



Analysis of Momentum and Impulse Misconceptions of College Students Using Four-Tier Diagnostic Tests

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Abstract: This study aims to find out the misconceptions on the momentum and impulse concept. The research method used in this study was a mixed method. The subjects of this research are students majoring in physics class 2019, 2020, and 2021 who have taken the fundamentals of physics course I with a total sample of 44 students. The instrument used is 15 four-tier multiple diagnostic tests. The research data was obtained based on the pattern of student answers on the four-tier multiple choice test. The results showed that students' understanding of concepts on momentum and impulse materials using the diagnostic four-tier diagnostic test was still relatively low, as seen from the percentage of students who partially understood the concept of 46%, understood the concept of 30%, misconceptions negative of 10%, misconceptions of 9%, and misconcepted positive concepts of 5%. Some misconceptions experienced by students on the concept of momentum and impulse include: (1) students assume that only mass affects the magnitude of momentum, (2) assume that the total momentum of an isolated system of objects is not constant, (3) assume that two objects that have the same mass have different velocities, (4) assume that changes in the speed of a particle is only affected by force and time and (5) assumes that the collision process on a smooth surface will move all objects.

INTRODUCTION

Physics is one of the subjects that is considered difficult because it has interrelated concepts, so if you don't dominate one concept it will be difficult to learn other concepts (Septikasari et al., 2021). Learning physics aims to gain an understanding of scientific products (concepts, laws, principles, theories) (Safarati & Rahma, 2020). The above statement is in line with the opinion (Sasmita, 2017) that the most appropriate first step to studying physics is to understand the concepts first. Mastery of concepts is a basic ability that must be owned by students to be able to understand concepts in accordance with the understanding of scientists (Hidayati & Taqwa, 2023; Shodiqin & Taqwa, 2023; Widodo, 2006). This is reinforced by (Rahmawati et al., 2019) who state that the purpose of learning is to have good conceptual abilities so that students can develop the knowledge they have previously.

Physics topics such as mechanics are one of the fields that have problems in understanding concepts (Rosa et al., 2018). Momentum and impulse are the sub-topics of

mechanics and also become an important part of learning physics at various levels (Singh & Rosengrant, 2016). This material is also the basis for studying advanced physics such as machine and structural design, advanced dynamics, and structural mechanics (Fang, 2012). The concepts of impulse and momentum are also close to the lives of students and can be applied in various technologies and industries such as helmet construction, crumple zones in a car, airbag construction, and the crack of the bat (Purwaningsih et al., 2020).

Based on the results of research in the last time, students' mastery of concepts is still relatively low. The results of the study stated that momentum and impulse are some of the materials in physics subjects that still often misunderstood concepts and are some of the chapters of physics that are not easy (Singh & Rosengrant, 2016). Previous studies have discussed many students' difficulties in applying concepts to momentum material and its implications for everyday problems (Close & Heron, 2011). The difficulty of students in understanding the concepts in the momentum and impulse material, among others, in connecting the relationship between the concepts of momentum and impulse in problem-solving (Bryce & MacMillan, 2009), understanding momentum as a vector quantity in relation to the conservation of momentum (Close & Heron, 2011), so that these difficulties trigger misconceptions in students.

One way to detect misconceptions in students is to do a diagnostic test. Diagnostic tests are tests that can be used to show and determine the weaknesses and strengths of students in particular topics (Ni'mah et al., 2021). The four-level diagnostic test is one of the diagnostic tests that has various advantages including the teacher can distinguish the level of confidence of students in providing answers and the teacher can also distinguish the level of confidence in giving reasons, can diagnose misconceptions that arise, and can also analyze parts of material that needs to be emphasized and finally, appropriate learning can be designed to improve understanding of concepts (Fariyani et al., 2017). Just as stated in Kaltakci's research that four levels of multiple choice test is the right choice to identify misconceptions (Kaltakci-Gurel et al., 2017).

