Research Article

Utilization of Video-based Laboratory (VBL) Using Tracker for Analysis of Object Motion on the Laboratory-Scaled Mini Roller Coaster

Dwi Sulistyaningsih, Rifa'atul Maulidah, Ifa Rifatul Mahmudah, Yanti Sofi Makiyah

Departement of Physics Education, Universitas Siliwangi, Siliwangi Street no. 24 Tasikmalaya City, 46115, Indonesia

ORCID
Dwi Sulistyaningsih: https://orchid.org/0009-0006-9967-1593
Rifa'atul Maulidah: https://orchid.org/0000-0002-5666-1225
Yanti Sofi Makiyah: https://orchid.org/0000-0003-0957-9365

Corresponding Author: Dwi Sulistyaningsih; email: dwi.sulistyaningsih@unsil.ac.id

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Abstract.
The use of teaching aids in learning can provide direct learning experiences to students so that learning becomes more meaningful. Students observe physics phenomena that occur and get physics data from these phenomena. The observed physics phenomena often happen very quickly, so it is impossible to record data manually. Therefore, a method is needed to facilitate data recording and analysis. One way to use a video-based laboratory (VBL) is by utilizing a tracker. This method allows for analyzing the objects contained in a video and displays the data in graphs and tables. This study aims to investigate the motion of objects using tracker video analysis on a mini-roller coaster tool. The video analyzed is a video of a solid ball-shaped object with a mass of 8.6 g moving along a roller-coaster trajectory. By tracking an object, physics data will be obtained to analyze acceleration and the law of conservation of mechanical energy. The analysis results match the experimental results and the physics concepts that apply to the roller coaster motion.

Keywords: video-based laboratory (VBL), tracker, laboratory-scaled mini roller coaster

1. INTRODUCTION

Physics as a part of science has the characteristics of teaching materials that are primarily abstract, so it requires reasoning and the ability to imagine in studying the material. However, only some students have the same imagination ability, so the ability to digest abstract information will be different. This resulted in some students needing help understanding the concept of physics, allowing the occurrence of misconceptions. The solution to reducing the event of conceptual errors due to students' inability to imagine abstractly is with the help of learning media, such as teaching aids, experimental tools, or practicum tools [1].

The use of teaching aids in learning can provide direct learning experiences to students so that learning becomes more meaningful. Students observe physics phenomena that occur and get physics data from these phenomena. The observed physics phenomena often happen very quickly, so it is impossible to record data manually. Therefore, a method is needed to facilitate data recording and analysis. One method that can use is a Video-Based Laboratory (VBL).

A Video-Based Laboratory (VBL) is a learning media based on object analysis contained in a video [2]. Using VBL makes it possible to observe swift movements that cannot mark with the human eye [2]. One of the software that can use for VBL is Tracker. Tracker is software that can analyze an object recorded on a video [3]. Data will obtain from the object's analysis results in tables and graphs. Utilization of VBL using Tracker software in experiments has been used to analyze the motion of Newton's pendulum swing [4], Rotational motion on fidget spinner toys [5], and parabolic motion analysis [6]. In this study, VBL will be used to analyze the motion of objects on a mini roller coaster.

A Roller coaster is a game vehicle in the form of a train driven at high speed on special rails [7]. Roller coasters take advantage of the force and potential of Earth's gravity to slide, dip and spin very quickly [8]. This vehicle can be used as a learning medium in the laboratory as a mini roller coaster. The mini roller coaster is a prototype designed to resemble the trajectory of a roller coaster ride. Can use this tool to understand physics concepts such as potential energy, kinetic energy, motion dynamics of an object, energy conservation, and the centripetal force experienced by objects moving along a roller coaster track [9]. This research is a follow-up study to previous research, where a mini roller coaster tool has been produced in previous studies. In this study, data collection carrying out to determine whether the device can obtain physics data by physics. From this research, we hope to use the tool to prove the truth of a theory in learning fundamental physics at the university level.

1.1. Physics Concepts on Roller Coaster Motion

Roller Coaster motion is accelerating, namely the change in velocity with time. Velocity increases with time while moving decreases. The roller coaster experiences a deceleration (negative acceleration), i.e., the velocity decreases with time as it moves up. Velocity changes also occur when the roller coaster changes direction [10]. The law of conservation of mechanical energy explains that the total kinetic and potential energy an object possesses at any point is always constant. This can happen if a system is isolated and the only influential forces are conservative [11]. Figure 3 shows that as the object moves from positions A to B and C, its potential and kinetic energy change at each point, but the sum of the two energies, mechanical energy, is constant.

