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Analysis of Student's Difficulties in Solving Physics Problem: Impulse and Momentum Topics

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Abstract

Physics education essentially intends to cultivate student's analytical and reasoning capabilities. However, this objective is hard to achieve because there are many students who facing difficulties in solving physics problems. This research was conducted to identify the types of student's difficulties in solving momentum and impulse problems, along with the factors causing it. This research was conducted using a descriptive qualitative approach to 66 students of Senior High School 2 Makassar who had studied momentum and impulse topics. The data collection process was carried out using test and interviews. Based on the results, it can be identified that there are two types of student's difficulties in solving momentum and impulse problems. The first type was physical difficulties which consisted of student's difficulty in understanding the questions (26%) and student's difficulty in determining the useable equations (25%). Then, the second type was mathematical difficulties which consisted of student's difficulty in substituting the data to the equation (63%) and student's difficulty in performing mathematical operations (76%). Based on interviews and analysis, it can be concluded that these difficulties was commonly faced by students while solving physics problems, including in momentum and impulse topic. Futhermore, the difiiculties were caused by several factors, namely: 1) the lack of student's understanding about physics concepts, 2) the weakness of student's mathematical skills, 3) the lack of physics learning process which is not honing student's problem-solving skills and 4) the lack of student's motivation on developing their problems solving skills in physics subjects. Thus, researchers recommend to all physics teachers in Indonesia to immediately develop or implement learning strategies or methods which are considered capable of overcome all student's difficulties that have been found.

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INTRODUCTION

Physics education essentially intends to cultivate student's analytical and reasoning capabilities. These capabilities can be reflected in the form of critical thingking, logical thingking and systematical thingking which can be indicated when students are able to solve physics problems using the physics concept (Suroso, 2016). But, this objective is hard to achieve. Most of students, who have studied physics, think that physics is difficult and less interesting (Charli et al., 2018). This assumption arises because students only think about the number of physics equations which must they know and remember according to the different concept and physics law (Sari, 2018). On the other hand, students are rarely taught about the examples of physics application in their daily lives by the teacher at school. So, many students think that physics is not an proper subject which can be used to solve their real problem after graduating (Sari et al., 2013). Whereas, physics is as one of the natural sciences which is fundamental and has an important role on the development of technology and other sciences. So, a good understanding of physics concepts is one of the best preparations which can be done by students before facing their future (Sa'diyah et al. 2017).

In Indonesia, there are many students who have not been able to understand the physics concepts well, especially at the secondary school level (Hastuti et al., 2012). According to Prihartanti et al. (2017), it happens because teacher are always oriented to solve physics problems on the physics textbook while teaching physics at school. It drives students to focus on physics formulas and calculation processes, without paying more attention to the physics concept itself, when solving the physics problems. Indirectly, it makes physics learning process sensed like mathematics learning. Djupanda et al. (2015) revealed that this teaching strategy is conducted by physics teacher in order to enhance the student's problem-solving skill in physics subjects. So, students can actualize all physics concepts which they have learned at school in their daily lives. On the other hand, Saifullah et al. (2016) found that this learning strategy is expected to improve the physics understanding as well as the student's problem-solving ability.

However, the students' problem-solving ability in Indonesia is still relatively low. It is proven by worldwide study results published by the Organisation for Economic Co-operation and Development (2019) in The Programme for International Student Assessment (PISA) report. On the report, Indonesia is rank 70th of 79 on science literacy subject. It means that the scientific literacy of Indonesian students is relatively weak compared by other participated countries. It is supported by the study of Ikshan et al. (2019) which revealed that the average score of Indonesian students for physics subjects in the national exam is relatively lower than other tested subjects each year. It happens because students often faced several difficulties in solving physics problems, including in momentum and impulse topic.

One of the difficulties faced by students is the difficulty in solving collision problems. Additionally, the researcher believes that there are other difficulties faced by students in the momentum and impulse topic. It can be seen from the exam score which are still low. However, these difficulties are often ignored by teachers, so that there are still many students who repeat a similar mistake when solving momentum and impulse problems. It happens because the lack of physics teacher awareness in identifying those difficulties (Rahmat, 2017).

