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The Characteristics of The Elevator Motion Based on The Object's Apparent Weight

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Abstract: This study aims to examine the characteristics of the lift motion based on apparent weight data. This type of research is quantitative research with a survey method. The results showed that the apparent weight change only occurred when the elevator started moving and just before it stopped, acceleration at the beginning of the motion and deceleration at the end of the motion. Elevator has two characteristics of motion; straight motion with constant velocity and straight motion with constant acceleration. Straight motion with constant acceleration consists of accelerated motion that occurs at the beginning of the elavator motion, and straight motion with constant acceleration slowed down at the end of the elevator motion. Meanwhile, straight motion with constant velocity occurs with a longer duration. This study's results have implications for learning physics, one of which can be used as data to develop learning resources for physics in the form of student worksheets.

Keywords: Apparent weight, Elevator motion, Newton's law

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INTRODUCTION

Physics as a natural science explains observable phenomena with concepts, laws, and theories based on experience, rationale, and experimentation (Suwindra *et al.*, 2015). Physics is also defined as an experimental science in which physicists must observe natural phenomena to find patterns and principles that connect them to these phenomena (Patriot, 2019; Young *et al.*, 2016). The essence of physics includes curiosity about natural objects and phenomena that cause new problems that can be solved through scientific methods (Erlina *et al.*, 2017). Everyday natural phenomena can be studied and analyzed to study physics concepts because many physics concepts are related to everyday life (Oktaviani *et al.*, 2017; Virani *et al.*, 2018). In learning physics, the material studied in physics is a phenomenon that occurs in nature and is always related to everyday events (Supeno *et al.*, 2017).

Many phenomena in the surrounding environment are related to the principles, theories, or laws of physics, but have not been widely explored and used as contextual learning resources in physics learning. One of the physical phenomena in the environment is the phenomenon of elevator motion. An elevator is a vertical vehicle with periodic movements. It is used to transport (up / down) people or goods through a vertical rail line, generally used in tall buildings (Musyahar *et al.*, 2017). An elevator can save energy and time compared to walking on stairs in tall buildings. The elevator works automatically at a certain speed. When we are in a moving elevator, our gravity will change according to the elevator's movement (Taufiq, 2017). When the elevator moves up, the bodyweight seems to increase, as well as when the elevator moves down; the weight seems to decrease. Meanwhile, when the elevator is at rest, our gravity is still normal. The amount of perceived weight that is felt depends on the elevator floor's upward force to humans (Roy, 2020). Perceived weight is commonly referred to as apparent weight.

Apparent weight can be studied based on Newton's Law of motion. When the elevator is at rest or moving at a constant speed, its acceleration is zero. In this condition, the force equilibrium (Newton's First Law) applies where $\sum \vec{F}_y = 0$ so that the compressive force of the load acting on the elevator floor is the same as the weight of the load. When the elevator is moving at constant acceleration, the load's weight is not the same as the normal force of the lift on the load. It can be explained using Newton's Second Law where $\sum \vec{F}_y = m\vec{a}$ (Pauliza, 2008). The apparent weight in a moving elevator can be used to analyze the characteristics of the elevator motion.

Elevator motion is a physical phenomenon that occurs in real terms in our environment. The elevator motion phenomenon has not been studied extensively, so it can be analyzed for its motion characteristics. In learning physics at school, the phenomenon of elevator motion can be used as a source of contextual learning. Contextual learning resources are needed in physics learning (Astro *et al.*, 2020; Pratiwi *et al.*, 2017) because physics is a natural phenomenon that requires students to understand knowledge contextually (Siswono, 2017). Although there are a lot of physical phenomena in the environment around students that can be used as learning resources (Ramadhani *et al.*, 2019), the teaching materials in some schools mostly emphasize material descriptions rather than applications and do not relate to physics concepts to everyday problems (Wahyuni *et al.*,2017). Therefore, it is necessary to research the characteristics of elevator motion to increase physics learning resources based on physical phenomena in the environment of students. The purpose of this study was to examine the characteristics of the lift motion based on apparent weight.