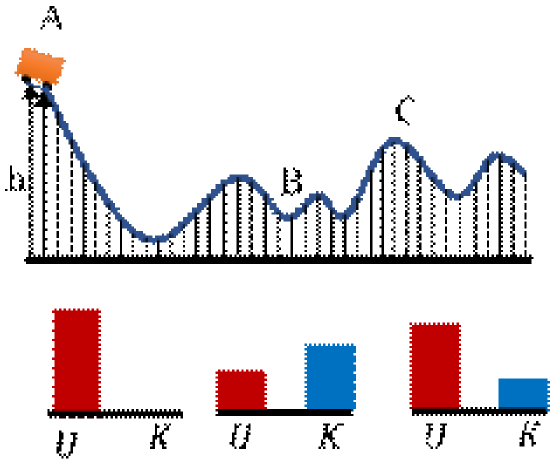


Figure 1: Illustration of the value of mechanical energy in the motion of an object with an up-and-down trajectory.

In real situations, non-conservative forces such as friction are challenging to ignore [12]. Work by non-conservative forces equals the change in mechanical energy [13]. This shows that the influence of non-conservative forces acting on the object causes its mechanical energy to be unstable.

$$W_{nk} = \Delta EM \tag{1}$$

Potential energy (U) is maximum when the roller coaster is at the top of the track on a roller coaster. And it's zero when it's at the lows. Potential energy is converted into kinetic energy when the roller coaster moves downhill. Meanwhile, Kinetic Energy (K) is the opposite of potential energy. Kinetic energy is at its maximum when it is at its lowest. Kinetic energy is converted into potential energy when the roller coaster moves [10].

Centripetal force is a force that tries to pull an object toward a central point (axis). When the roller coaster moves through a circular path, the centripetal force keeps the roller coaster moving in a circle [10]. When an object is in a vertical circular way, a normal force and a gravitational force are acting on the object. For the object to pass the trajectory perfectly, the normal force of the object will be zero because, at its minimum speed, the object will fall and not come into contact with the trajectory so that there is no frictional force [14].

$$F_g = ma_c \tag{2}$$

Where is the gravitational force, m is the object's mass, and $a_c$is the centripetal acceleration? The circular track on a roller coaster is not a perfect circle but a clothoid shape, as shown in Fig. 2. The clothoid shape can produce a relatively constant centripetal acceleration at each point [8].

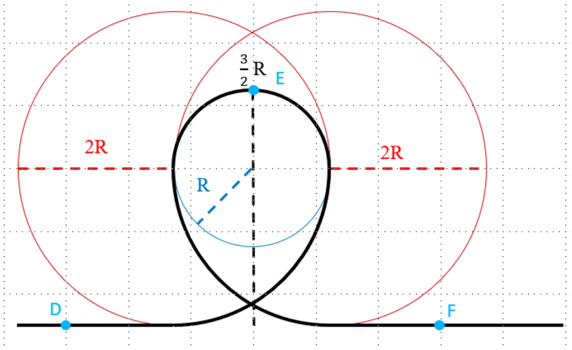


Figure 2: Clothoid loop.

2. RESEARCH method

This research uses using experimental method. This practical research tool consists of a mini roller coaster with dimensions of 120x40x20 cm, a solid ball of mass of 8.6 grams, a Samsung S8 cellphone camera, a camera tripod, a laptop Asus A42J Core i3, a software Tracker, a ruler, and analytical balance. The steps carried out in this experiment are as follows: (1) Prepare the mini roller coaster by placing the tool on a flat place; (2) Mounting the camera on a tripod for easy video shooting; (3) Adjusting the camera position so that the object will analyze in the video is in a 2-dimensional plane; (4) Recording the movement of objects along a roller coaster track; (5) Analyze videos using Tracker to get physics data.

The steps taken to obtain physics data using the Video-Based Laboratory method using Tracker are as follows: (1) Import the video to will analyze into the Tracker; (2) Setting the coordinate axes (x and y axes); (3) Calibrate the stick so that the data obtained from the Tracker analysis matches the actual size; (4) Tracking objects (solid-ball); and (5) Analyze physics data.