Most physics teachers assess students' problem solving abilities from the exam results, regardless of the process. If the student answers wrongly, then the student is considered not mastering the physics concept which have been learned, without considering the reasons why students cannot solve the questioned problem (Susiana, 2017). On the other hand, Dwi and Woro's (2015) study revealed that the evaluation of learning process carried out by physics teachers, when giving an assessment, is based on the answer key, teacher did not evaluating the working process which has been conducted by students while answering the questioned problems. So that, the teacher does not really understand the abilities or the difficulties experienced by students while working on the questions.

Therefore, a research about the difficulties faced by students in solving physics problems is very important to conduct in order to understand the type of difficulties and the factors caused it (Azizah et al., 2015). Additionally, the research results can also be used by physics teachers to find out the existence of students who have mastered the physics concept taught in the classroom (Juwariyah et al., 2018). So, teacher can develop certain teaching strategies which can be applied to help students coping their difficulties and to improve their understanding on physics concept (Nurjannah & Sunarto, 2018).

Actually, there is slight research which has been conducted regarding to the Indonesian

student's difficulties in physics. Most of the Indonesian research focused on the implementation of learning models, methods or strategies which are considered effective in improving students' conceptual understanding and problem-solving skill. As the results, there are many studies revealed that a model, method or strategy is suitable for teaching a certain topic in physics. But, occasionally it is not suitable in certain classroom condition of Indonesian schools. Nowadays, there are many students who still facing the difficulties in learning and solving physics problems. Eventhough their teachers had implemented an appropriate learning strategy or method considered to enhance students' learning motivation and understanding of physics insight. But, those difficulties are not investigated properly.

According to preliminary research, researchers found that there are several studies investigated about student's difficulties in solving physics problem based on the George Poyla theory. Those studies were conducted on physic subject in general (Jiwanto et. al., 2012), linear motion topic (Andriani et. al., 2016), work and energy topic (Pratama, 2017), elasticity and Hooke law (Hidayatulloh, 2020). Their studies used Poyla's problem solving theory as the main framework to analyse student's difficulties in solving physics problems. Actually, Poyla's problem solving theory is for mathematics subjects, although the principles can also be applied to another subject, including physics. However, this approach is inaccurate to inspect the student's difficulties in solving physics problems because this approach merely reviews the difficulties experienced by students while executed the four problem solving steps, which are: 1) understand the problem, 2) devise a plan, 3) carry out the plan and 4) look back (check and interpret). The research has not identified the student's difficulties in solving physics problem specifically, but only identifying their difficulties on certain stage of problem solving steps.

According to explaination above, researchers conducted a research in order to analyse student's difficulties in solving physics problems. This research specifically identified and categozied type of difficulties faced by students in solving momentum and impulse problems. Researchers hope that the type of difficulties provided in this research can be a fundamental framework which correcting the earlier approach which is inaccurate. So, the next researcher can conducting similar research about student's difficulties in another topics of physics in the near future. Finally, the results can be used to help Indonesian students and teachers in understanding their difficulties and needs on learning and teaching physics at secondary schools.

METHOD

The research was a descriptive qualitative research which describing a phenomenon without manipulating or giving other treatment to the reseach objects (Arikunto, 2015). The research was conducted at Senior High School 2 Makassar and involved 66 students who had studied the momentum and impulse topics before the research taken place. The students acted as respondents as well as informants regarding to their difficulties in solving momentum and impulse problems.

The data collection process was carried out using test instruments and interviews. The test instrument is used to determine the types of student's difficulties in solving physics problems. The instrument consisted of five essay questions which related to momentum and impulse problems. Before it used, the content validity of the instrument was checked by experts to determine whether the instrument is feasible to be used or not. Test instruments used in this research were:

A 1,400 kg truck moving rightward with a speed of 20 m/s collides with a car moving leftward with a speed of 10 m/s. The two vehicles stick together and move with velocity of 17 m/s after the collision. Determine mass of the car collided by the truck!

A ball of mass 200g is thrown horizontally with a speed 5 m/s. The ball strikes a bat and rebounds along the same line at a speed 15 m/s. The length of contact time with the bat is 1 ms. Find the force exerted by the hitter!

