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Development of Gravity Acceleration Measurement Using Simple Harmonic Motion Pendulum Method Based on Digital Technology and Photogate Sensor

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Abstract. Development of gravitation acceleration measurement using simple harmonic motion pendulum method, digital technology and photogate sensor has been done. Digital technology is more practical and optimizes the time of experimentation. The pendulum method is a method of calculating the acceleration of gravity using a solid ball that connected to a rope attached to a stative pole. The pendulum is swung at a small angle resulted a simple harmonic motion. The measurement system consists of a power supply, Photogate sensors, Arduino pro mini and seven segments. The Arduino pro mini receives digital data from the photogate sensor and processes the digital data into the timing data of the pendulum oscillation. The calculation result of the pendulum oscillation time is displayed on seven segments. Based on measured data, the accuracy and precision of the experiment system are 98.76% and 99.81%, respectively. Based on experiment data, the system can be operated in physics experiment especially in determination of the gravity acceleration.

1. Introduction

Physics is one branch of natural science that studies the nature of the phenomenon. Natural phenomena in physics can be reviewed both theoretically and experimentally. Experiments were conducted to validate the theory while the theory was used to guide the net of an experiment. Physical experiments can be done by involving a measurement system [1][2]. The measurement system is a combination of activities, procedures, measuring instruments, software, and subjects that aim to obtain measurement data against the characteristics being measured. Measurements are utilized as a means of obtaining data to draw conclusions and means to determine the linkages between two or more variables. Measuring tools used in the measurement must be in accordance with the quantity to be measured and have a good accuracy in order to obtain the exact measurement results. The development of measurements can be observed by the transition from mechanical or manual systems to digital systems [3]. The transition from a mechanical to a digital system requires a sensor. Sensors are devices that convert physical quantities into electrical quantities. Through the sensor can be designed various systems that can work automatically and able to analyze the phenomena that occur in nature, both for measurement and for control. Physics has provided a strong basis on technological progress. Technological advances are closely related to the progress of physics. One of the areas of physics studies that are not less rapid development of today is the Electronics and

Instrumentation. Progress Electronics and Instrumentation is enough to help humans in the field of science [4]. One of his roles is the experiment of physics.

Physical experiments produce various theories. Physical theory was born and developed from Einstein era until now. Through experiments new theories develop. Many experiments have been carried out, among which there are Regular Straight Motion (GLB), Straight Circularly Changed Motion (GLBB), Circular Motion, Simple Harmonic Motion (GHS), viscosity, pendulum and many others. In general, almost all measuring devices are still used manually. The manual measurement tools make the researchers difficult because much of the data obtained is less precise than the theories studied. This incorrect data is caused by several mistakes made in the experiment, such as tool calibration, scale reading and precision in the use of tools. With the design of digital tools is expected to be used as a tool for education and facilitate students who follow the activities of practicum in recording the results of activities [5]. This can be done by students only by looking directly from the display that is provided in the form of seven segments that display the results of the experiment. In this work, a simple digital harmonic motion measurement in physical pendulum will be presented.

Motion is a physical science that we apply every day. One simple harmonic motion application is the physical pendant swing. Simple Harmonic Motion (GHS) is the motion of alternating objects through a certain equilibrium point with the number of vibrations of objects in every second always constant. Electronic components used in the form of sensors and digital signal processing using Arduino microcontroller. One of the sensors used is a photogate sensor in which the sensor is used to detect the number of oscillations pendulum. This paper will explain the development of measuring tools acceleration of earth gravity using simple experimental harmonic movement tool.

2. Method

Based on the problem proposed that the research model will be conducted is laboratory experimental research (laboratory experimentation), research that apply science into a design in order to get the performance as expected. The cause or effect relationship of an independent variable to the dependent variable can only be obtained through the experimental procedure [6]. In a pure experimental procedure, the researcher exercises full control to manipulate the independent variables. The experimental procedure intends to compare the effects of the independent variables on the dependent variable through the manipulation of the independent variables. Changes that occur in the dependent variable are returned to the cause of the different treatments given to the independent variables.