3. result and discussion

This study obtained physics data from video analysis results using Tracker software. Therefore, paying attention to several things in taking a video is necessary, including

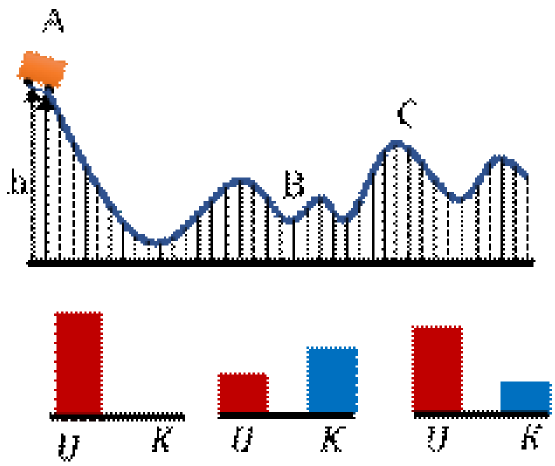


Figure 3: Reading point of physics data.

Table 1: Position of object.

Position	Height (m)
A	0.310
B	0.064
C	0.191
D	0.046
E	0.127
F	0.046

video quality. The analyzed video has UHD (Ultra High Definition) quality with a resolution of 2160x3840 and a 29 frames/second frame rate. This will make tracking videos easier because it's still apparent when the object will zoom in. In addition, the object's movement is captured in more detail so that the data reading is more accurate according to the desired point.

Another thing to note is an object of known actual size into the video frame for calibration. This is so that the data obtained from the Tracker analysis results by the actual size. In this study, the object used as a calibration stick is the base of a mini roller coaster with a length of 1.188 m—the results of the video analysis with Tracker, as shown in Fig. 4.

The results of video tracks are in the form of data presented in graphs and tables. The standard modeling display generated after a video will analyze as a position versus time graph. However, users can add variables to find other quantities, such as velocity on the x-axis and y-axis, acceleration, energy, and different amounts. Video tracking is repeated five times to determine the accuracy and precision of the resulting data. The

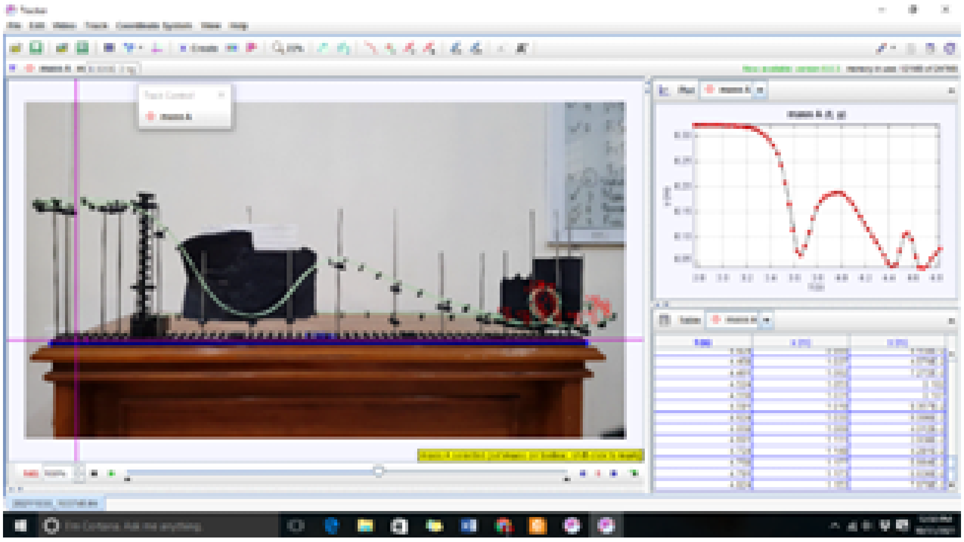


Figure 4: Tracking video results with a tracker.

data obtained is then analyzed to prove the truth of the physics concept of roller coaster motion.

