

# Tracker Application to Determine the Moment of Inertia in a Video-Based Laboratory to Improve Students' Learning Activity

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**Abstract.** This study aims to determine the value of cylinder inertia moments with different radii using a tracker application. This study also aims to make students more active in understanding the content. Students conduct experiments independently, starting from assembling experiment tools, taking videos, and analyzing the track data. Respectively, the moment of inertia is  $0.34 \times 10^{-5}$  for the cylinder with radius equal  $1.1 \times 10^2$ ; the moment of inertia is  $2.23 \times 10^{-5}$  for the radius equal  $2.8 \times 10^{-2}$ , and the moments of inertia is  $5.15 \times 10^{-5}$  for the radius equal  $4.2 \times 10^{-2}$ . This result shows that the longer the radius, the higher the moment of inertia.

**Keywords:** *learning activity, Tracker, physics learning, moment of inertia, video-based learning*

## INTRODUCTION

Various advantages are offered by technology to improve the quality of learning, including physics learning. The use of technology in learning physics can make students more productive than the lecture method. Also, appropriate technology can enhance teachers' professional abilities, as learning resources, as a medium for interactive learning, and as a forum for learning. But in reality, both students and teachers have relatively not utilized this technology in education. Correctly, information and communication technology are still used only as a means of communication and social interaction. As a result, many students waste time studying because information technology literacy is still low. This condition is one of the opportunities that teachers have not taken to improve student learning performance.

Physical phenomena are inseparable from human life. However, several physical symptoms are not easy to observe and to experiment, especially in terms of measuring the invisible eye [1]. In learning physics, students have difficulty in understanding the phenomena [2]-[4]. The tendency

of demonstrative experiments without actual data collection makes it difficult to study physics in everyday life. Technology provides new possibilities and opportunities for further learning perspectives, including student-teacher relationships and learning materials [5]. Technological development is an opportunity for various learning media to manipulate natural phenomena [4], [6], [7]. However, students used the availability of technology such as computers and the internet in activities outside the school. It is not used as it should [8]. Not optimal use of technology in schools has an impact on students' lack of understanding of the material, such as the material balance and dynamics of rotation, especially in determining the moment of cylinder inertia.

One of the problems in experimental activities in physics laboratories is the slow method of data collection [9]. The length of time required results in the delay in achieving the planned learning goals. Thus a breakthrough is needed to shorten experimental activities. The utilization of technology in innovative activities can reduce the time in data collection and graphical representation [10].

In physics learning, there is an experiment based on a Video-Based Laboratory, which uses a computer as an experimental tool and uses video as material. Students obtained the object analysis results from a set of data presented in the form of tables and graphs. The teacher's interpretation of the data was used as a source of student understanding in the classroom. Video-Based Laboratory is a decisive breakthrough to be used as one of the electronic media for learning in the school because this media can further familiarize students in carrying out scientific activities digitally. In addition to getting closer to students with various phenomena that occur around them, there is continuity between the concepts of physics learned in school and the daily environment of students

The software is Tracker, which can analyze an object recorded on a video. In the Tracker application, some features are complete enough to learn in school, such as a feature to track the

position of an object recorded video per unit time, determine the velocity and acceleration in the form of display overlays and graphics, special effects filters, multiple reference frames, calibration point, line profile to analyze spectroscopic results and interference patterns, as well as particle dynamics models. The student used the software to calculate the moment of inertia of the cylinder.

In determining the moment of inertia of the cylinder and the factors that influence the rolling object, the student indicated it from the processing of the object's motion review. For the data produced to have a high level of accuracy and accuracy, the motion of objects that roll must be constant [11]. One learning strategy that utilizes this technology is a video-based laboratory as a practicum activity using software for video analysis. Video-based laboratories are learning media based on objective review contained in a video. Video-Based Laboratory (VBL) helps students analyze physical phenomena quickly. An efficient video-based laboratory can make students more active in learning as an indicator of motivation. Students can find their physics concepts from their activities. This media can then familiarize students with scientific activities digitally. It also allows students to get closer to various phenomena that occur around them. Video analysis will enable students to connect abstract physics concepts with real-life through innovative video modeling. This method is quite useful for learning about the phenomenon of motion.

