Design of Simple Harmonic Motion (SHM) devices based on IR obstacle sensors

W Setya¹*, D N Fariha¹, W Handayani¹ and A Syafei²

¹Departemen Physics of Education, UIN Sunan Gunung Djati Bandung, Jl. A.H Nasution 105, Bandung 40614, West Java, Indonesia
²Prodi Manajemen Keungan Syariah, Fakultas Ekonomi dan Bisnis Islam, UIN Sunan Gunung Djati Bandung, Jl. A.H Nasution 105, Bandung 40614, West Java, Indonesia

*suratwindasetya@uinsgd.ac.id

Abstract. The development of science and technology is inseparable from the availability of hardware and software. One of its uses is teaching aids in physics practicum, especially simple harmonic motion. Digital technology can shorten the time in the implementation of practical work in the field. In this study aims to design a simple harmonic motion practicum tool using Arduino Uno based on IR resistance sensors. Data was collected using a small angle of 10° with variations in the number of waves and time obtained. The results will be displayed on the LCD. This study also compares the results of recording digitally and manually. Based on the data obtained, the results of digital experiments are more accurate than the results of manual experiments with an accuracy of 96.69% and digital SHM device experiments also show precise results. So that digital SHM tools can be performed on physics experiments in simple harmonic motion material.

1. Introduction

Today, the development of technological have influenced all fields of life, such as education, health, and government [1]. Advances in technology such as electronics and instrumentation are enough to help humans in science [2]. One of its roles is physics experiments.

Physics experiments always involve measurement systems. Measurement is intended to get data so, it can determine the relationship between variables and draw conclusions. Measuring instruments used in measurements have good accuracy to get precise measurement results. In general, almost all measuring devices are still used manually. Manual measurement tools still have many weaknesses caused by some mistakes made in experiments, such as tool calibration, scale reading and accuracy in the use of tools [3]. Therefore, we need a measuring instrument that has good accuracy in order to avoid many errors in measurement. One way is to digitally design a physics experiment kit or kit.

The transition from mechanical systems to digital systems requires sensors. A sensor is a device that converts physical quantities into electrical quantities. The use of sensors can design various systems that can work automatically to make measurements. A sensor can work if programmed using a microcontroller to get the desired variable or data. One microcontroller that was developed for teaching and learning science and is popular in the field of physics is the Arduino Uno board [4-8]. The use of Arduino Uno board is widely used in physics experiments, such as Hooke's law experiments, determining the spring constant of a spring system, and simple harmonic motion [7]. Arduino Uno was
chosen because it is a low-cost, reliable system, obtains data at a fast speed and can be used to measure dynamic variables with reasonable precision in experiments [4].

In previous studies, many have discussed the simple harmonic motion experiment using sensors, such as Photogate [3], ultrasonic [4,7,9], magnetometer [10], and acceleration [11]. However, this research will discuss the design of digital experimental devices for simple harmonic motion using Obstacle IR (Infrared) sensors. IR sensors are used because they are cheaper in cost and faster in response time than ultrasonic sensors [9]. IR sensor serves to detect obstacles [12]. This tool is designed to measure the number of vibrations or certain waves and the time needed when these waves occur. This research was also conducted to find out how the level of accuracy and precision of this tool. The existence of a digital design tool is expected to be used as a tool for education and facilitate students in participating in practical activities [13].

2. Methods
Based on the problems presented, the research method used is an experimental research method. This method is done because applying a science into a tool design in order to get the expected performance.

2.1. Design of the mechanic and electronic system
The mechanical and electronic design of a simple harmonic motion experiment tool is presented in Figure 1.

![Figure 1](image)

(a) Mechanical design, (b) Electronic design and (c) Electronic circuit design.

In Figure 1, tools and materials used for mechanical design include wooden boards, ropes, protractors, pendants, screws, nails, and rubber glue. Whereas in electronic design the tools and materials used are pushbutton, Obstacle IR sensor, Arduino Uno board, I2C module, 16 x 2 LCD, USB cable, male/female jumper cable and mini breadboard.