Research Variables are basically anything in the form of what is set by the researchers to be studied so that obtained information about it, then drawn conclusions. Preparation of simple harmonic motion experimental set on pendulum based photogate sensor with seven segment display consists of three variables, namely independent variable, dependent variable and control variable. The Free variable is the variable that influences or causes the change of the dependent variable (bound). The dependent variable is a variable influenced by the independent variable. Control Variables are variables that are controlled or made constant so that the relationship of independent variables to the dependent variable is not influenced by outside factors that are not examined. In this study the independent variable is the length of the rope. The dependent variable is the time of vibration and period. The control variable is the amount of vibration spring and the system builder electronics component.

2.1. Design of the Mechanic System

The design of simple harmonic motion instrument is illustrated in Figure 1. This system consists of mechanic and electronic sub system. In mechanic design, the swing ball is hanged to a stand that equipped with the photogate sensor and angle indicator.
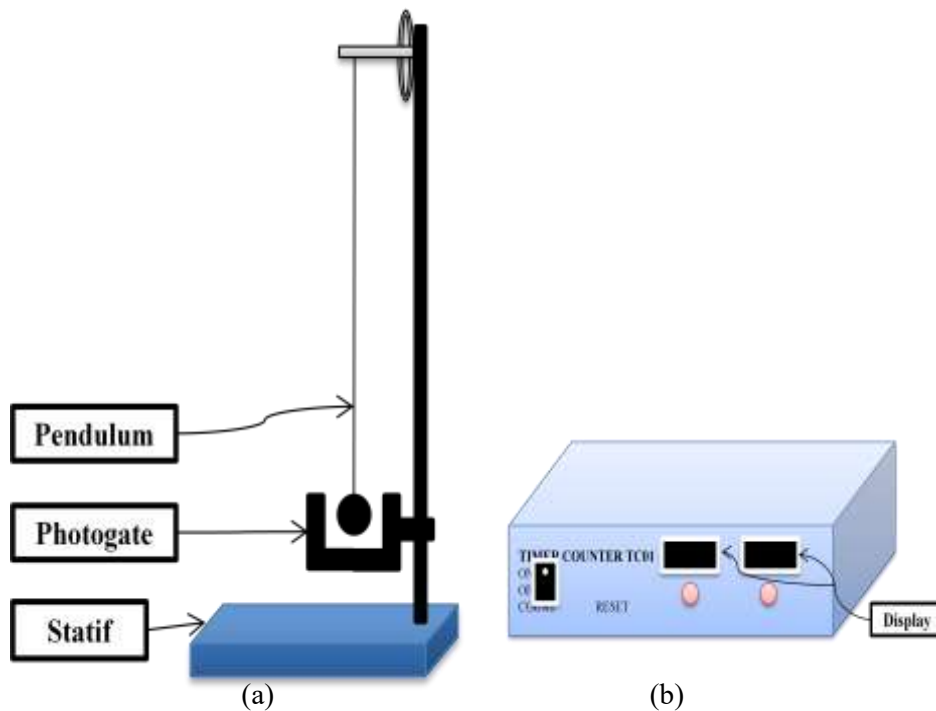
Figure 1. Design of simple harmonic motion instrument; (a) Mechanics system and (b) Electronic system.

Figure 1 shows the design of mechanics and electronic systems that have been made. Photogate sensor serves to calculate the number of oscillations. Stative serves as a hanging place pendulum. The electronic system consists of power supply, arduino pro mini and seven segment. Power Supply serves to provide power to the electronics system. Microcontroller is used to program the experimental experiment set of simple harmonic motion experiments on pendulum and seven segments used to display the measurement data [7][8].