METHOD

Research Design & Procedure

The type of research is quantitative research with a survey method. The survey method is used to get data from a specific place naturally. Researchers collect data by observing actual events in the form of elevator movements. Data were collected using a digital floor scale, a load of 39.28 kg, a stopwatch, and a smartphone as a recorder. Data acquisition was carried out in 3 different lifts. Elevators 1 and 2 are located in the Center for Development of Advanced Science and Technology (CDAST) building, University of Jember. Elevator 1 reaches a height of 8 floors with a maximum load of 1000 kg or 15 person. Elevator 2 reaches a height of 8 floors with a whole load of 800 kg. Elevator 3 is in the Postgraduate building, Faculty of Law, University of Jember. Elevator 3 spans five floors with a maximum load of 1150 kg or 17 person. This research was conducted in several stages, as shown in Figure 1.

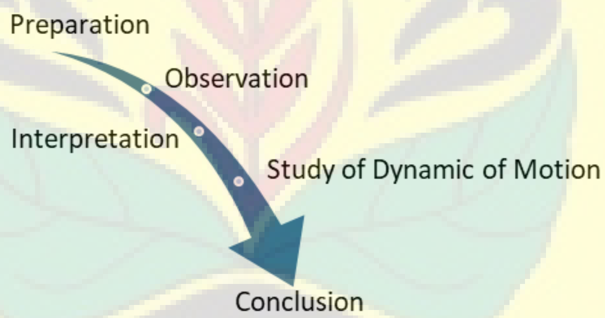

Figure 1. Research stages

The research begins with the preparation stage. At this stage, a literature review is carried out to obtain data, information, and theories that support the research. The literature review is carried out using physics books and scientific journals. The second stage is data acquisition in the field. Data acquisition is an act of measuring the load's weight directly in a moving elevator with a specific travel time. The actual mass of the load used is 39.28 kg. Measurements are made by recording the weight gauge LCD screen and the time when the elevator moves until it stops. Based on these records, the measurement data can be tabulated. The measurement data consists of building height, load weight, elevator travel time, and apparent load weight. The measured data were analyzed for 4 seconds. The balance used has a time response of 3 seconds to obtain valid data. The data must be interpreted with an interval of $\geq$ 3 seconds from the time response of the scale.

Analysis

The measurement result data is then analyzed based on Newton's Second Law equation (Eq. 1) to obtain elevator acceleration data.

$$\vec{F}_N - \vec{F}_g = m\vec{a} \quad (1)$$

Based on the lift acceleration data, a study of the lift motion dynamics can be carried out. When the elevator is moving with constant acceleration, it has a straight and regular motion (Prihatini *et al*., 2017). When the elevator is moving at a constant speed, it has the characteristic of regular straight motion (Handayani *et al*., 2019)

RESULT AND DISCUSSION

Elevator 1 at CDAST University of Jember

Data acquisition in elevator 1 at CDAST University of Jember is carried out in 2 conditions: the elevator moves up and down. The measurement result data is shown in Table 1.

Table 1. Data from elevator 1 at CDAST University of Jember

Height (floor)	Direction of motion	w (N)	t (s)	F_N (N)	a (m/s^2)
8	To the top	384.94	0	384.94	0,00
			4	401,11	0,41
			8	384,94	0,00
			12	384,94	0,00
			16	384,94	0,00
			20	385,04	0,00
			24	384,94	0,00
			28	384,94	0,00
			32	368,68	-0,41
			36	384,94	0,00
8	Down	384.94	0	384,94	0,00
			4	368,77	0,41
			8	384,94	0,00
			12	384,94	0,00
			16	384,94	0,00
			20	384,94	0,00
			24	384,94	0,00
			28	384,94	0,00
			32	401,11	-0,41
			36	385,14	0,00

Based on the research data in Table 1, it can be seen that the travel time when elevator move from the 1st floor to the 8th floor is around 36 s. When the elevator moves vertically upwards, the measured load weight value or apparent weight changes. The changes of apparent weight occur when the elevator starts moving and when the elevator stops. The change of apparent weight occurred at 4 s and 32 s. In the 8th to