Research conducted by (Ariani, 2019) on maps of students' understanding of the concepts of momentum, impulse, and collision using a diagnostic four-tier test did not use interviews in data collection, then the subjects in the study were only for high school students. Meanwhile, in this research, interviews will be added to obtain more extensive and in-depth information and the subject of research is conducted on students.

The purpose of this study was to find out the misconceptions of students majoring in physics at the State University of Malang on the concepts of momentum and impulse through the four-tier diagnostic test. The questions given in this study were presented in the form of a four-tier diagnostic test. This is very important considering the need for a complete understanding of concepts and understanding of concepts in minimizing misconceptions. In analyzing students' conceptual understanding, the discussion will be reviewed based on the instrument used in this study, namely the four-tier diagnostic test which functions to identify knowledge abilities and misconceptions, and can assess students' misconceptions of knowledge.

METHOD

This research is a descriptive research. This type of descriptive research has the aim of providing a description, explanation, and validation of the phenomenon being studied. The research method used in this study is a mixed method, which is a combination of qualitative and quantitative research. Before conducting the research, the researcher did not do any treatment to the research subject. The subjects of this study were undergraduate students of physics education who had taken the basic physics course I with a total sample of 44 students. To achieve the research objectives, a four-tier test diagnostic test instrument is used to determine the ability of knowledge and misconceptions, and can assess misunderstandings, not assess errors or even lack of knowledge of students on momentum and impulse material, where this test instrument adapts from research (Ariani, 2019). The data collection technique in this study used a four-tier diagnostic test, which consisted of 15 questions and each question consisted of four main levels. The first level is multiple choice with five choices of answers regarding the concept of the material, the second level is the confidence rating of the first question, the third level students choose the reasons for the answers to the first level with five choices, and the fourth level is the confidence rating of the answers to the reasons for the questions. Interviews will also be conducted to consider the reasons for each answer selection. Data from the assessment of understanding the concept of momentum and impulse in the form of quantitative data. While qualitative data in the form of students' reasons for choosing answers and interview results.

RESULT AND DISCUSSION

The results of the research that have been carried out show that students' understanding of the concept of momentum and impulse using the four-tier diagnostic test is still relatively low. This can be seen from the average score of students which only reached 55.23%.

Table 1. Descriptive statistics of the score of understanding the concept of momentum and impulse using the four-tier diagnostic test

Minimum	Maximum	Mean	Mode	Median	Standard Deviation
16,67	86,67	55,23	60,00	56,67	16,08

Based on table 1, it can be seen that the percentage of student respondents who answered correctly was 86.67%. Students' answers are grouped into categories of understanding levels based on the pattern of answers, namely understanding concepts, understanding partial concepts, positive concepts, negative concepts, and misconceptions. After processing the data from the test results, the percentage based on the category of understanding of the students as a whole is 44 students from each item. The following data is presented in graphical form in Figure 1.

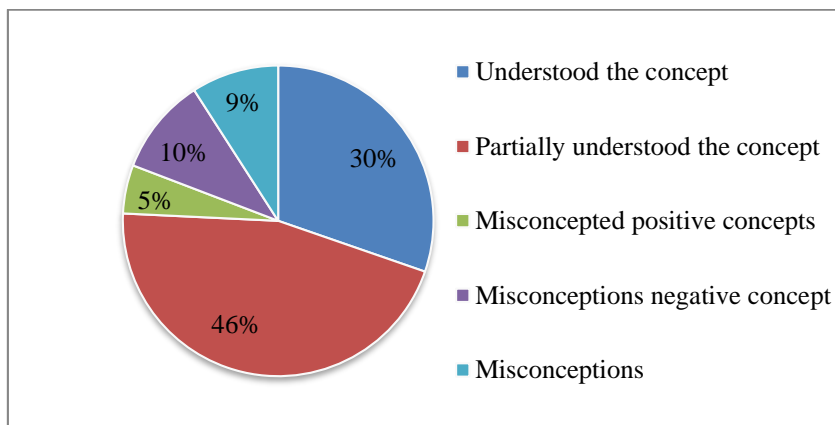


Figure 1. Percentage of Overall Student Understanding

Based on Figure 1, the category of understanding the concept partially occupies the highest position with a percentage gain of 46%, the percentage of the category understanding concept is in the next position at 30%, the percentage of the category of misconceptions is negative concepts by 10%, then the percentage of misconceptions is 10%, and the lowest percentage is misconceptions positive concepts by 5%.