A 4 kg steel ball moving horizontaly in opposite direction with ball of mass 5 kg as shown below:

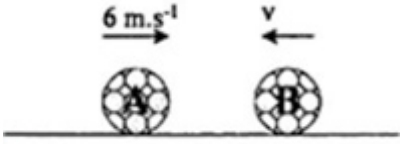

Figure 1. The balls is collided elastically and move in reverse direction.

The velocity of 4 kg ball is 4 m/s and the velocity of 5 kg ball is 2 m/s. Calculate the velocity of 5 kg ball before the collision!

A 20 g bullet is fired into a stationary block of (m = 60 g). The original speed of bullet when traveling to the block is 10 m/s. The bullet embe-

ds in the block after the collision. Find the velocity of the bullet and the block after collision!

Two ball with same mass are moved toward each other with velocity 4 m/s and 6 m/s as shown below:

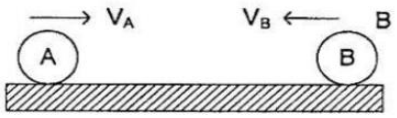

Figure 2. The balls is elastically colliding.

Respectively, the B ball returns back with velocity 4 m/s. Find the velocity of A ball after the colliding!

In this study, students were given as much time as possible to solve the problems individually. This is performed in order to drive students to solve the test instrument properly according to their personal abilities without asking help from others. Thus, the results will reflect their abilities and difficulties while solving momentum and impulse problems.

Next, the test results were analyzed in order to determine the types of difficulties faced by students while solving the tested instrument. The types of difficulties was identified by examining all of respondent answers one by one. The examination result were categorized based on the similarity of mistake or error made by respondents. Those mistake were considering as representation of difficulties faced by respondent while working on the tested instrument.

Then, the difficulties found in this study used as basic information on conducting interview. The interview processes were performed in a semi-structured interview aimed to find out all factors which cause the student's difficulties (Sugiyono, 2015). The interview activity was carried out on several students who made different mistakes while answering the tested instrument. Some sample questions asked in the interview section can be listed: What did you think about this problem?; Why don't you write down the known and asked variables in the question while answering this problem?; How did you determine the equation which you will use to solve this problem?; Why did you choose this equation to solve this problem?; I found that you made a mistake in substituting the variable to the equation. How did you explain that?; What made it difficult for you to solve the problem?

In addition, researchers also conducted a simple descriptive statistic analysis in order to calculate the percentage of difficulties faced by students in solving the momentum and impulse problems. According to Sudijono (2018), the analysis can be carried out using the following equation: $P= x/N\times100\%$

Where:

P=percentage of student's difficulties

x=number of respondents who experienced difficulties

N=total number of respondents

RESULT AND DISCUSSION

The research was conducted at Senior High School 2 Makassar in order to analyse the student's difficulties in solving physics problems, especially in the momentum and impulses topics, which were tested in the test instrument. Based on the analysis process which has been carried out on all respondents' answers, it is found that there are many students who still face difficulties in solving momentum and impulse problems. Based on data analysis and interview process, reseachers identified that there are five types of difficulties faced by respondents when working the tested intruments. Those difficulties can be described in the Table 1.

The Table 1 indicate that the number of students who have difficulty in answering the research instrument varies for each number. But in average, it is known that there are several constant difficulties faced by students when solving the instruments, namely: 1) difficulty in understanding the questions (26%), 2) difficulty in determining the useable equations (25%), 3)

Table 1. Type and Percentage of Student's Difficulties

Type of Difficulty	Percentage of Student's Difficulty on Each Problem (%)					Average Percentage (%)
	1	2	3	4	5	
Difficulty in Understanding the Questions (D1)	33	20	17	27	33	26
Difficulty in Determining the Useable Equations (D2)	14	21	20	47	26	25
Difficulty in Substituting the Data to the Equation (D3)	71	67	55	59	65	63
Difficulty in Performing Mathematical Operations (D4)	85	77	68	73	77	76

difficulty in substituting the data to the equation (63%) and 4) difficulty in performing mathematical operations (76%). The data in this table can be illustated through Figure 3.

