Design And Build A Practicum Equipment For The Law Of Conservation Of Mechanical Energy Of Rolling Objects

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Abstract. Using photo gate sensor technology and digital displays, the research team created a legal practicum for energy conservation. This study aims to replace manual practicum equipment that is prone to measurement errors during practicum. This practicum equipment is used to prove the law of conservation of mechanical energy in rolling objects. Practicum equipment is developed using a development research process that starts with identifying needs and continues through design, manufacturing, and testing. At the design stage, validation of design results is carried out, while at the manufacturing and testing stages, design specifications and performance (measurement of accuracy and precision) are carried out. Based on the results of design validation, a value of 0.85 with a valid category was obtained, while accuracy was 90.7%, with an average accuracy of 97.46%, and a relative error of 8.33%. The thoroughness of the practicum equipment for the law of conservation of mechanical energy of rolling objects is quite good. We are currently developing several pieces of practicum equipment with IoT-assisted smartphone displays.

1 Introduction

The problem commonly encountered in learning physics today is that there are still limited experimental equipment options, so learning physics tends to be theoretical. Learning physics requires an in-depth understanding of concepts. To explain the concept, the teacher must be able to design the learning as well as possible so that students can understand the learning material easily. To meet the demands of the 2013 curriculum, the learning process in schools is student-centered. One way to do this is to carry out practical activities in the learning process. The practicum proves the theoretical studies that have been studied in schools, both at the junior and senior high school levels. In schools, laboratory practicum equipment is usually inadequate due to its high price. The law of conservation of energy is a topic that students in class XI.This material will be easier to understand through practical activities. This practicum could not be carried out optimally due to the limited availability of equipment.

To overcome this problem, the authors are interested in designing and assembling simple practical equipment related to the concept of the law of conservation of energy and several concepts related to it. This experiment was also inspired by the concept that an object sliding at a certain height will experience a change in energy from maximum potential energy to maximum kinetic energy with constant mechanical energy. This condition is based on the concept of the law of conservation of mechanical energy.

The law of the conservation of mechanical energy states that if an object experiences a displacement from one position to another with a change in position and speed, and provided that no energy is lost (usually due to friction), then the object will have the same amount of mechanical energy in every direction.

$$EM_A = EM_B \quad (1)$$
$$(EP + EK)_A = (EP + EK)_B \quad (2)$$
$$mgh_1 + \frac{1}{2}mv_1^2 = mgh_2 + \frac{1}{2}mv_2^2 \quad (3)$$

Law of Conservation of Mechanical Energy on an Inclined Plane.

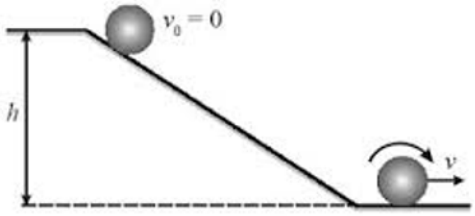

Fig 1. Rolling ball

If an object is placed on an inclined plane with a very smooth inclined surface, there is no frictional force that inhibits the object's movement. It has a maximum EP value.At that point, the KE is zero because the object is still. Potential energy = total mechanical energy of the object (EM = EP) [1][2][3].

In a rolling object, there are two movements at once, namely straight motion (translation) and circular motion (rotation). An object is said to be rolling if the total velocity of the object at the point of contact with the floor is zero. This means that the speed of the object due to straight motion (v) and the tangential velocity (.r) of the object due to rotation are of the same magnitude, v =ω.r. When an object is rolling, it has two kinetic energies: the kinetic energy of straight motion (translation) and the kinetic energy of rotational motion (E_c rotation). A solid cylinder descends an inclined plane, and there are two motions that can occur: sliding and rolling. When an object rolls, the law of conservation of mechanical energy occurs, namely that the potential energy of the object is converted entirely into the object's kinetic energy, namely translational kinetic energy and rotational kinetic energy [4][5][6].

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In previous research, several tools have been developed related to this topic, including using a video track as an application to detect the movement of objects rolling on an inclined plane [9]. The use of sensor technology has also been used on this topic by using infrared sensors and LCD displays, but the data taken focuses on the speed of objects and trajectories used that are different from those being developed by the author [10].

2 Method

A laboratory experiment (laboratory experimentation) is a type of research. This research was conducted at the Laboratory of Electronics and Instrumentation, Padang State University. This research was conducted in January 2018 [7]. Mechanical System Design Practical equipments This practicum equipment uses several components, namely the photogate sensor, as shown in Figure 2.

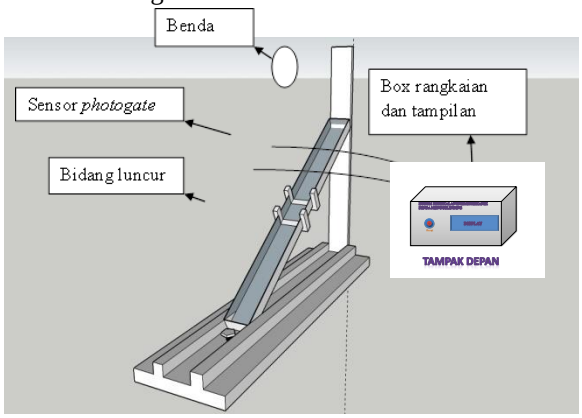

Fig 2. Design of a practical equipment for the Law of the Conservation of Mechanical Energy for rolling objects.