28th seconds, the apparent weight is equal to the weight of the real load. The data of apparent weight can be analyzed mathematically to determine the acceleration of the elevator motion. The study was carried out using Newton's second law. Based on the results of the analysis, it can be seen that there is a very significant increase in velocity at 4 s and a very significant decrease in velocity at 32 s. For intervals 8 s to 28 s, the elevator moves at zero acceleration. It means that the elevator moves at a constant velocity. When 0 s and 36 s, the elevator is at rest.

The apparent weight becomes 368.77 N at 4 s when the elevator moves vertically downward. At 32 s, the apparent weight becomes 401.11 N. For intervals 8 s to 28 s, the weight of the load is equal to the real weight. The apparent weight and the elevator travel time are then analyzed mathematically using Newton's Second Law equation to determine the elevator's acceleration. The acceleration of the elevator can be seen in Table 1. The elevator experiences acceleration only occurs when the elevator starts moving and when it is about to stop.

The research data in Table 1 can be interpreted in the form of a graph of the apparent weight-to-time relationship and the acceleration-time relationship graph shown in Figure 1 to Figure 5.

Figure 1. Apparent weight and time in elevator 1 as it moves upward

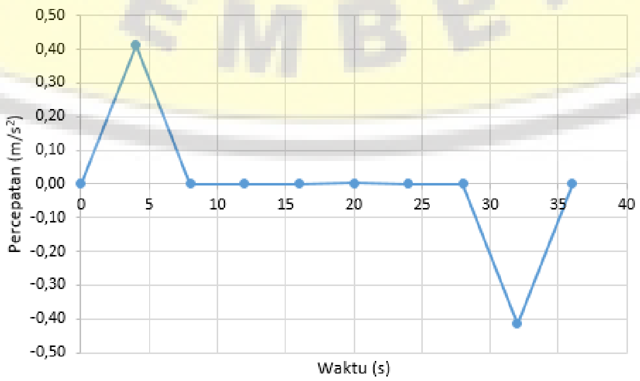

Figure 2. Acceleration and time in elevator 1 as it moves upward

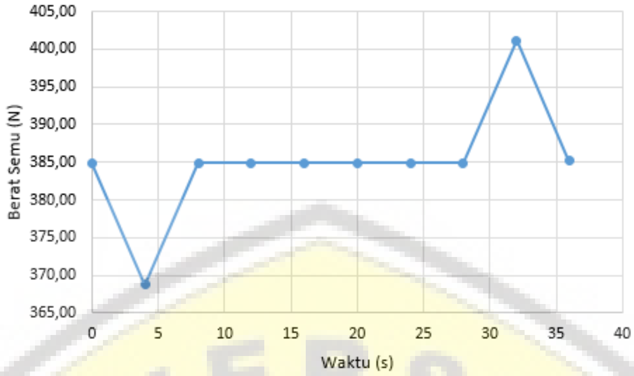

Figure 3. Apparent weight and time in elevator 1 as it moves downward

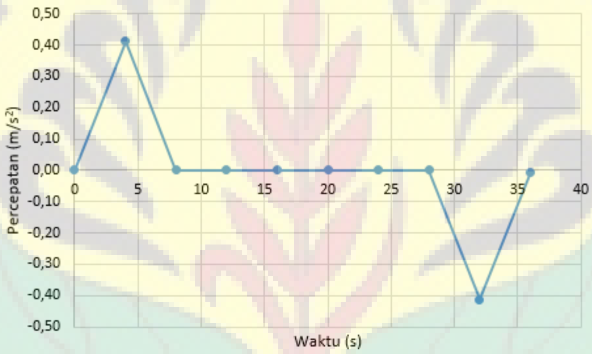

Figure 4. Acceleration and time in elevator 1 as it moves downward

Elevator 2 at CDAST University of Jember