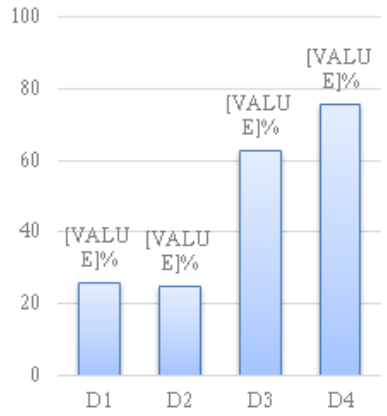

Figure 3. Graph of the Average Percentage of Student's Difficulties in Solving Momentum and Impulse Problems

On the Figure 3, it can be seen that D4 had the highest percentage of students' difficulties. It happen because majority of respondents (76%) made a mistake in performing mathematical operation, so they did not get the correct answer. It still happen eventhough they succeeded in understanding the question (D1), determining the useable equation (D2), and substituting the variabel to the equation (D3) correctly. Consequently, when they can not undertanding the question or determining the useabel equation or subtituting the data correctly, they will face D4 difficulties and get a wrong answer, like what happen to R-50 showed in Figure 5 below.

After further analysis, the type of student's difficulties above can be classified into Physical Difficulties and Mathematical Difficulties, which can be described as follows:

Physical Difficulties

The physical difficulties are type of student's difficulties related to the physics abilities possessed by students. These types of difficulty include:

Difficulty in Understanding the Questions

In this study, students were considered to have this difficulty when they were unable to write down variables provided on the question, along with its values and units, correctly. The variables include the known variables and the asked variabel. Based on the research data above, there were varies number of students who facing this difficulty on each problem. On average, there were 26% of students who faced this difficulty while solving problems provided on the research instrument.

The interview results revealed that this difficulty is caused by students' lack of understanding on the vector and scalar concepts. Most of students thought that velocity is a scalar quantity. So, they did not pay much attention to the signs, either positive or negative, when they wrote down the value of known variables on the problem. This is an examples of student's answers which showing the student's difficulty in understanding the questions referred in this study:

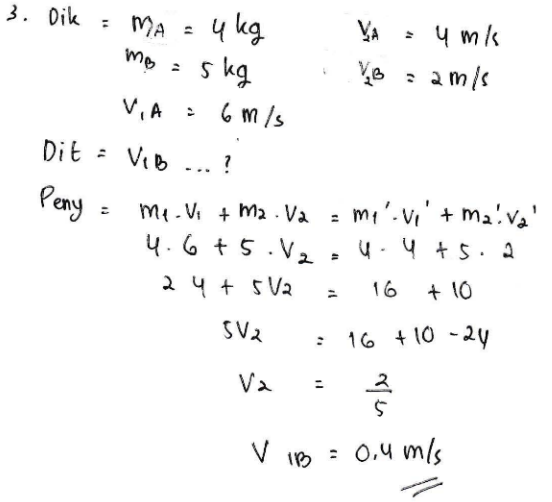

Figure 4. Respondents' (R-25) Answers on Question Number 3.

The question number 3 on the test instrument illustrates a collision between two balls moving in opposite directions. Based on Figure 4, it can be seen that the velocity of the objects has the same sign, which is both positive, neither before or after the collision. This is the response of R-25 while asked:

Q: "What do you think about this question? Why the known variables that your write down has positive sign?"

A: "I think, this question asks me to find the velocity of 5 kg ball before the collision. If I consider this is A ball and this is B ball (ponting to the picture on tested instrument), it means the velocity of A ball before collision is 6 m/s and after collision is 4 m/s. For B ball, the velocity before collision is unknown and after collision is 2 m/s. Hm, is it wrong?"

Q: "It almost right, I mean, the value is right, but the sign is wrong. Don't you considering the sign of velocity before and after collision?"

A: "Oh, do you mean the positive sign if traveling to the right and negative sign if traveling to

the left? I don't think about it. Actually, I don't understand what is the direction of the balls after the collision.
Q: "Hm, didn't you read at the question that the ball is move in reverse direction after the collision?".
A: "Oh, is it the condition after collision? I thought it's before the collision, like on the picture."

The answers of R-25 above explained that the respondent does not fully understanding the problem. If the respondent understands it well, the respondent will surely know that the velocity of objects will have different values and directions after the collision happen. This mistake indicates that the respondent faces difficulty in understanding the meaning of questions properly.