System design specifications include precision and accuracy. Accuracy is the measurement value or result that is close to the actual measurement value. Accuracy is the degree of similarity within a group of measurements or several instruments.

Determination of the Accuracy of the Measurement System

Accuracy is the similarity or closeness of a measurement result with actual numbers or data. Determination of system accuracy is done by comparing the results of system measurements with those of standard equipment and then investigating the accuracy.

Determination of the Precision of the Measurement System

The precision of the measurement system is carried out by comparing the results of system measurements with theoretical calculations, then repeated measurements are carried out, data is entered into tables, and the accuracy of the measuring instrument system is investigated.

The data collection technique in this study was carried out by measuring the physical quantities contained in the design of the legal practicum equipment for the mechanical energy conservation of rolling objects. The measurement techniques carried out include two methods, namely, directly and indirectly. Direct measurements are measurements that do not depend on other quantities. Indirect measurement is the measurement of a quantity whose value is influenced by other quantities but is not directly obtained.

3 Result and Discussion

The results of the research equipment for the Law of the Conservation of Mechanical Energy practicum equipment are translated by describing the design results, explaining the performance specifications and design specifications for the Law of the Conservation of Mechanical Energy practicum equipment, as well as by analyzing the research data so that the relationship between the related variables is obtained to explain the achievement of the research objectives set. The presentation of the data obtained can be expressed in the form of tables and graphs.

Data analysis performed on this measurement system includes the accuracy and precision of the system. Accuracy data is obtained by comparing the measurement results with the calculation results. The data accuracy was determined by repeating measurements five times.

The mechanical design of this practical equipment consists of several components, namely a photo gate sensor, an inclined plane, a solid object that will roll on an inclined plane, and a circuit box that will display the time and speed of the object when it is rolling, as shown in Figure 3.

Fig 3. Design of a set of equipment for the law of the conservation of energy for rolling objects

Based on Figure 3, the practical equipment for the law of the conservation of mechanical energy is two photo gate sensors installed on an inclined plane at a certain height. Objects are launched on an inclined plane, so the object will roll down. When an object passes through the photo gate sensor, a signal for the travel time and speed of the object will be sent to Arduino. From these measurements, the signals that have been detected will be sent to the Arduino, where they will be processed and then displayed through the display. The output form of the measured parameter value of the law of conservation of mechanical energy of the measured rolling object can be displayed on the LCD display [8].

Measurement Accuracy

The accuracy of the laboratory equipment for the conservation of mechanical energy is obtained by comparing the measurement results with those obtained with standard measuring instruments. The time measurement generated by the practicum equipment is compared with the measurement made by the stopwatch, which is parallel to the practicum equipment. The precision of the time measurements ranged from 0.83 to 1, and the average precision was 0.917. The average relative accuracy of the time measurements is 90.7%. The biggest measurement error is 0.076%. This shows that the practical equipment for the law of conservation of mechanical energy for rolling objects has high accuracy for calculating time.

Measurement Precision

Determination the precision measurement is obtained by making repeated measurements. The accuracy level of the system can be determined by making repeated measurements five times. Based on this case, the average value, standard deviation, error percentage, and accuracy can be determined. Table 1 shows the accuracy of the law and practicum equipment for the mechanical energy conservation of the rolling objects.

Table 1. Measurement Precision Data

NO	X	ΔX	$Precision$	KR %
1	0.76	0.08	0.9567	8.97
2	0.78	0.06	0.9646	7.59
3	0.73	0.06	0.9961	10.53
4	0.79	0.07	0.9777	6.85
5	0.78	0.05	0.9777	7.69
Average	**0.77**	**0.06**	**0.9746**	**8.33**

Based on table 1, it can be seen that the practicum equipment for the law of the conservation of mechanical energy of rolling objects has a fairly high accuracy. The average accuracy is 0.9746, with a relative error of 8.33%.

Testing of the practicum equipment for the law of conservation of mechanical energy for rolling objects is done by comparing the results of measurements using standard equipment and experimental sets for the law of conservation of mechanical energy for rolling objects that have been made. From the results of measuring the travel time of objects, we obtained quantitative differences between the two. This is because the electronics part of the system has a program delay, so when the travel time for an object from the photo gate 1 sensor to the photo gate 2 sensor is very fast, there is a delay in calculating the time.

As a result, improvements to the electronic part of the Law of Conservation of Mechanical Energy practicum equipment for rolling objects are required. The advantage of this practicum equipment is that it has a simple mechanical system with calculations done digitally, and the output display from this practicum equipment is displayed on the LCD.

so that drawing conclusions from practice and theory is easier and more quickly obtained. Time measurement is done automatically using a microcontroller so as to minimize errors compared to measurements using a stopwatch.

In making a piece of practical equipment for the law of conservation of mechanical energy, this digital rolling object has several weaknesses, including a sensor holder that is not permanent. Therefore, a permanent sensor holder is needed to make it easier to take measurements and ensure that there are no errors in measurement. Now it is being developed to display data on smartphones so that practicum activities are easier to understand and increase student enthusiasm for learning..

4 Conclusion

Based on the results of testing, data analysis, and discussion of the practical law equipment for the conservation of mechanical energy of digitally rolling objects using the photo gate sensor, it can be concluded that the results of the specifications for the design of this practical equipment are as follows: the accuracy for the object's travel time is 90.7%, the average accuracy is 97.46%, and the relative error is 8.33%. The accuracy of the law of conservation of mechanical energy in practical equipment is quite good.

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