**METHOD**

This research is an experiment to determine the moment of cylinder inertia by using a tracker. This application can be run on the Web with a file size of 3.9 Mb from Tracker\_461.jar. This application installer can be found at <http://www.cabrillo.edu/~dbrown/Tracker/>, especially to activate the Xuggle video engine, which can decode most video file formats. Installer for Tracker version 4.62 is available on Windows, Mac OS X, and Linux operating systems. This research tool is a laptop, camera, cylinder, cotton, incline, ruler, calipers, and balance sheet—the arrangement of the experimental circuit, as shown in Figure 1.

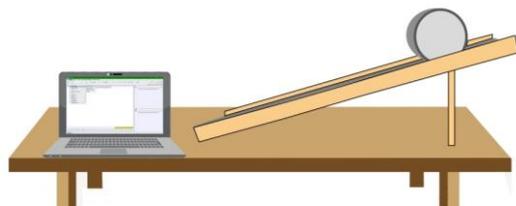


Figure 1: Experiment Series

The research subjects were cylinders filled with

cotton with different radii. The mass of each cylinder is made the same and fixed. Furthermore, the student took a video using a camera from the cylinder that rolls on an inclined plane until it stops along with a table. It was as the X-axis. Finally, students processed video using the Tracker to find the time, the position, the velocity, and linear acceleration during rotation on the X-axis.

**RESULT AND DISCUSSION**

During this time in studying this phenomenon, students tend to be given formulas without providing sufficient explanation related to real conditions. Also, by using this technology, students can hone their scientific thinking skills by observing a phenomenon, identifying various influential variables, measuring some of the changes that occur, connecting these variables, and explaining why the phenomenon occurs. The "taken for granted approaches" in learning physics can be improved by this method.

The use of various open-source applications has its advantages in inexpensive and applicable science learning. In learning physics, multiple phenomena can be simulated and analyzed using the Tracker application. The Tracker is a free video analysis and modeling tool built on the Open Source Physics (OSP) Java framework designed to be used in physics education. Video modeling tracker is a powerful way to combine videos with computer modeling. With this application, students can learn many phenomena better. This application will display the trajectory of a phenomenon and provide a graph of y vs. x, position, and velocity of x and y as a function of time. With the manipulation of these data can be obtained various relationships between variables and can explain the observed phenomena.

In this study, students learn the phenomenon of a moment of inertia of cylinder rolled on an inclined plane by changing the magnitude of the cylinder radius, incline angle, or height. Students in this activity also learn to take videos as the cylinder rolled. Students then analyze the video using the Tracker application. Students can explain the phenomenon of a moment of inertia of the cylinder.

Data from the measurement of moment of inertia with cylinder radius variation using Tracker as Table 1.

Table 1. Cylinder Tracker Data Results

| No | Radius (m)            | dr (m) | dt (s) | V (m/s) |
|----|-----------------------|--------|--------|---------|
| 1  | 1.1x10 <sup>-2</sup>  | 862.47 | 1.54   | 560.20  |
| 2  | 2.8x 10 <sup>-2</sup> | 759.36 | 2.38   | 319.21  |
| 3  | 4.2x10 <sup>-2</sup>  | 713.73 | 2.67   | 267.31  |

And the Tracker is processed using Equation 1.

$$I = \frac{1}{2}MR^2 \tag{Equation 1}$$

Data  $dr$  is the average distance generated per one track click movement. Each track click results in a different time ( $dt$ ). From the tracker data also the speed of each track click is taken, then flattened to produce the average rate of each  $dt$  and  $dr$  obtained. The motion of rolling on the incline accelerates the speed of objects causing the speed provided by each track is not constant. The tracker process will be accurate when the object's observed motion is constant, and the direction of the ball moves also stays straight even in a rolling motion. The motion of rolling objects must be constant, and it influenced the resulting data to have a high level of accuracy and high accuracy [11]. Figure 2 shows the tracking process for determining moment inertia.