In addition, there were also some students who did not write down the known and asked variables while answering the questions. This is an example response while a respondent asked:
Q: "Why don't you write down the known and asked variables in the question while answering this problem?"
A: "Actually, I am not used to write down the variables because it confusing. I must consider the value and the sign of the variable before use it. I prefer to write down the equation directly so I can understand what is being asked and what variabel I need to find the solution."

According to the answer, it easier for some students to use the data provided in the questions when they has write down the equation first. So, they can immediately perform the calculation in order to get the answer they want. But, this strategy is tricky because most of student will get a wrong answer if they are not careful.

This results are in line with Rohmah (2018) and Juwariyah's (2018) study which stated that most of students were not used to write down the known variables when they were working on physics problems. In some cases, this condition will not cause a significant problems on the final answer. However, on momentum and impulse topics, most of students will experience several problems when they do not pay attention to the condition of variables.

Difficulty in Determining the Usable Equation

In this study, students were considered to have this difficulty when they were unable to write down the correct equations which would be used to solve the problems posed in the research instrument. Based on Halliday Resnick (2004), the usable equation in impulse and momentum concept are:
The linear momentum equation:
$p=mv$
The impulse equation:
$I=F\,\Delta t$
The impulse-momentum equation:
$I=\Delta p$
The law of consevation of linear momentum equation:
$^{\Delta p}i=^{\Delta p}f$
$m_{1i}.v_{1i}+m_{2i}.v_{2i}=m_{1f}.v_{1f}+m_{2f}.v_{2f}$

In this research, there were 25% of students who faced this difficulty while solving problems provided on the research instrument. Based on interviews with selected respondents, it is known that majority of students faced difficulty in solving collisions problem. It is caused due the students' lack of understanding on the collisions concept and conservation of momentum. This condition occurs because students always memorize the physics equation without understanding its usability. So, they frequently experienced difficulty while solving a problem which served in different form as examples they have worked on before. Although the questions is still applying the same concept and equation to solve it. This is an example of students' answer which showing the student's difficulty in determining the correct equations referred in this study:

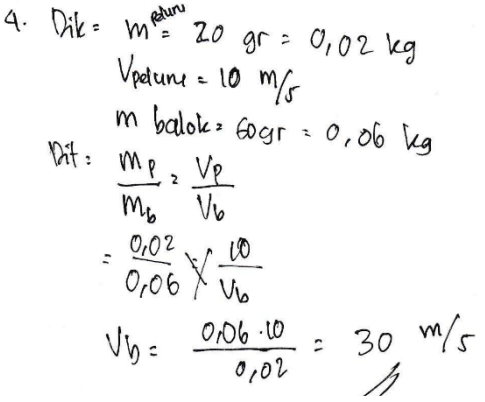

Figure 5. Respondents' (R-42) Answers on Question Number 4.

The question number 4 on the test instrument asked students to determine the velocity of a block after being hit by a bullet fired at it. In this problem, students should use the conservation of momentum equation. Based on Figure 5, it can be seen that the respondent use different equation which have never been taught in class. During the interview, the respondent stated that he forgot the equation which must be used. So, he decided to make his own equation by comparing the mass of the block and the bullet with its velocities. This

condition is supported by the reseach results of Rahmat (2017) which revealed that some students who do not remember the usable equation to solve a physics problem prefer to modify a remembered equation in order to get the expected answer.

Mathematical Difficulties

The mathematical difficulties are type of student's difficulties related to the mathematical abilities possessed by students. These types of difficulty include:

Difficulty in Substituting the Data to the Equation

In this study, students were considered to have this difficulty when they were unable to substitute the known variables in the questions into the equations which they had written correctly. In this research, there were 63% of students who faced this difficulty while solving problems provided on the research instrument. Based on interview results, it is known that this difficulty are basically influenced by student's mistake when determining the values of variables. All students who have difficulty in understanding the questions and made mistakes when writing the values of variables, can be preconcerted facing difficulty in substituting the variable values into the equations. This condition is a domino effect of the mistakes which they have done before.