Understood the concept

Students are said to be included in the category of understanding concepts, if they can answer with an answer pattern according to Derya Kaltakci Gurel, et al. namely true, sure, true, sure (Gurel et al., 2015). The majority of students' answers with a combination pattern of answers in the category of understanding concepts, one of which occurs in question number 2, can be seen in figure 2.

<p>Attention to the following statements!</p> <ol style="list-style-type: none"> 1) If the velocity of the object is increased, the value of the momentum will be small. 2) If the velocity of the object remains constant, the momentum of the object will not change. 3) If the velocity of the object is reduced, the value of the momentum will decrease. 4) The speed of the object's motion does not directly affect the value of the object's momentum, but rather affects the position of the object <p>The correct statement in accordance with the concept of momentum of an object is in the number....</p> <ol style="list-style-type: none"> A. 1 and 2 B. 1 and 4 C. 2 and 3 D. 2 and 4 E. 3 and 4 <p>The reason for your answer....</p> <ol style="list-style-type: none"> 1. Certain 2. Uncertain 	<p>The reason for your answer....</p> <ol style="list-style-type: none"> A. The value of an object's momentum is not affected by its mass and velocity B. The value of the momentum of an object whose mass remains is inversely proportional to its velocity C. The value of the momentum of an object whose mass remains is directly proportional to its velocity D. The value of the momentum of an object whose mass remains unaffected by the value of its velocity E. The value of the momentum of an object whose velocity remains inversely proportional to its acceleration <p>The reason for your answer....</p> <ol style="list-style-type: none"> 1. Certain 2. Uncertain
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Figure 2. Question Number 2

Question number 2 is included in the momentum sub-concept with indicators explaining the meaning of momentum, on this question about 61% of students answered correctly. In a study conducted by Gul Sekercioglu, et al stated that if the velocity changes, the momentum will also change (Şekercioglu & Kocakulah, 2008). This is in accordance with what is stated in Giancoli's book that the value of an object's momentum is directly proportional to the mass and velocity of the object (Giancoli, 2001).

So, the mass and speed of an object affect the size of the momentum value of an object, if the velocity is large then the object will have a large momentum, but if it has a small velocity then the object will have a small momentum as well. Meanwhile, if an object has a heavy mass it will have a large momentum, and an object with a light mass will have a small momentum. So it can be concluded that, the value of an object's momentum will not change if the object's velocity is constant and the value of the momentum will decrease if the object's velocity is reduced.

Partially understood the concept

The majority of students' answers with a combination pattern of answers in the category of understanding the concept partially occurred in questions number 5, 7, 8, 9, 10, 14, and 15. The pattern of combination answers in the category of understanding the concept partly on question number 7 which is included in the sub concept impulse with a question indicator that is formulating the relationship between momentum and impulse, can be seen in figure 3.