The workings of this simple harmonic motion experiment tool are measuring the pendulum mass using a 4-arm balance and hanging the pendulum on the rope, adjusting and measuring the length of the rope with a ruler, placing the sensor under the pendulum and connecting it to the cable for the LCD box and connecting to a voltage source, pressing the reset button on the LCD box, giving an intersection with a small angle to the pendulum (10°), releasing the pendulum until it moves or oscillating and determining the desired amount of vibration. The amount of vibration formed can be seen on the LCD and if the desired amount of vibration is reached, then press the stop button. The LCD screen will also show the time needed to oscillate.

The data obtained are the number of vibrations formed and the time required for the formation of vibrations. The way to analyze it is by comparing the data obtained from the results of the digital SHM experiment with the results of the experiment using a manual SHM tool that is a stative rod, pendulum, stopwatch and ruler. In addition, gravity values will be compared from the calculation of the results of data from the digital SHM experimental device and the manual SHM experiment kit with the agreed gravity value, to know the accuracy and precision of the digital device.

3. Results and discussion

3.1. Theory of Simple Harmonic Motion (SHM)
A simple pendulum is an ideal object consisting of a point of mass, which is hung on a lightweight rope that cannot stretch out. A simple pendulum consists of a length of rope and a mass load [15]. The periodic
motion shown by a simple pendulum will be harmonic when the oscillation angle is small, but if the oscillation angle is large then the equation of motion is nonlinear [14]. Vibration or oscillation is a repetitive motion that passes through its equilibrium point at a specified time interval. One vibration or one wave is when the pendulum moves from position A-B-C-B-A as shown in Figure 2.

**Figure 2.** Pendulum movement one vibration.

In oscillations there are several physical quantities including vibration/wave (n), time of vibration (t), period (T), frequency (f), and amplitude (A). The wave period is the time for the object to do one full oscillation. Mathematically it can be written as follows:

\[
T = \frac{t}{n}
\]

(1)

The wave frequency is the number of oscillations per second, mathematically can be written

\[
f = \frac{n}{t}
\]

(2)

The force acting on the pendulum depends on mg and the tension on the rope (L), as shown in Figure 3.

**Figure 3.** Force in pendulum.

Based on Figure 3, the magnitude of the period and frequency of the pendulum are [16]

\[
T = 2\pi \sqrt{\frac{l}{g}}
\]

(3)

\[
f = \frac{1}{2\pi} \sqrt{\frac{g}{l}}
\]

(4)

Based on the above equation, the simple harmonic motion experiment can also determine the value of gravitational acceleration using the oscillation time period value [17].

3.2. Measurement data of simple harmonic motion

The data obtained is based on the results of experiments using a digital GHS tool with the results of manual experiments as follows:

3.2.1. Data of experiment (Different Vibration Counts). In first experiment, it was carried out to measure the time required with a pendulum rope length of 0.36 m and the given deviation of 10°. The number of vibrations determined for time measurement is 5, 10, 15, 20, and 25 vibrations. The data obtained through digital SHM device experiments and the data obtained through a manual SHM tool experiment is shown in Table 1.
Table 1. Data of first experiment.

| No. | l (m) | sudut (°) | n | Digital t (s) | Manual t (s) |
|-----|-------|-----------|---|--------------|--------------|
| 1.  | 0.36  | 5         | 5.204 | 5.8          |
| 2.  | 0.32  | 10        | 12.230 | 12.3        |
| 3.  | 0.36  | 10        | 18.806 | 18.9        |
| 4.  | 0.28  | 10        | 25.141 | 25.1        |
| 5.  | 0.20  | 25        | 31.350 | 31.5        |

Based on the first experiment in Table 1, the results of the experiment manually and digitally are the same. However, when viewed with more detailed accuracy, the results obtained are different but only by a difference of about 10^{-1} seconds. The oscillation time data obtained using a digital SHM tool is more accurate than a manual SHM tool, because the digital SHM tool counts up to 10^{-3} seconds. Also according to theory, the more waves that are formed, the greater the time required. The results of experiments using a digital GHS tool also produce the same thing that the more waves are formed, the greater the time required.

In theory, the more waves that are formed, the greater the time required [15]. The results of experiments using a digital GHS tool also produce the same thing that is the more waves formed, the greater the time needed. This shows that this digital GHS tool can be used for SHM experiments.