2.2. Block diagram of the Digital Timer Counter

Digital experimental set of simple harmonic motion in pendulum consists of several series of electronics, including power supply circuit, photogate sensor circuit, Arduino Uno microcontroller circuit, and Seven Segment. The system block diagram of the simple digital harmonic motion experimental set on the pendulum can be seen in Figure 2.
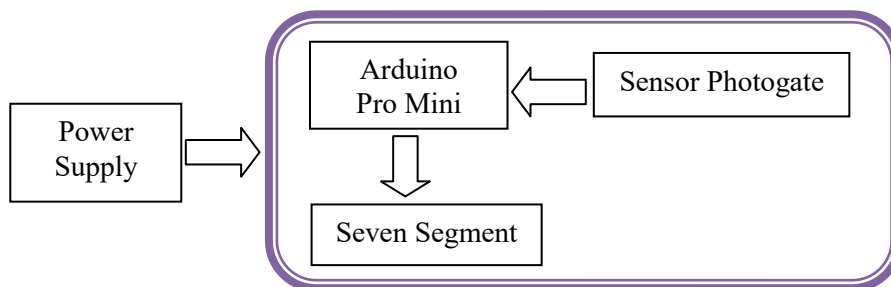

Figure 2. Block Diagram of the digital Timer Counter.

Figure 2 shows a block diagram of a set of simple harmonic motion digital experiments on the pendulum. Power supply is used as a DC voltage source, the voltage used ± 5 Volts [9]. Power supply is voltage source for photogate sensor, arduino pro mini and series of seven segments. Arduino pro mini receive digital data from photogate sensor and process digital data into timing data of oscillation pendulum. The calculation result of the pendulum oscillation time is shown on seven segments.

3. Results and Discussion

3.1. Specification of the System Performance

The set of simple harmonic digital motion experiments in the pendulum consists of mechanical systems and electronic systems. Figure 3 is a mechanical form, in which the photogate sensor is used to calculate the number of oscillations. Stative is used as a hanging place pendulum and electronic systems used as data processors and displays on seven segments. Figure 4 is an internal part of the timer counter, where (1) Represents an electronic circuit that serves as a power supply with a DC source, a voltage generated by a power supply of ± 5 Volts. Supply power circuit systems are used for voltage gators on Arduino pro mini, photogate sensors and seven segments. (2) A data processing system, Arduino pro mini receives digital data from photogate sensors and processes digital data into timing data of pendulum oscillation. (3) Represents part of digital data input; photogate sensor transmits digital data to Arduino pro mini. (4) Is display data measurement, seven segment display data in 4-digit number.
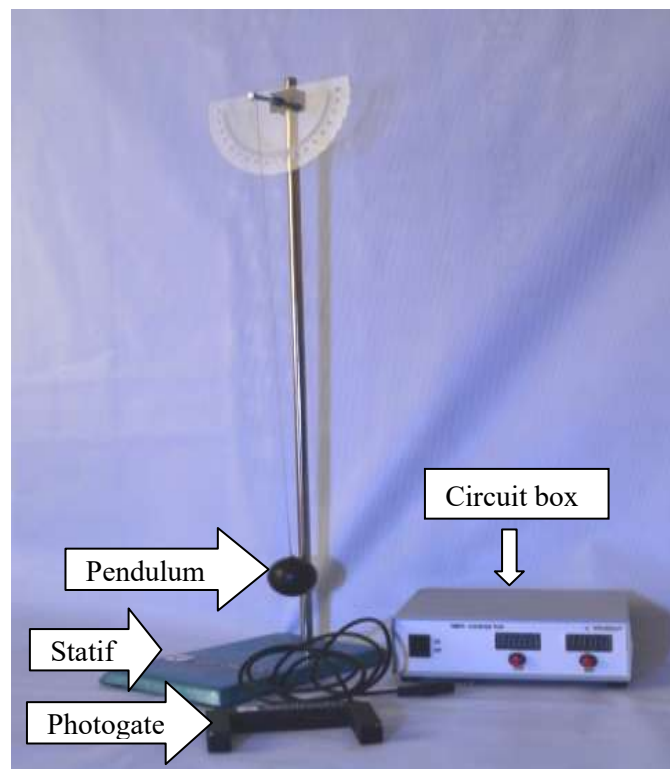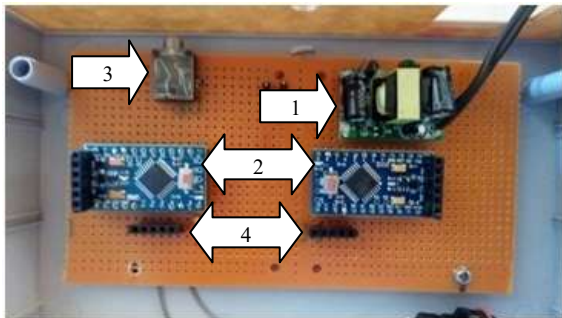