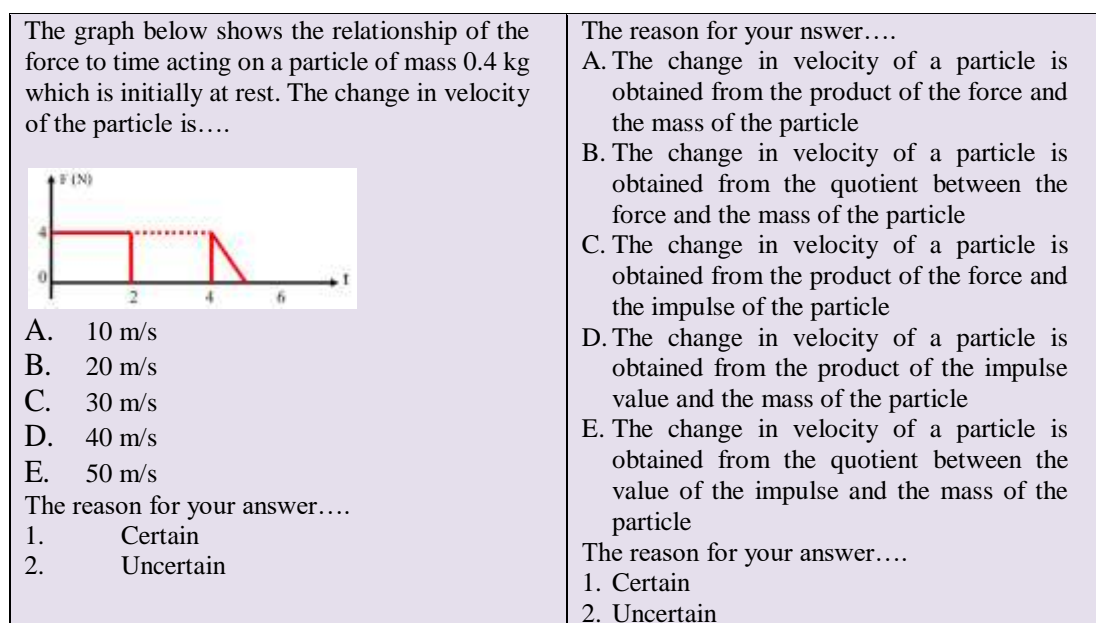


Figure 3. Question Number 7

In this question, it was identified that students had understood the concept partly seen from the majority of student answer choices, namely the change in the speed of a particle obtained from the quotient between the impulse value and the mass of the particle, besides that, it was also seen from the answers of students in tier 2 choosing Uncertain, in tier 3 choose the reason for the wrong answer, and at tier 4 choose Uncertain. As many as 61%

of students from the total sample belong to the category of understanding the concept partly in working on this problem. Previous research conducted by Ridwan Abdullah Sani, et al. found that as many as 56.67% of students had difficulty in answering questions that demanded to understand the graph of the relationship between force, momentum and impulse in the motion of an object (Sani & Aulia, 2018). When working on this problem, students do not look for impulse values by knowing the value of the area formed on the graph, but the graph is only used as data and then calculated using the impulse formula they know. In addition, students also only use the reason option to determine the formula used to find answers to the questions and only assume that changes in the velocity of a particle are only affected by force and time.

Misconceived positive concepts

The majority of students' answers with a combination pattern were in the wrong category of positive concepts, namely question number 6 which was included in the impulse sub-concept with an indicator of the question of formulating the relationship between momentum and impulse, which can be seen in figure 4.

<p>A baseball has a mass of 0.4 kg, it is thrown with a speed of 10 m/s. After being hit, the speed of the ball changes to 24 m/s and is perpendicular to the direction of the original motion.....</p> <p>A. 2,6 Ns B. 3,6 Ns C. 4,6 Ns D. 5,6 Ns E. 6,6 Ns</p> <p>The confidence level of your answer....</p> <p>1. Certain 2. Uncertain</p>	<p>The reason for your answer....</p> <p>A. The magnitude of the impulse experienced by an object is affected by the value of the change in its mass B. The magnitude of the impulse experienced by an object is influenced by the value of the change in the impulse C. The magnitude of the impulse experienced by an object is affected by the value of the change in velocity D. The magnitude of the impulse experienced by an object is affected by the value of the change in its acceleration E. The magnitude of the impulse experienced by an object is influenced by the value of the change in its momentum</p> <p>The reason for your answer....</p> <p>1. Certain 2. Uncertain</p>
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Figure 4. Question Number 6