Data acquisition in elevator 2 at CDAST University of Jember is carried out in 2 conditions: the elevator moves up and down. The measurement result data is shown in Table 2. The apparent weight increases to 399.64 N at 4 s when the elevator moves vertically upwards. At a time interval of 8 s to 28 s, the weight of the load does not change, which is 384.94 N. When the elevator is about to stop, at 32 s, the apparent weight decreases to 370.15 N. The acceleration of the elevator is obtained using Newton's Second Law. The analysis results show that the elevator only experiences acceleration at 4 s and 32 s, where the elevator acceleration is 0.37 m/s^2 and -0.38 m/s^2, respectively. A positive sign at 4 s indicates increasing acceleration, while a negative sign at 32 s indicates a deceleration of the elevator motion.

The apparent weight changes for intervals 4 s and 32 s when the elevator moves vertically downwards. When 4 s, the apparent weight is smaller than the real weight, which is 370.24 N. The apparent weight at 32 s is greater than the real weight, which is 399.74 N. The elevator accelerates at an interval of 4 s to 32 s, respectively 0.37 m/s^2. The elevator is accelerating at 4 s, and slowing down at 32 s.

Table 2. Data from elevator 2 at CDAST University of Jember

Height (floor)	Direction of motion	w (N)	t (s)	F_N (N)	a (m/s^2)
8	To the top	384.94	0	384,94	0,00
			4	399,64	0,37
			8	384,94	0,00
			12	384,94	0,00
			16	384,94	0,00
			20	384,94	0,00
			24	384,94	0,00
			28	384,94	0,00
			32	370,15	-0,38
			36	384,94	0,00
8	Down	384.94	0	384,94	0,00
			4	370,24	0,37
			8	385,04	0,00
			12	385,04	0,00
			16	385,04	0,00
			20	385,04	0,00
			24	384,94	0,00
			28	384,94	0,00
			32	399,74	-0,37
			36	384,94	0,00

The research data in Table 2 can be interpreted in the form of a graph of the apparent weight-to-time relationship and the acceleration-time relationship graph shown in Figure 6 to Figure 9.