Figure 3. Photograph of the Mechanic System and Circuit Box

(a)	(b)

Figure 4. Electronic system (a) electronic circuit and (b) front panel

3.2. Specification of the Design

3.2.1. Accuracy of the system

Accuracy or precision is obtained from the comparison between gauges made with standard gauges. A simple set of digital experimental harmonic motion on pendulum compared to measurement on oscilloscope as standard gauge. In addition to measurements using timer counters and oscilloscopes, manual measurements are also made. Figure 5 shows the relationship between the length of the rope and the value of gravity on the measurement using timer counter, standard gauge and manual measurement.
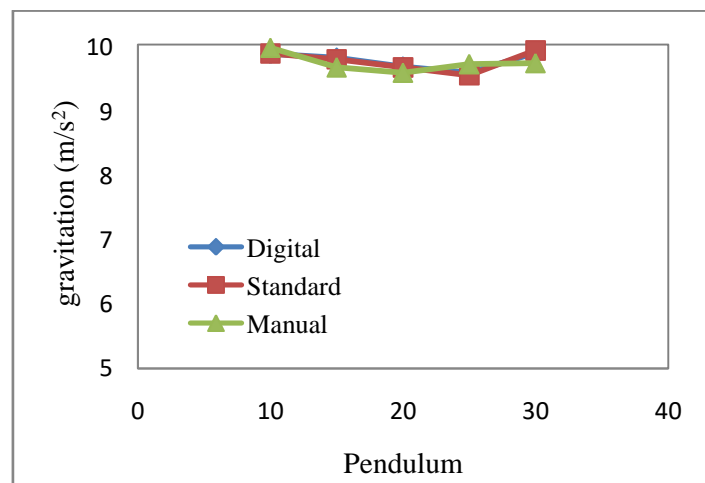

Figure 5. The relationship between the pendulum and gravitation

Figure 5 shows a comparison between digital measurements, standard measuring instruments and manual measurements. Based on the graph above, the measurement digitally produces the value of gravity closer to the standard gauge compared with the measurement manually. From result of data processing got average gravity value at timer counter is 9.797 m / s2. The average gravity score in the measurement of standard gauge is 9.79 m / s2. The measured gravity of the system has accuracy of about 98.76% and relative error 0.24%. While the average gravity value on manual measurement is 9.762 m / s2. Compare to the standard value of the gravity, accuracy of the system is 98.64% and relative error 1.36%. Figure 6 shows the relationship between the length of the rope and the oscillation time on the measurement using timer counter, standard gauge and manual measurement.
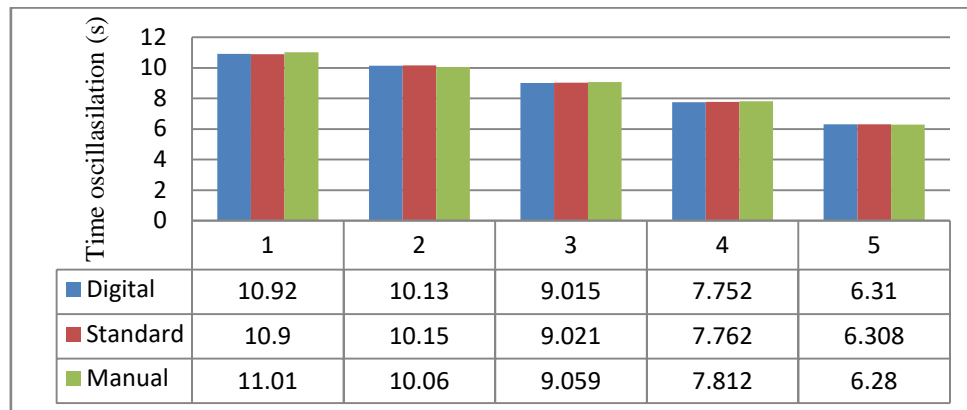
Figure 6. The relationship between the pendulum and time oscillation

3.2.2. Precision of the system

Precision or accuracy of measuring instruments obtained from the results of repeated measurements. Table 1 shows repeatable measurements in the Digital experiment set of simple harmonic motion on the pendulum.