In this question, a positive concept was identified, namely the student answered the first level question correctly, but answered the third level question with the wrong answer, namely the amount of impulse experienced by an object is influenced by the value of the change in its momentum, besides being seen from the answers in tier 2 choosing sure, and at tier 4 choose sure too. As many as 34% of students from the total sample were included in the category of positive misconceptions in working on this problem, where students experienced misconceptions about the concept because they thought that the magnitude of the impulse was influenced by the value of the change in mass. So it can be concluded that, the magnitude of the impulse experienced by an object is influenced by the value of the change in velocity or in other words the value of the impulse experienced by an object is directly proportional to the change in the velocity of the object.

Misconceptions negative concept

The majority of students' answers with a combination pattern are in the wrong category of negative concepts, namely question number 11 which is included in the momentum sub concept and the question indicator, which explains the law of conservation of momentum in everyday life, can be seen in figure 5.

<p>The Toyota Avanza has a mass of 1045 kg and the Ford Ranger has a mass of 1878 kg. If the two cars are traveling at the same speed, then...</p> <p>A. The two cars have different momentum because they have different masses</p> <p>B. Both cars have the same momentum because they have the same speed</p> <p>C. Both cars have the same momentum because the momentum is not affected by the mass of the object</p> <p>D. The two cars have different momentum because momentum is affected by mass and velocity</p> <p>E. Both cars have the same momentum because the momentum is not affected by the object's velocity</p> <p>The reason for your answer....</p> <p>1. Certain</p> <p>2. Uncertain</p>	<p>The reason for your answer....</p> <p>A. The value of an object's momentum is obtained from the product of the mass and the object's velocity</p> <p>B. The value of an object's momentum is obtained from the product of the mass by the square of the velocity of an object divided by two</p> <p>C. The value of an object's momentum is obtained from the product of the forces acting on the object at a certain time interval</p> <p>D. The value of an object's momentum is obtained from the quotient between the change in the object's velocity and the time interval</p> <p>E. The value of an object's momentum is obtained from the product of the forces acting on the object at the object's velocity in a certain time</p> <p>The reason for your answer....</p> <p>1. Certain</p> <p>2. Uncertain</p>
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Figure 5. Question Number 11

In this question, misconceptions are identified based on the majority of student answers, namely the two cars have different momentum because they have different masses, besides that, it can also be seen from the answers in tier 2 choosing sure, in tier 3 choosing the right answer reason, and in tier 4 choose sure. Around 43% of students from the total sample still experience negative misconceptions, and about 34% of students from the total sample experience partial misconceptions.

From the results of interviews conducted, students understand the equation of momentum, but students only assume that momentum is only influenced by mass and velocity has no effect. This is in accordance with the general understanding of momentum, momentum is directly proportional to the value of the mass of the object and the velocity of the object (Diyanaheza et al., 2017). So it can be concluded that the magnitude of the momentum that occurs in an object is not only influenced by the mass of the object, but is also influenced by the value of the velocity of the object. Thus, the faster an object and the heavier the mass of an object, the greater its momentum will be, on the contrary if the object moves slowly and has a light mass, the momentum that works is also of small value.

Misconceptions

Questions that fall into the category of misconceptions, namely question number 10 which is included in the sub-concept of question number 10, namely collisions with the question indicator explaining collisions, can be seen in figure 6.