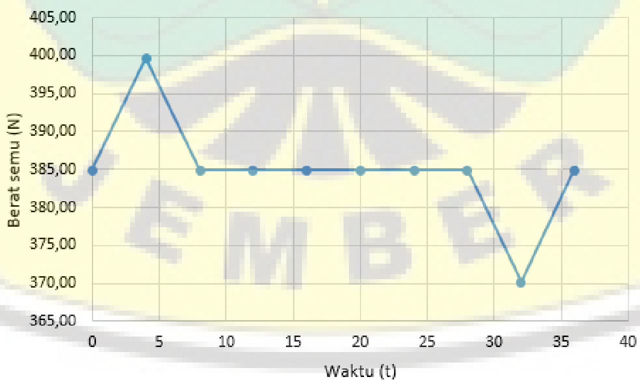

Figure 5. Apparent weight and time in elevator 2 as it moves upward

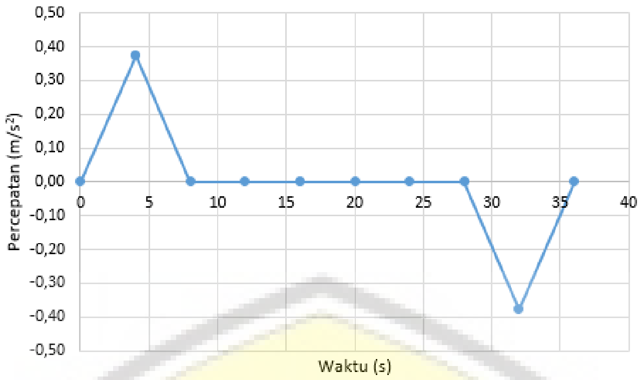

Figure 7. Acceleration and time in elevator 2 as it moves upward

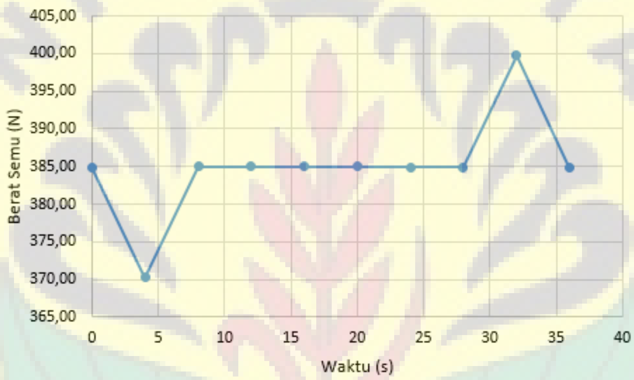

Figure 8. Apparent weight and time in elevator 2 as it moves downward

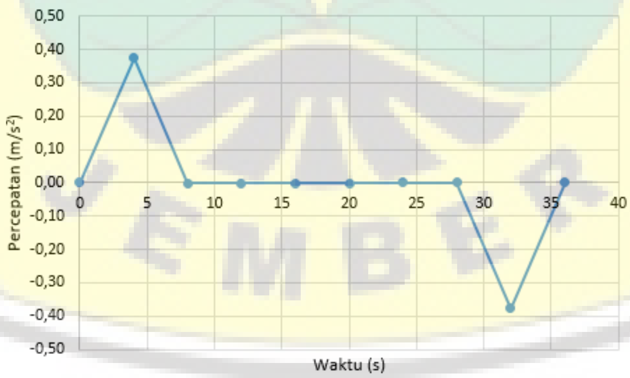

Figure 9. Acceleration and time in elevator 2 as it moves downward

Elevator 3 in Postgraduate building, Faculty of Law, University of Jember

The third research location is elevator 3 at the Postgraduate building, Faculty of Law, University of Jember. The measurement result data is shown in Table 3.

Table 3. Data from elevator 3 Postgraduate building, Faculty of Law, University of Jember.

Height (floor)	**Direction of motion**	**w (N)**	**t (s)**	**F_N (N)**	**a (m/s^2)**
5	To the top	384.94	0	384,94	0,00
			4	406,01	0,54
			8	384,75	0,00
			12	384,94	0,00
			16	384,94	0,00
			20	363,68	-0,54
			24	384,94	0,00
5	Down	384.94	0	384,94	0,00
			4	363,58	0,54
			8	384,94	0,00
			12	384,94	0,00
			16	384,94	0,00
			20	406,01	-0,54
			24	384,94	0,00

Based on the research data in Table 3, it can be seen that the elevator travel time when moving from the 1st floor to the 8th floor is around 24 s. When the elevator moves vertically upwards, the measured load weight value changes. Changes in load weight occur when the elevator starts moving and when the elevator stops. The most significant change in weight value occurred at 4 s and 20 s. For intervals 8 s to 16 s, the weight of the load is relatively the same as the weight of the actual load. The apparent weight can be analyzed mathematically to determine the acceleration of the elevator motion. The study was carried out using Newton's second law. Based on the results of the analysis, it can be seen that there is a very significant increase in velocity at 4 s and a very significant decrease in velocity at 20 s. In the range of 8 s to 16 s, the elevator moves at zero acceleration. It means that during that time, the elevator moves at a constant velocity. When 0 s and 20 s, the elevator is at rest.

The apparent weight becomes 363.58 N at 4 s when the elevator moves vertically downward. When 20 s, the apparent weight becomes 406.01 N. For intervals 8 s to 16 s, the weight of the load is relatively the same as the weight of the actual load. The apparent weight and the elevator travel time are then analyzed mathematically using Newton's second law to determine the acceleration of elevator motions. The acceleration of the elevator can be seen in Table 3. The elevator experiences acceleration only occurs when the elevator starts moving and when it is about to stop.

The research data in Table 3 can be interpreted in the form of a graph of the apparent weight-to-time relationship and the acceleration-time relationship graph shown in Figure 10 to Figure 13.