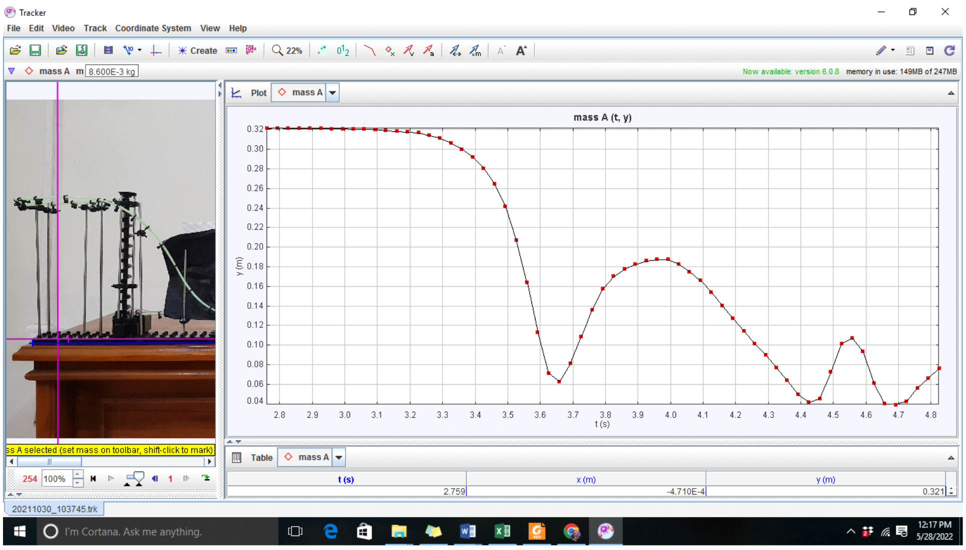


Figure 5: Graph of position (in the y-axis) vs. time.

3.1. Analysis of Object Acceleration

One mode of representation that needs to be understood is the graphical representation mode. If students correctly understand this, it will be easier to solve various physics problems [15]. The data from the video tracking results determine the object's acceleration graph. Acceleration is the change in velocity with time. The acceleration analyzed here is the acceleration in the y-axis direction, which is the acceleration in the direction of the earth's gravitational acceleration. The acceleration graph in the y-axis direction versus the time of an object moving from point A to point F (Fig. 3) is shown in Fig. 6.

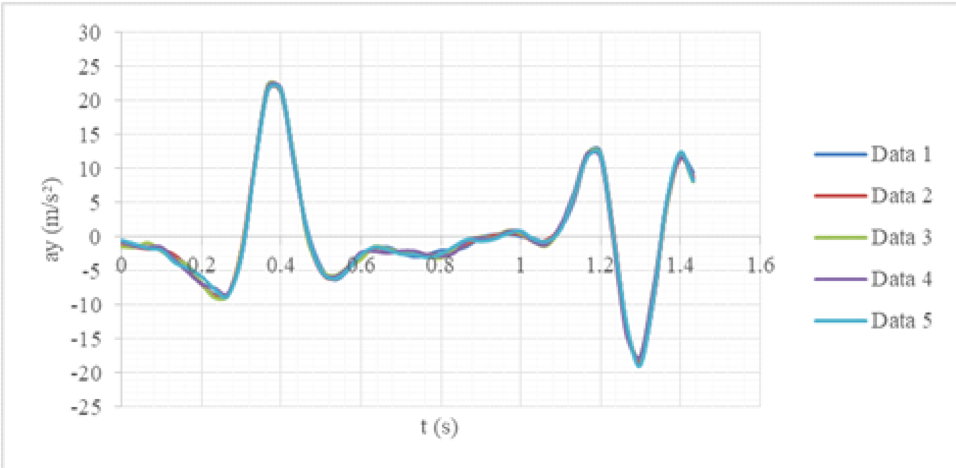


Figure 6: Graph of acceleration (in the y-axis) vs. time of an object moving from point A to point F.

An object takes 1.43 seconds to move from point A to point F. The acceleration values are taken at six points and graphed, as shown in Fig. 7.