3.2.2. Data of experiment (Different Lengths of Pendulum Straps). In second experiment, it was carried out to measure the time taken by the different lengths of the pendulum ropes and the given deviation was 10°. The number of vibrations determined for the measurement of time is 10 vibrations with different lengths of rope, namely 0.36 m, 0.32 m, 0.28 m, 0.24 m and 0.20 m. Data obtained through digital SHM device experiments and data obtained through manual SHM tool experiments are shown in Table 2.

Table 2. Data of second experiment.

| No. | l (m) | sudut (°) | n | Digital t (s) | Manual t (s) |
|-----|-------|-----------|---|--------------|--------------|
| 1.  | 0.36  | 12.230    | 12.4 |
| 2.  | 0.32  | 11.500    | 11.6 |
| 3.  | 0.28  | 10.821    | 11.2 |
| 4.  | 0.24  | 9.987     | 10.0 |
| 5.  | 0.20  | 9.154     | 9.5  |

Based on the first experiment in Table 2, the results of the experiment manually and digitally are the same. However, when viewed with more detailed accuracy, the results obtained are different but only by a difference of about 10^{-1} seconds. The oscillation time data obtained using a digital SHM tool is more accurate than a manual SHM tool, because the digital SHM tool counts up to 10^{-3} seconds. Also according to theory, the more waves that are formed, the greater the time required. The results of experiments using a digital GHS tool also produce the same thing that the more waves are formed, the greater the time required. So it can be said that this tool approaches the value done by a manual experiment.

3.3. Specification of the design

3.3.1. Accuracy of the system. Accuracy is obtained from a comparison between gauges made with standard gauges [3]. In this study, the experimental data from the digital SHM tool is compared with the data from the results of manual experiments and standard measurement data. The relationship between the length of the rope and the value of acceleration of gravity in measurements using a digital SHM tool, manual measurements, and standard measurements are shown in Table 3.
Table 3. Relationship between the length of the rope and the value of acceleration of gravity.

| No. | l (m) | T (s) | g (m/s²) | T (s) | g (m/s²) | T (s) | g (m/s²) |
|-----|-------|-------|----------|-------|----------|-------|----------|
| 1.  | 0.36  | 1.223 | 9.492    | 1.240 | 9.234    | 9.48   | 9.79     |
| 2.  | 0.32  | 1.150 | 9.543    | 1.160 | 9.379    | 1.206  | 9.77     |
| 3.  | 0.28  | 1.0821| 9.431    | 1.120 | 8.803    | 9.78   | 9.93     |
| 4.  | 0.24  | 1.0007| 9.452    | 1.000 | 9.465    | 9.78   | 9.86     |
| 5.  | 0.20  | 0.9158| 9.413    | 0.950 | 8.740    | 9.77   | 9.65     |

In Table 3 shows that no matter how long the rope is used, it will get the same value of acceleration of gravity. Comparison of measurements using a digital SHM tool results in a acceleration of gravity value closer to the standard acceleration of gravity value. The standard acceleration of gravity n value is 9.79 m/s² [3]. The results of the experimental data processing of the digital SHM tool obtained an average acceleration of gravity value of 9.466 m/s². While the results of manual SHM experimental data processing obtained the average of the acceleration of gravity value is 9.124 m/s². The acceleration of gravity obtained from digital SHM device experiments has an accuracy of around 96.69%. Whereas the acceleration of gravity obtained from manual experiments has an accuracy of around 93.20%. Based on these results, it means that the accuracy of the digital SHM tool is higher than the manual SHM experiment tool.

3.3.2. Precision of the system. The accuracy of the measuring instrument is obtained from the results of repeated measurements. The results of repeated measurements from a digital SHM tool are shown in Table 4.

Table 4. Precision of digital experiment.

| l (m) | t (s) | Average |
|------|------|---------|
| 0.36 | 12.229 | 12.230   |
| 0.32 | 11.502 | 11.501   |
| 0.28 | 10.819 | 10.821   |
| 0.24 | 9.985  | 9.987    |
| 0.20 | 9.153  | 9.153    |

Table 4 shows the repeated measurements of oscillation time measurements. The results of time measurements carried out ten times show almost constant results from each measurement. Therefore, it can be said that this digital SHM tool has a high level of precision with the measured data.