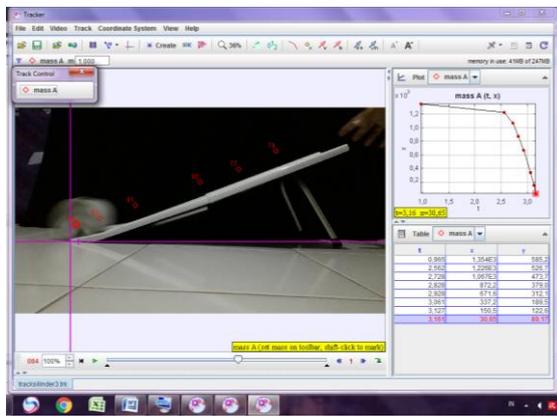


Figure 2: The tracking process using the application

Students calculate the moment of inertia value from the results of data processing using a tracker, as shown in Table 2.

Table 2. Data Calculation of Moment of Inertia

| No | Radius (m)             | m <sup>2</sup> | Volume (m <sup>3</sup> ) | Density (Kg/m <sup>3</sup> ) | I (kg.m <sup>2</sup> )  |
|----|------------------------|----------------|--------------------------|------------------------------|-------------------------|
| 1  | 1.1 x 10 <sup>-2</sup> | 0.000121       | 0.000037994              | 1500.23688                   | 0.34x 10 <sup>-5</sup>  |
| 2  | 2.8 x 10 <sup>-2</sup> | 0.000784       | 0.000246176              | 231.5416613                  | 2.23 x 10 <sup>-5</sup> |
| 3  | 4.2 x 10 <sup>-2</sup> | 0.00180625     | 0.000567163              | 100.5002957                  | 5.15 x 10 <sup>-5</sup> |

Based on the data in Table 2, the longer radius of an object, the higher the moment of inertia. This calculation proves the theory that the moment of inertia is proportional to the square of the distance of objects [12].

Raw data result is very appropriate for students to learn the reading and analysis of data [13]. Data obtained quickly and analyzed directly makes learning time efficient. Besides, in solving problems related to certain phenomena, students can experience scientific activities such as

hypothesizing, conducting experiments, and synthesizing [6],[14]. Significant benefits by the teacher in using these learning activities are:

1. Enabling a better understanding of mathematics and graphics of cylinder movements in the inclined plane analyzed using a Tracker. Students can deduce equations of the moment of inertia and mathematical representations during activities.
2. Video modeling pedagogy is suitable for active and deep learning. Students can predict outcomes by entering specific values, observing by comparing real data with the currently proposed models, and explaining their choice of values and understanding video analysis data. Even with this model can enable the facilitation of data-based social discussions between students and teachers.

The ease in installing and using the Tracker allows students to carry out these activities independently. So that the concept of student-centered learning can be more applied utilizing this application, students can gain contextual understanding related to the phenomenon of the moment of inertia on the cylinder by conducting their proof through changes in the value of variables. These repetitive hands-on activities can gradually develop ways of thinking like scientists and reduce misconceptions. This improvement in understanding occurs because they can connect abstract concepts and formulas with real-world examples.

There are several implications of the results of this study on knowledge, learning practices, and educational policies. The use of technology (Tracker) enables an understanding of science obtained by various groups more easily. Various abstract physical phenomena can be explained easier using this technology application. However, the use of this technology needs to be supported by educational management policies, especially related to supporting facilities. Some schools in Indonesia, especially in suburban areas, still have this problem, like students are not allowed to carry cellphones at school. Better policies are needed to enable the use of technology. In learning practices, the level of confidence and competence of teachers in the use of technology is also a determining factor for success. Teacher socialization and training in the use of technology to improve learning becomes essential.

**CONCLUSION**

In video-based laboratory learning, the use of Tracker in determining the moment of inertia of a cylinder can shorten the time. It is also useful in increasing students' understanding of the physics

content. This learning strategy allows students to participate directly in proving the concept of the material. This hands-on investigation activity teaches the actions of scientists. Students can gain experience in how researchers work within particular limitations. This method is perfect for students to build their understanding of physics through real-world video, without the need to refer to authoritative knowledge sources such as teachers and books. After determining the variables through video analysis, students can utilize the pedagogical advantages of video modeling. Besides, it allows students to test their understanding of the moment of inertia. The understanding gained from this hands-on activity can minimize misunderstandings in physics concepts.

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