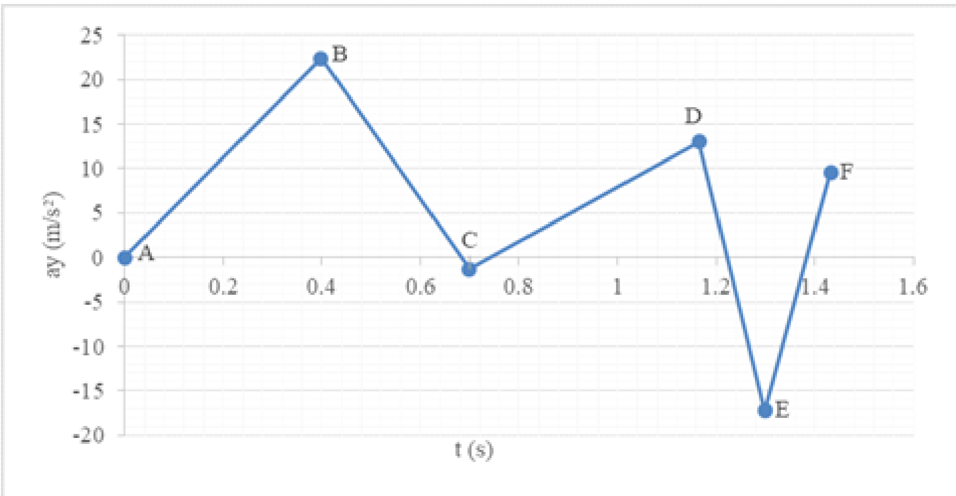
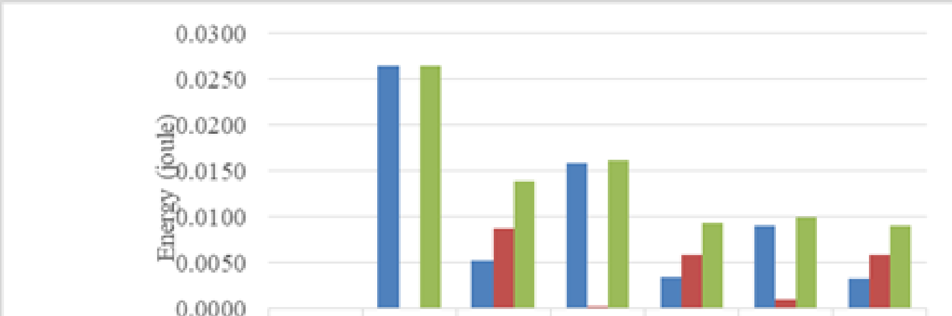


Figure 7: Graph of acceleration of an object at six points from point A to point F.

An object moves from a certain height and travels three paths. The first path is A-B-C in the form of a polynomial; the second is a linear path, namely C-D, and the third is a clothoid path, namely D-E-F. From points A to B, C to D, and E to F, the object moves downwards, and the velocity increases with time so that the object accelerates. From points B to C and D to E, the object moves up, and the velocity decreases with time, so the object decelerates (negative acceleration). This result is by the concept of physics in roller coaster motion.

3.2. Analysis of the Law of Conservation of Mechanical Energy

The law of conservation of mechanical energy explains that the total kinetic and potential energy an object possesses at any point is always constant.



	A	B	C	D	E	F
Potential Energy	0.0265	0.0052	0.0158	0.0035	0.0090	0.0032
Kinetic Energy	0.0000	0.0087	0.0003	0.0059	0.0010	0.0058
Mechanic Energy	0.0265	0.0139	0.0161	0.0093	0.0100	0.0090

Figure 8: The potential, kinetic, and mechanical energy of the objects at each analysis point.

Based on Fig. 8, it can see that the amount of mechanical energy of an object varies with each position. It shows work in non-conservative energy acting on objects moving along the mini roller-coaster trajectory. Point A is the highest position of the mini roller coaster, which is 0.31 m. This means the object has sufficient mechanical energy to move along the trajectory. The amount of mechanical energy at point A equals the magnitude of its potential energy. The amount of potential energy at point A, based on the tracking results, is 0.0265 joules, while based on the results of the formula calculations, it is 0.0261 joules. It can be concluded that the experimental data match the data calculated from the formula.

4. CONCLUSION

From the research results on the use of Video-Based Laboratory (VBL) using Tracker software for motion analysis on mini roller coasters, it can conclude that from the effects of video tracking, physics data can be obtained from the phenomena of roller coaster motion. The analysis in this study consists of analyzing acceleration and the law of conservation of mechanical energy. The analysis results match the experimental results and the physics concepts that apply to the roller coaster motion.

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