Apparently, there were students who still faced this difficulty even they did not make mistakes when writing the values of the known variables. This is an example of the mistake which have been made by these students:

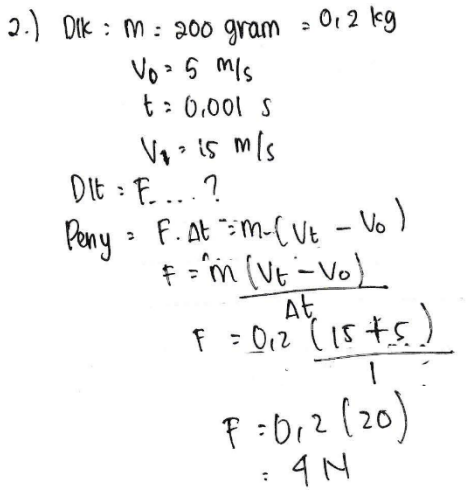

Figure 6. Respondents' (R-13) Answers on Question Number 2

The question Number 2 on the test instrument asked students to determine the amount of force exerted by a hitter on a ball. Based on Figure 6, it can be seen that the respondent has written down the value of known and asked variables, as well as the usable equations, correctly. But when substituting process, the respondent made a mistake in substituting the values of initial velocity and contact time into the equation. As a result, the respondent's answer gone wrong.

Based on interview results, this condition happened because the respondent faced difficulty when trying to substitute the initial velocity value into the equation. According to the respondent's explanation, the initial velocity value which known in the question is positive, while the initial velocity on the equation is negative. This made the respondent confused, so he decided to change the velocity sign on the equation in order to matched it with the initial velocity value in the question. In addition, the respondent also said that he was not meticulous when working on the problem. So, he made a mistake when substituting the value of time variable into the equation.

This results are supported by Pratama et al. (2017) which revealed that students who made mistakes in writing the known variables will automatically made a mistake when substituting the variable values into the equations. Finally, it will drive student to get a wrong answer during the processes. However, this mistake does not absolutely happen to all these students, but can also happen to other students due to meticulous and human error while solving the physics problem.

Difficulty in Performing Mathematical Operations

In this study, students are considered to have this difficulty when they are not able to perform mathematical operations, both in the form of addition, subtraction, multiplication or division, properly to get the correct answer. In this research, there were 76% of students who faced this difficulty while solving the problems provided on the research instrument. Based on interviews, it is known that this difficulty occured due to the weakness of student's abilities in performing mathematical operation. This weakness generally lies in the ability to solve problems in linear equations. Based on respondent's answers, most of the mistakes occur when the respondent multiplies or divides a positive integer by a negative integer or vice versa. On the written answers, respondents only perform the mathematical operation without paying more attention to the signs accompanying the numbers. This result is supported by Aufah et. al. (2014) research result which revealed that the difficulties caused by inaccuracies in performing mathematical calculations. They did not careful

in multiplying or dividing numerical numbers.

In addition, some students also seem to have difficulty in performing operations which involved equalizing linear equations. This happened because most of students have misunderstand the basic concept of solving the linear equation. Where they often assume: if a number has "moving segment" (*pindah ruas*), then the 'sign' must be changed (either from positive to negative or vice versa). Based on this answer, they indirectly did not realize that this action was wrong, especially if the number that they operate is in the form of a multiplication or division. At that stated, the 'sign' cannot be changed outright. Aufah et. al. (2014) study revealed that students who faced difficulty in mathematical calculations because they did not change the numerical sign when moving segments.

According to Laja (2020), it happened as an result of teacher mistakes while teaching the process of solving linear equations in math. The rule of 'moving segments' is actually a procedural error which is inexcusable even if it simplifies the process of solving mathematical problems. Because this rule is never existed and was unjustified in mathematics theory. The correct process of solving linear equations is through line elimination operations which are conducted by adding, subtracting, multiplying or dividing the two segments by the same number. This mathematical misunderstanding cannot be tolerated because it causes several mistakes which driving students to get a wrong answer at the end of their problem solving process.