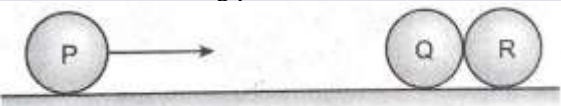
<p>Look at the following picture!</p>  <p>P, Q, R are three billiard balls lying on a smooth surface. Balls Q and R touch each other. Ball P is poked and hits Q and the resulting collision is perfectly elastic. Shortly after the collision will be obtained....</p> <p>A. P bounces, Q stops, R moves B. P bounces, Q and R move C. P and Q stop, R moves D. P stops, Q keeps moving E. P, Q, and R keep moving</p> <p>The reason for your answer....</p> <p>1. Certain 2. Uncertain</p>	<p>The reason for your answer....</p> <p>A. P strikes Q, P and Q have velocity, consequently Q strikes R so that Q and R are at rest B. P hits Q, P and Q have velocity, consequently Q hits R so that Q and R move C. P hits Q, P and Q have velocity, consequently Q hits R so that Q moves and R stays still D. P hits Q, P and Q have velocity, consequently Q hits R so that Q is stationary and R moves E. P hits Q, P, and Q have velocity, consequently Q hits R so that Q and R move together</p> <p>The reason for your answer....</p> <p>1. Certain 2. Uncertain</p>
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Figure 6. Question Number 10

In this question, misconceptions were identified based on the majority of students' answers, namely when ball P was poked, then ball P would bounce, while ball Q stopped and R moved, besides that, it was also seen from the answers that students at tier 2 chose sure, in tier 3 chose the reason for the answer. wrong, and at tier 4 choose sure. This is in accordance with previous research conducted by Geraldine Cintia Rosa, namely the first object will stop right at the initial position of the second object, and only the second object will move with the same speed as the initial velocity of the first object, this can occur because of the energy The kinetic energy of the first object is completely transferred to the second object, if the second object has the same mass as the first object then the velocity of the second object and the first object is the same, whereas when the first and second objects stick together and move together, the kinetic energy of the two objects will be lost at the second time. the object undergoes a perfectly elastic collision (Rosa et al., 2017).

In the case of billiard balls colliding with each other, the law of conservation of momentum applies which states, "the total momentum of an isolated system of objects remains constant". So, if P is poked then Q will continue to move, this can happen because when P hits Q, P and Q have speed, as a result Q hits R so Q is stationary and R moves. In other words, the momentum possessed by an object is always the same at all times if the velocity is also constant, in this case, a velocity transfer event occurs between the balls P, Q, and R. Meanwhile, students assume that if the ball is poked on a slippery surface, the ball will move. and assume that the total momentum of an isolated system of objects is not constant and some students also have a misunderstanding of the concept that two objects with the same mass have different velocities.

In learning physics, it is important to identify students' misconceptions and difficulties. This can be one of the teacher's considerations in designing learning (Taqwa, 2017). Misconceptions will really "hinder" learning because students will find it difficult

to accept new knowledge that is different from their old knowledge (Başer, 2006; Taqwa & Pilendia, 2018). If misconceptions are not detected before learning, and no efforts are made to reduce them, then students will find it difficult to understand physics concepts. We hope that the results of this research will be a useful source of information for teachers, and can be used as information in designing learning designs.

CONCLUSION

Based on the discussion of research results from the four-tier multiple choice diagnostic test for students majoring in physics at the State University of Malang, it can be concluded that students' understanding of the concept of momentum and impulse using the diagnostic four-tier multiple choice test is still relatively low, as seen from the percentage of students partially understood the concept of 46%, understood the concept of 30%, misconceptions negative of 10%, misconceptions of 9%, and misconcepted positive concepts of 5%. Some misconceptions experienced by students on the concept of momentum and impulse include: (1) students assume that only mass affects the magnitude of momentum, (2) assumes that the total momentum of a system of isolated objects is not constant, (3) assumes that two objects that have the same mass have different speeds, (4) assume that the change in velocity of a particle is only affected by force and time and (5) assume that the collision process on a smooth surface will move all objects. Based on previous research, this is very important considering the need for a complete understanding of concepts and understanding of concepts in minimizing misconceptions. In analyzing students' conceptual understanding, the discussion will be reviewed based on the instrument used in this study, namely the four-tier diagnostic test which functions to identify knowledge abilities and misconceptions, and can assess students' misconceptions of knowledge.

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