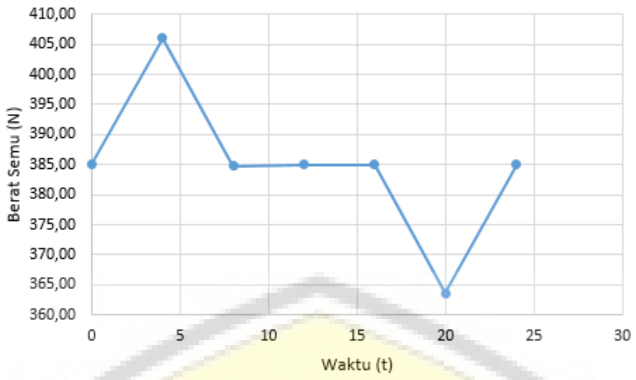

Figure 10. Apparent weight and time in elevator 3 as it moves upward

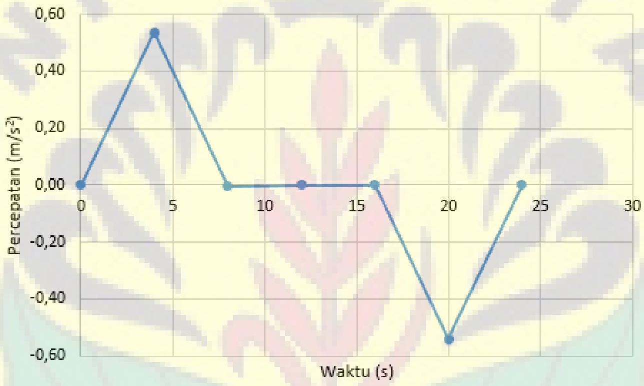

Figure 11. Acceleration and time in elevator 3 as it moves upward

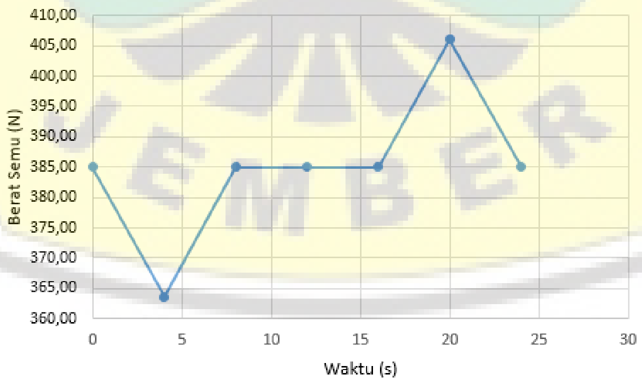

Figure 12. Apparent weight and time in elevator 3 as it moves downward

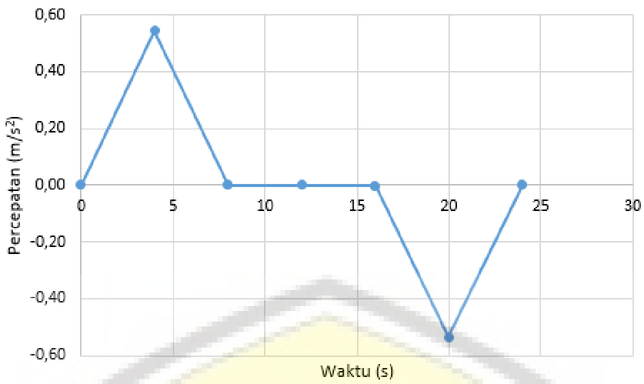

Figure 13. Acceleration and time in elevator 3 as it moves downward

Discussion

Based on data analysis on the motion of the three elevators, it shows consistent results. Elevator travel time can be divided into three intervals. The first time interval is a condition where the elevator starts moving. The second time interval is a condition for the elevator to move uniformly. The third time interval is a condition for the elevator just before it stops. The apparent weight changes when the elevator moves vertically upward. The apparent weight increases at the beginning of the elevator motion. When the motion is uniform, the apparent weight is equal to the real weight. The apparent weight decreased at the third time interval.

