three-tier diagnostic test instrument on momentum and impulse material.

## 2. Literature Framework

### *2.1 Conceptual understanding*

One of the students' understanding of physics learning is influenced by the level of ability possessed by students to absorb many concepts, some students think that there are some concepts that are very easy to understand, but some students are very difficult and relatively weak in understanding these concepts (Gunawan et al. 2018). The lack of understanding level possessed by students because students experience difficulties and there are obstacles during the process of learning activities so that later it will potentially cause students to experience misconceptions (Kurniawan, Muliyani, and Nassim 2019).

Another cause of students experiencing misconceptions is the preconceptions (predetermined ideas) that students get from various sources such as the family environment and the ideas that have been formed are not necessarily true or false. The teacher's task is to revise each concept that students learn whether there is still something wrong with students' understanding of the concept. When a bad idea is preconceived, if left unchecked and not immediately given a proper formulation, it can lead to persistent misunderstandings. The location of the misunderstanding must be known with certainty so that the solution given is truly appropriate (Suprapto 2020).

Understanding the concepts of momentum and impulse is very difficult to train. Moreover, it is related to the vector concept. For example, in the concept of collision with the analysis of the law of conservation of momentum, many students fail to understand the direction of momentum. In fact, the existence of the direction of momentum is very important in marking positive and negative in calculations. The positive sign corresponds to the direction of motion to the right and the negative sign corresponds to the opposite direction. In addition, understanding the concept of impulse often has a misconception that impulses have no direction. This misunderstanding can be investigated through a diagnostic test using a graded test.

### *2.2 Tier test as a diagnostic test*

Over the last decades, the development of tests in science education research has been characterized by the development of graded tests. Treagust (1988) as the first initiator to develop a two-tier test. This two-level test is divided into two questions. The first question provides an opportunity for students to answer questions regarding specific content-specific knowledge. In the context of Treagust, content knowledge is related to chemical knowledge (Treagust 1988). The second question relates to the reasons students have to choose about why they choose a particular choice in the first question. The use of two-tiered tests is useful because students are required to express their ideas on specific content-specific knowledge (Tsai et al. 2007; Tsui and Treagust 2010).

Misconceptions that occur in students can be measured using a three-tier multiple-choice diagnostic test because it is considered to provide an accurate picture. The results of the process of identifying these misconceptions can be used as an assessment document for teachers when carrying out learning activities or after carrying out learning evaluation activities for students. The next development of the two-level test is the three-tier test where in this three-level test, the researcher adds an index of confidence in the reasons proposed (Caleon and Subramaniam 2010). The first and second questions in the three-level test are exactly the same as the two-level test, namely regarding certain physics concepts. The first question refers to the general concept and the second question refers to the reasons that must be chosen why choose a particular concept in the first question.

## 3. Research Method

### *3.1 Research design*

The type of research used in this research is quantitative with descriptive methods. Quantitative is an approach that quantifies numerical results and analyzes data using statistics as a medium or tool. The descriptive method (descriptive research) is a research method that focuses on describing symptoms or phenomena that occur either in the present or in the past (Williams et al. 2007). Quantitative descriptive research aims to provide an overview of the extent of student misconceptions or misunderstandings by describing the size and frequency. In this study, data was obtained in the form of numbers which would later go through a more detailed and structured analysis process.

### *3.2 Participants*

The population in this study were all tenth-grade science students at a public high school in Garut. The number of samples is 37 students aged between 15 and 16 years. The sample technique used in this study was purposive sampling, namely a sampling technique by determining certain criteria that

the researcher wanted (Etikan, Musa, Alkassim, et al. 2016). This technique was chosen for certain purposes and reasons based on the research taken, for the criteria were tenth grade science students who had finished studying the material of momentum and impulse. All students have learned about the concepts of momentum and impulse in class, so they should have a basis for choosing certain concepts and reasons.