An example of mistakes which has been made by these students can be seen below:

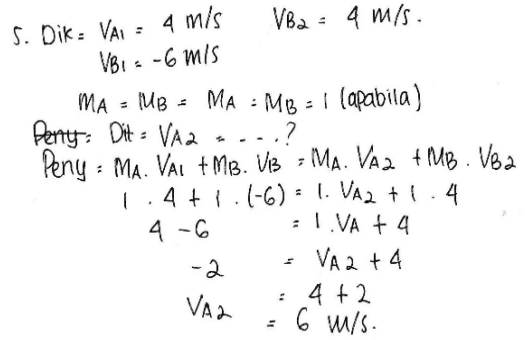

Figure 7. Respondents' (R-50) Answers on Question Number 5

The question Number 5 on the test instrument asked students to determine the velocity of a ball which experienced elastic collision. Based on Figure 7, it can be seen that the respondent facing difficulty in performing mathematical operation, especially in solving the linear equation problem. When answering question number 5, the respondent was successful in understanding the question (D1), determining the useable equation (D2), and substituting the variabel to the equation (D3) correctly. However, when performing mathematical operations related to linear equations, the respondent made an error when performing the moving segment operation. It can be seen on Figure 5 that the respondent only moved the existing variables () without paying attention to the sign, so the results obtained were wrong.

According to interview, R-50 admitted that he was not careful in the process of completing the moving segment operation. This condition did not only occur in physics subjects, but also in mathematics and chemistry subjects which require moving segment operations to solve the problem. This results is supported by Rufaida (2012) which revealed that some students admitted that they could not conduted the linear equation operation while working on momentum and impulse problems. This happened because they did not really understand the mathematical operation of linear equation. Whereas according to Lestari et. al. (2016), the mathematical skills possessed by students had significant affect to the problem solving skill in physics. Where the weaker their mathematical skills, the more difficulties they faced in solving physics problems, and vice versa. Therefore, this mathematical skill really needs to be considered by the teacher, so that their students are able to solve physics problems without experiencing difficulties or making any mistakes.

Additionally, some respondents also revealed that their difficulties in solving physics problem were actually caused due to lack of physics learning process which is not honing their problem solving skills. This condition is supported by Datur (2016) which revealed that the physics learning strategies carried out by teacher are rarely polished the student's problem solving skill in physics subject. Whereas, physics problem solving skill is one of important skills which is need by students who want to continue their education or aspire to find a job related to physics field.

On the other hand, those difficulties also happened because majority of students were lazy to practice in solving physics problems outside predetermined class. This result is also consistent with the research result achieved by Khairani (2019) which shown that the lack of students motivation in learning physic also one of the causes of the advent of student's difficulties in solving physics problems at secondary schools. Accor-

ding to Sari (2018), those difficulties will decrease student's achievement in physics subject. Thus, these student's difficulties must be overcome immediately by the teacher or student itself. So, it will not have a critical impact on the physics learning outcomes and student achievement in the near future.

According to Azizah (2015), one of the efforts which can be conducted by the teacher to overcome the students difficulties on problem solving is by applying a learning method which focused on solving physics problems based on its concepts. Furthermore, students must be given more opportunities to solve various physics problems individually. So, they can develop their problem solving skills by his/herself. However, this method must also be flexible and adjustable to the student conditions and abilities in each level. Hoping that they can learn physics well without any pressured which can ruin their motivation and their interest in learning physics. Susiana (2017) suggested that to improve students' problem-solving abilities, the learning activities in physics must be student-centered not teacher-centered. Teachers must applied learning strategy and provide learning materials which can help students improving their problem solving skills.

CONCLUSION

Based on the results and discussion, it can be concluded that student's difficulties in solving momentum and impulse problems can be grouped into physical difficulties and mathematical difficulties. The physical difficulties consist of student's difficulty in understanding the questions (26%) and student's difficulty in determining the useable equations (25%). Meanwhile, the mathematical difficulties consist of student's difficulty in substituting the data to the equation (63%) and student's difficulty in performing mathematical operations (76%). Based on interviews and analysis, these difficulties are caused by several factors, namely: 1) the lack of student's understanding about physics concepts, 2) the weakness of student's mathematical skills, 3) the lack of physics learning process which is not honing student's problem-solving skills and 4) the lack of student's motivation on developing their problems solving skills in physics subjects.

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