Meanwhile, when the elevator moves vertically downwards, the apparent weight also changes three times. The apparent weight has decreased at the start of the elevator motion. The apparent weight is equal to the real weight when the motion is uniform. The apparent weight decreased at the third time interval. The results of this study are in line with the research conducted by Roy (2020). The number that is read on the weighing screen shows the apparent weight, not the object's actual weight (Halliday *et al*., 2011). This weight is the normal force that the elevator floor exerts on objects when the elevator moves with a certain acceleration. Newton's Second Law applies in the apparent weight phenomenon, where the resultant force on an object is directly proportional to the object's acceleration (Giancoli, 2014).

The apparent weight depends on the acceleration, and it can be positive and negative according to the direction of motion of the elevator. The elevator experiences acceleration when it starts moving upwards so that the weight seems to increase. Shortly before stopping, the elevator is slowing down so that the acceleration is negative. Its condition causes the apparent weight to be less than the actual weight of the object. When the elevator starts moving downwards, the elevator speed increases downward so that it is negative. Its condition causes the apparent weight to be less than the actual weight of the object. Shortly before stopping, the elevator is slowing down so that the acceleration is positive, which causes the apparent weight to be greater than the actual weight.

Based on the analysis of apparent weight data and elevator travel time, acceleration of motion data can be obtained. The elevator is accelerating when it starts moving and when it is about to stop. The elevator acceleration is positive at the beginning of its motion and negative at the end of its motion when it moves vertically up or down. This condition indicates that the elevator is accelerated when the elevator starts moving and is slowed down when the elevator is about to stop. The elevator acceleration is zero with a longer duration when the motion is uniform. So, it can be said that the elevator has two characteristics of motion, namely regular straight motion and regular changing straight motion. Straight motion changes regularly consist of two conditions, accelerated motion which occurs at the beginning of the motion, and slowed motion which occurs at the end of the motion. Meanwhile, regular straight motion occurs with a longer duration, namely when the elevator moves constantly.

The apparent weight is the normal force that the lift floor exerts on the load when the elevator is moving at a certain acceleration. If viewed from the rope tension force, the magnitude of the apparent weight is equivalent to the magnitude of the rope tension force. When the elevator is accelerating upward or slowing downward, the tension in the rope is greater than when the elevator is at rest. When the elevator is moving slowed up and accelerated downward, the tension in the rope is less than when the elevator is at rest. When the elevator is moving at constant speed, the tension force on the rope is equal to the tension force on the rope when the elevator is at rest. Meanwhile, when the elevator moves in free fall, the tension in the rope changes to zero. In that condition, someone who is in the elevator will feel weightless.

The implication of research on lift motion in learning physics can be used as a source of contextual physics learning. Learning resources are arranged in the form of worksheets. A simple experimental procedure can be presented in the worksheet regarding the apparent weight of objects in the elevator. The worksheet can be a guide for students to conduct experiments about apparent weight in the elevator. These activities can train skills in applying scientific methods (Supeno *et al.*, 2020) and improve scientific reasoning so that students are able to build their knowledge (Indahsari *et al.*, 2020) and able to solve problems (Efrihani *et al.*, 2017; Fitriyani *et al.*, 2019).

CONCLUSION

The apparent weight of a load in an elevator can be measured directly on the spot. Based on the apparent weight data, an analysis can be carried out to determine the elevator motion characteristics. In this study, it can be concluded that the elevator has two characteristics of motion; straight motion with constant velocity and straight motion with constant acceleration. Straight motion with constant acceleration consists of accelerated motion and slowed motion. Accelerated motion occurs at the beginning of the elevator motion, while slowed motion occurs just before the elevator stops. Straight motion with constant velocity occurs over a longer duration. The results are expected to provide critical information for physics teachers to develop learning resources in accordance with the phenomenon of elevator motion. Learning resources can be created in the form of worksheets or information corners inserted in textbooks. Contextual phenomena in physics learning resources are expected to help students know the application of physics in everyday life.

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