Table 1. Precision of Digital Instrument

Pendulum (cm)	Time oscillation (s)										Average
	t1	t2	t3	t4	t5	t6	t7	t8	t9	t10	
30	10.92	10.91	10.92	10.92	10.90	10.92	10.92	10.92	10.93	10.92	10.918
25	10.13	10.14	10.14	10.13	10.12	10.13	10.13	10.13	10.12	10.13	10.130
20	9.014	9.015	9.015	9.013	9.015	9.015	9.017	9.015	9.015	9.015	9.015
15	7.753	7.752	7.754	7.752	7.751	7.752	7.752	7.752	7.751	7.752	7.752
10	6.313	6.311	6.312	6.310	6.310	6.313	6.310	6.310	6.310	6.301	6.310

Table 1 shows repeated measurements on timer counters. Based on the data processing on the value of precision Set of digital experiment simple harmonic motion on the pendulum is 99.81% and error 0.19%. Table 2, Table 3 and Table 4 show the measurement results using timer counters, standard measuring instruments and manual measurements.

Table 2. Results of manual measurement

L (cm)	t (s)	T	g (m/s^2)
30	11.01	1.101	9.760
25	10.06	1.006	9.742
20	9.059	0.905	9.611
15	7.812	0.781	9.694
10	6.280	0.628	10.00

Table 3. Results of digital measurement

L (cm)	t (s)	T	g (m/s^2)
30	10.92	1.092	9.922
25	10.13	1.013	9.608
20	9.150	0.915	9.705
15	7.752	0.775	9.844
10	6.310	0.631	9.905

Table 4. Results of standard measurement

L (cm)	t (s)	T	g (m/s^2)
30	10.90	1.090	9.958
25	10.15	1.015	9.570
20	9.021	0.902	9.693
15	7.762	0.776	9.819
10	6.301	0.630	9.911

4. Discussion

The measurement results show the performance system specification, accuracy and accuracy set of digital experiment simple harmonic motion on pendulum. The performance system specifications consist of mechanical tools and some electronic circuits, including power supply circuit, photogate sensor circuit, Arduino Uno microcontroller circuit and Seven Segment. The measurement process is initiated by power supply as voltage giver on Photogate, arduino pro mini and seven segments. The arduino pro mini receives digital data from the photogate sensor and processes the digital data into the timing data of the pendulum oscillation. The result of calculation of the pendulum oscillation time is shown on the seven segments. From the result of measurement and data processing the average gravity score on the measurement of standard gauge is 9.79 m / s2. If the value of gravity measurement digitally compared with the measurement of standard gauge then got the value of timer count accuracy is 98,76% and relative error 0,24%. While the average gravity value on manual measurement is 9.762 m / s2. If the value of gravity of manual measurement is compared with measurement of standard measurement then the value of manual measurement accuracy is 98,64% and relative error 1,36%. Precision value Set of simple digital harmonic motion experiment on pendulum is 99,81% and error 0,19%.

5. Conclusion

The development of the acceleration tool for gravity acceleration with simple harmonic motion of pendulum method based on digital technology and photogate sensor has been completed. Digital experimental set of simple harmonic motion in pendulum consists of several series of electronics, including power supply circuit, photogate sensor circuit, Arduino Uno microcontroller circuit, and Seven Segment. Based on the results and discussion, the average gravity score on the measurement of the standard gauge is 9.79 m / s2. If the value of gravity measurement digitally compared with the measurement of standard gauge then got the value of timer count accuracy is 98.76% and relative error 0.24%. While the average gravity value on manual measurement is 9.762 m / s2. If the value of gravity of manual measurement is compared with measurement of standard measurement then the value of manual measurement accuracy is 98.64% and relative error 1.36%. Precision value Set of simple digital harmonic motion experiment on pendulum is 99.81% and error 0.19%.

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