4. Conclusion

Based on the data that has been analyzed, the results of this study indicate that the SHM tool using the Obstacle IR sensor has a higher accuracy in measuring oscillation time that is up to 10-3 s. In addition, the data from the digital SHM measurement results are more accurate than the results of manual experiments with an accuracy of 96.69% and the digital SHM device experiments also show precise results. So that digital SHM tools can be performed on physics experiments in simple harmonic motion material.

Acknowledgement

The author expresses his appreciation and thanks to the Research and Publishing Center of UIN Sunan Gunung Djati Bandung for providing financial support for the publication of this article.
References

[1] Mailizar J and Rahmawati 2018 The Effectivity Of Using Videotron As Socialization Media For The Government Program In Increasing The Knowledge Of Banda Aceh’s Citizens (A Survey Conducted On Videotron Located In Taman Ratu Safiatuddin Lampriet, Banda Aceh) Jurnal Ilmiah Mahasiswa FISIP Unsyiah 1 1-14

[2] Ihsan N, Yulkifli, and Yohandri 2017 Development of Speed Measurement System for Pencak Silat Kick Based on Sensor Technology IOP Conference Series: Materials Science and Engineering 180 012171

[3] Yulkifli, Z Afandi and Yohandri 2018 Development of Gravity Acceleration Measurement Using Simple Harmonic Motion Pendulum Method Based on Digital Technology and Photogate Sensor IOP Conference Series: Materials Science and Engineering 335 012064

[4] Suchatpong N and Suknui V 2018 Photogate Sensor for Compound Physical Pendulum Experiments A Creative Path to Sustainable Innovation 1144 1-4

[5] Wong W K, Chao T K, Chen P R, Lien Y W and Wu C J 2015 Pendulum experiments with three modern electronic devices and a modeling tool Journal of Computers in Education 2 77-92

[6] Zachariadou K, Yiasemides K and Trougkakos N 2012 A low-cost computer-controlled Arduino-based educational laboratory system for teaching the fundamentals of photovoltaic cells European Journal of Physics 33 1599

[7] Galeriu C 2014 An Arduino Investigation of Simple Harmonic Motion The Physics Teacher 52 157-19

[8] Atkin K 2016 Using The Arduino with Makerplot Software for The Display of Resonance Curves Characteristic of A Series LCR Circuit Physics Education 51 1-6

[9] Mohammad T 2009 Using Ultrasonic and Infrared Sensors for Distance Measurement,” World Academy of Science Engineering and Technology 3 273-278

[10] Pili U, Violanda R and Ceniza C 2018 Measurement of g Using A Magnetic Pendulum and A Smartphone Magnetometer Physics Teacher 56 257-259

[11] Vogt P and Kuhn J 2012 Analyzing Simple Pendulum Phenomena with A Smartphone Acceleration Sensor Physics Teacher 50 438-440

[12] Ismail R, Omar Z and Suaibun S 2016 Obstacle-Avoiding Robot with IR and PIR Motion Sensors IOP Conference Series: Materials Science and Engineering 152 012064

[13] Park H S, Hwang J S, Choi W Y, Shim D S, Na K W and Choi S O 2004 Development of micro-fluxgate sensors with electroplated magnetic cores for electronic compass Sensors and Actuators A: Physical 114 224-229

[14] Lima F M S and Arun P 1998 An Accurate Formula for The Period of A Simple Pendulum Oscillating Beyond The Small Angle Regime American Journal of Physics 74 892–895

[15] Halliday D 1998 Fisika (Jakarta: Erlangga)

[16] Hurianti F and Yusro A 2017 Pengembangan ODD (Osilator Digital Detector) sebagai Alat Peraga Praktikum Gerak Harmonik Sederhana Jurnal Inovasi dan Pembelajaran Fisika 4 1-9.

[17] Pálka L, Schauer F and Dostál P 2016 Modelling of The Simple Pendulum Experiment MATEC Web of Conferences 76 1-8