### *3.3 Instruments*

The test is a series of questions, exercises or tools used to measure skills, knowledge, intelligence and abilities possessed by individuals or groups of people with specific goals (Sugiono, Noerdjanah, and Wahyu 2020). The test used in this study is a diagnostic test in the form of a reasoned multiple choice or three-tier. This three-tier diagnostic test is used to identify and determine the percentage of students who experience misconceptions in understanding the concept of momentum and impulse material.

The instrument used in this study is of course an instrument that can identify students' misconceptions in studying physics on momentum and impulse material. Then the data obtained for research needs has more accurate results. In the study of this instrument, the instrument developed is a three-tier diagnostic test on momentum and impulse material. The number of questions used in this study amounted to 15 items and was sufficient to describe or reveal misconceptions in students, because each question on this test instrument already represented each sub-matter on momentum and impulse along with indicators on each item. The form of this diagnostic test is at the first level of questions in the form of multiple-choice questions with the main answer choices. The second level questions are in the form of questions about students' reasons/reasoning regarding the answers at the first level which consist of five choices of question answers with the addition of one empty option intended if students do not find answers to the five choices. The third level questions are questions about students' beliefs about questions at the first and second levels, which consist of two answer choices, namely "Sure" and "Not Sure".

The validity of this instrument is carried out so that the measuring instrument used is appropriate and appropriate for the variable to be measured or studied. The validity of these items is carried out by validation experts and assessors, so that it is known that the results of the validity test of the items are of good quality. In this item validation activity, it is carried out by finding the total score along with the number of responses for each expert validator by filling out the question validation sheet. Then if the item shows good or valid results then the item can be categorized as an appropriate instrument to use.

This validity activity was carried out by 2 experts, namely in the field of physics and Physics Education. The results of the instrument validation test by the instrument validator are suitable for use with revision. Based on the results of the expert validation test, the researcher carried out revisions to the diagnostic test instrument in accordance with input from the validator so that the diagnostic test instrument was truly feasible to use in this study.

### *3.4 Data analysis*

The process of analyzing and classifying each category of misconceptions uses a three-tier test and guidelines according to Kaltakci Gurel and Didis, et al (8). First, grouping students' answers by giving a score to each item based on the scoring format as shown in the table 1. Second, categorizing each student's answer based on the possible pattern of student answers on the three-tier test based on the pattern of answers from (Kaltacki and Didis, 2007) as in the following table.

Third, analyze the percentage of each pattern of student answers in the three-tier diagnostic test by using the percentage calculation with the equation 1. Information for this equation includes: P is the percentage of students who understand the concept, lack understanding of the concept, misconceptions and other categories; S is the number of students in each category (understanding the

**Table 1.** Rubric of scoring on tier test

| Scoring | | | Scoring | |
|---|---|---|---|---|
| **First tier** | **Second tier** | **Score** | **Third tier** | **Score** |
| True | True | 1 | sure | 1 |
| False | True | 0 | | |
| True | False | 0 | not sure | 0 |
| False | False | 0 | | |

**Table 2.** Coding category of students' score

| Category | Type of coding criteria |
|---|---|
| Understanding concepts | True Answer+ True reasoning + sure |
| Not understanding concepts | True answer + true reasoning + not sure |
| | False answer + True reasoning+ not sure |
| | True answer + False reasoning + no sure |
| | False answer + False reasoning+ not sure |
| Misconception | True answer + False reasoning + sure |
| | False answer + True reasoning+ sure |
| | False answer + False reasoning + sure |

concept, not understanding the concept, misconceptions and other categories); Js is the number of students. Fourth, calculating the percentage of students' overall understanding level for the category of understanding concepts, lack of understanding of concepts and misconceptions using the percentage formula (equation 2). Where f is the total number of students included in the understanding category, and N is the maximum value or the total number of students multiplied by the number of items. Fifth, determine criterion of misconceptions according to the table of criteria for the level of misconceptions (Kaltakci and Didiş 2007).

$$P = \left[\frac{S}{J_s}\right] \times 100\% \tag{1}$$

$$Percentage = \frac{f}{N_t} \tag{2}$$

## 4. Result of the research

### *4.1 Misconceptions and level of understanding of students as a whole*

Each student's answer has been grouped based on each category of misconceptions and level of student understanding. The results obtained are the percentage for each category based on student answers on each item and as a whole based on a diagnostic test that has been followed by 37 students.

Overall, based on the results of the three-tier diagnostic test on each of the sub-concepts of the material on momentum and impulse, it can be seen that 52.70% of students are identified as having misconceptions and this is a level of misconception in the moderate category. Even though it is said to be in the moderate category, this should still be a concern for both teachers and other researchers, because it does not rule out the possibility that the misconceptions experienced by these students have increased and exceeded the identification results carried out in this study.

### *4.2 Level of understanding on the sub-concepts of momentum and impulse*

The level of student understanding in each category is processed by adding up the number of students in the category of misconceptions and the level of student understanding in the momentum and impulse sub-concepts then dividing by the number of items per sub-concept multiplied by the total number of students, the final result is a large percentage of each category of misconceptions and students' level of understanding for each material sub-concept of momentum and impulse.

Students who experience misconceptions occur in the collision sub-concept, the law of conservation of momentum, impulse and momentum occurs a lot in succession, namely on indicators explaining collisions, applying the concept of the law of conservation of momentum in solving problems and explaining the concepts of momentum and impulse and the relationship between the two with magnitude the percentage of each sub-concept is 86.4%, 72.9%, 64.8% and 70.2%. While the lowest level of misconception is in each of the momentum and impulse sub-concepts with a percentage of 72.9% for the collision sub-concept with indicators explaining collisions, 29.7% for the law of conservation of momentum sub-concept with indicators applying the law of the concept of conservation of momentum in solving problems .35.2% for the impulse sub-concept with indicators explaining the concepts of momentum and impulse and the relationship between the two, and 21.7% for the momentum sub-concept with indicators describing the meaning of momentum. Students who understand the concept have a percentage with 0% percentage data on the collision sub-concept. This means that around 34.8% of students from the total percentage of students as a whole are only identified as having a lack of understanding of concepts and misconceptions and no students really understand the sub-concept of collisions so that it shows a very low level of understanding of the concept. It can be seen that students who understand the concept with the highest percentage are the momentum sub-concept and students who are included in the category of understanding the lowest concept are the collision sub-concept. The largest percentage of students who understand the concept of the momentum sub-concept is the indicator describing the meaning of momentum with a percentage of 40.6%, while the smallest percentage of the collision sub-concept occurs in the indicator describing the collision, namely 00.0%.

The highest percentage of students who fall into the category of lack of understanding of concepts at the level of student understanding occurs in the sub-concept of impulse, while the level of understanding of students in the category of lack of understanding of the lowest concept occurs in the sub-concept of the law of conservation of momentum. The highest percentage of the impulse sub-concept occurs in indicators describing the meaning of impulse with a large percentage of 45.9%, while students who fall into the category of less understanding of the concept, the lowest in the sub-concept of the law of conservation of momentum with a percentage of 32.4%, occurs mostly in implementing indicators. the concept of the law of conservation of momentum in solving problems.

## 5. Discussion

The results obtained from the diagnostic test research instrument to identify students' misconceptions with three-tiers, namely the high and low levels of misconceptions and the level of student understanding based on the large percentage of understanding the concept, lack of understanding of concepts and misconceptions as a whole are equal to 19.8%, 27.5% and 52% .7%. This percentage shows the level of misconceptions for each category as a whole which includes momentum, impulse and collision which are included in the moderate category of misconceptions.

The results of the misconception data for each item indicator and student understanding level category were obtained by multiplying all 15 items by the total number of students who took the test as a whole, namely 37 students and the number of questions that had been answered, namely 555 items. The highest misconception experienced by students occurred in item number 10, namely in the indicator describing collisions with a percentage of 86.4%, at the level of understanding the most

students understood the concept, namely in question number 12 with the indicator applying the concept of the law of conservation of momentum in solving problems with a percentage by 45.9% and students who do not understand the concept mostly occur in question number 4, namely the indicator describing the meaning of impulse with a percentage of 45.9%.

The results of the analysis of student answers and the pattern of answers on the diagnostic test using three tiers on questions number 6, 9 and 13 answered questions with the same answer pattern, namely at first tier and second tier giving wrong answers and reasons but at tier 3 still choosing answers with confidence , Likewise with questions number 10 and 14 showing the same pattern of student answers except that at tier 1 the student answered correctly, at second tier answered the reason incorrectly and chose to believe in the question of the level of confidence in the answer, while in question number 11 the student's answer pattern was the opposite of the pattern of student answers to questions number 10 and 14, namely at first tier choosing the wrong answer but choosing the correct reason for the answer at second tier and choosing a sure answer at third tier (Caleon and Subramaniam 2010).

So based on each pattern of student answers on questions number 6, 9, 10, 11, 13 and 14 students were identified as experiencing misconceptions with the acquisition of sequential percentages, namely in question number 6, a percentage of 70.2% was obtained with a high level of misconception category, on Impulse sub-concept with indicators explaining the concept of momentum and impulse and the relationship between the two, questions number 9 and 10 are included in the collision sub-concept with indicators describing collisions with a large percentage gain for each item, namely 72.9% and 86.4%, including the category of misconceptions high level, while for questions number 11, 13 and 14 are included in the sub-concept of the law of conservation of momentum but the indicators are different. For question number 11 the indicator for the problem is to describe the law of conservation of momentum and for questions number 13 and 14 the indicator is to apply the concept of the law of conservation of momentum in solving problems with a large percentage for each question sequentially, namely 64.8% in the medium misconception category, 72, 9% and 70.2% fall into the category of high-level misconceptions. This means that in the sub-concepts of impulse, collision and the law of conservation of momentum it is identified that students experience the most misconceptions or wrong interpretations of these concepts (Cetin-Dindar and Geban 2011).

Based on the results of the analysis and explanation in the discussion section, it can be seen that students experience misconceptions about each of the sub-concepts of momentum and impulse. Every student still experiences difficulties when analyzing any questions related to phenomena that are linked between material concepts contained in momentum and impulses with actual conditions. It is different again when students do an analysis on the identification of misconceptions given related to mathematical calculations students do not experience significant difficulties, one of the reasons is that students experience difficulties when solving calculation problems because the student forgets what formulas must be used to solve the problem. So after it is known that students have misconceptions and their causes, what must be done is remediation by improving the method of delivering material how teaching and learning activities should be able to provide high motivation and enthusiasm for learning towards students, trying to eliminate students' bad views of the physics subject itself, using teaching techniques and must more often carry out analytical activities both phenomena that exist around us or work on questions in order to train thinking power, student analysis processes which can later support student success in understanding every concept of the physics material they are learning (Etikan, Musa, Alkassim, et al. 2016).

## 6. Conclusion and implication

The total percentage of misconceptions and the level of student understanding for each category identified in the concept of momentum and impulse material as a whole is 19.8% in the category of understanding concepts, 27.5% lacks understanding of concepts and misconceptions is 52.7%

and is included in misconceptions with the category currently. For each of the sub-concepts of momentum and impulse, students are identified as experiencing misconceptions, namely the material concept of momentum is 17%, impulse is 22%, collision is 35.4% and the law of conservation of momentum is 26%. A good level of student understanding will greatly influence student outcomes and achievements during learning, especially in understanding each concept in physics subjects, so that it can reduce the level of misconceptions that occur in students.

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