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Design of An Inclined Plane Experiment Tool Using E18-D80NK Infrared Proximity and MPU6050 Accelerometer Sensors: An IoT-Based Approach

Yulia Ardila[1], Yulkifli[2*], Asrizal[3]
[1,2,3]*Universitas Negeri Padang, Padang*
[1]yuliaardila06@gmail.com, [2*]yulkifliamir@fmipa.unp.ac.id, [3]asrizal@fmipa.unp.ac.id

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ABSTRACT

Electronics plays an important role in science, especially in the development of laboratory equipment technology in schools, which is the main pillar in education. Current laboratory equipment still relies on manual operation, reducing measurement efficiency and accuracy. This research focuses on developing an IoT-based inclined plane measurement system that can display results digitally. The system utilizes IoT-based E18-D0NK proximity sensor and MPU6050 accelerometer to ensure more precise and efficient measurements. The main objective of this research is to establish the performance specifications and system design of the inclined plane experimental tool. This research is an engineering research that measures the inclined plane by the object launch method, using both direct and indirect approaches. Direct measurements were taken via a mobile phone screen, while indirect measurements assessed the accuracy and precision of the digital system compared to conventional methods. The data was analyzed with statistical and tabular analysis to provide an overview of the system's performance. The system used proximity sensors to start stop the movement and accelerometers to calculate the tilt angle. The MPU6050 sensor showed an average accuracy of 99.22% and an average precision of 0.991. This tool shows an average accuracy of 98.83% with an accuracy of 0.996.

Keywords: *E18-D0NK Proximity; ESP32 Microcontroller; Inclined Plane; IoT; MPU6050 Accelerometer*

ABSTRAK

Elektronika memegang peranan penting dalam ilmu pengetahuan, terutama dalam pengembangan teknologi peralatan laboratorium di sekolah yang merupakan pilar utama dalam pendidikan. Peralatan laboratorium yang ada saat ini masih mengandalkan pengoperasian secara manual sehingga mengurangi efisiensi dan akurasi pengukuran. Penelitian ini berfokus pada pengembangan sistem pengukuran bidang miring berbasis IoT yang dapat menampilkan hasil pengukuran secara digital. Sistem ini menggunakan sensor jarak E18-D0NK berbasis IoT dan akselerometer MPU6050 untuk memastikan pengukuran yang lebih presisi dan efisien. Tujuan utama dari penelitian ini adalah untuk menetapkan spesifikasi kinerja dan desain sistem dari alat eksperimen bidang miring. Penelitian ini merupakan penelitian rekayasa yang mengukur bidang miring dengan metode peluncuran objek, menggunakan pendekatan langsung dan tidak langsung. Pengukuran langsung dilakukan melalui layar telepon genggam, sedangkan pengukuran tidak langsung menilai akurasi dan presisi sistem digital dibandingkan dengan metode konvensional. Data dianalisis dengan analisis statistik dan tabel untuk memberikan gambaran umum tentang kinerja sistem. Sistem ini menggunakan sensor jarak untuk memulai dan menghentikan gerakan dan akselerometer untuk menghitung sudut kemiringan. Sensor MPU6050 menunjukkan akurasi rata-rata 99,22% dan presisi rata-rata 0,991. Alat ini menunjukkan akurasi rata-rata 98,83% dengan presisi 0,996.

Kata kunci: Proximity E18-D0NK; ESP32; Bidang Miring; IoT; Akselerometer MPU6050

1. INTRODUCTION

Technology has developed rapidly in recent decades, and its application has extended to various aspects of life, including in the field of education (Selwyn, 2021). The development of science and technology (IPTEK) is closely related to electronics (Amalia et al., 2022), which has brought many conveniences and benefits to human life.

Electronics has become the main focus for future technology designers (Tjandrawinata, 2016), given its crucial role in advancing various fields of life.

In the 21st century, technology integration in education has become very important and is no longer considered foreign (Agustinova, 2020). Digital literacy and skills in utilizing technology have become basic needs in the modern learning process (Çoban & Salar, 2023). One of the technologies that has gained wide popularity is the Internet of Things (IoT) (Rachman et al., 2024). IoT technology allows the automatic operation of various electronic devices through remote control (Kopetz & Steiner, 2022), making it a very effective tool in supporting various activities and research (Heidari & Jabraeil Jamali, 2023) including teaching and learning activities.

Physics plays an important role in driving technological progress(Mardiansyah et al., 2022), especially through its contribution in the development of physics experiments. One experiment that is often applied in physics education is the inclined plane experiment (Erlangga et al., 2023), which is used to investigate various factors affecting the movement of objects on an inclined surface (Fitrianingrum & Pawarangan, 2024). However, the execution of these experiments often faces challenges, especially in terms of measuring travel time using a stopwatch, which is prone to errors due to limited human response(Fantoni et al., 2021). These errors can impact the accuracy of the data generated and reduce the quality of learning (Raflesiana, 2019).

To overcome these problems, various innovations have been developed in the form of more sophisticated physics experiment sets, such as mechanics and dynamics experiment sets (Carleo et al., 2019). Nonetheless, some weaknesses are still found in these sets, including the use of sliding planes with large friction forces and less accurate manual measurement methods. Therefore, there is a need to develop more responsive and precise experimental devices, utilizing sensor and microcontroller technology.

The inclined plane is one of the fundamental concepts in physics often studied at various levels of education. An inclined plane is a flat surface tilted at an angle to the horizontal, used to facilitate the movement of objects by reducing the force required to lift them vertically (Aksan, 2023). This concept is important for understanding how force and acceleration work when an object moves on a sloped surface. Understanding and analyzing experiments using inclined planes is essential for improving students' understanding and skills in physics (Febriyana et al., 2022) , as well as supporting the advancement of science and technology.

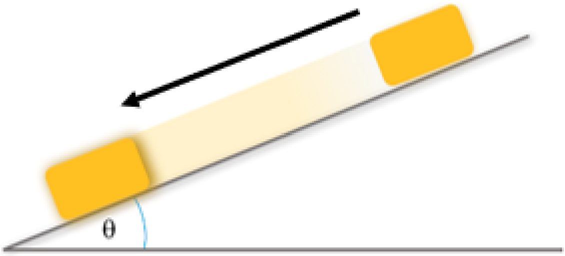

Figure 1. Objects Slide on an Inclined Plane

A more responsive inclined plane experimental device system was designed and built to improve measurement accuracy. It is equipped with travel time control, slope measurement, as well as the ability to display calculation results and data in real-time through the Blynk application that can be accessed through a smartphone. By using a servo motor to hold the object, an E18-D80NK infrared proximity sensor to detect the sliding object, and an MPU6050 accelerometer sensor to measure the slope of the track, this tool is expected to provide more accurate and efficient results in conducting experiments. The data obtained can be monitored and analyzed in real-time, providing convenience for educators and students in the learning process.

2. METHOD

This research falls into the category of engineering research that focuses on the design and development of an Internet of Things (IoT)-based free fall experiment tool. The tool utilizes the E18-D80NK proximity sensor and the HC-SR04 ultrasonic sensor. This engineering research seeks to present new contributions, both in the form of processes and products or prototypes (Mahmood Ali, 2020).

This research was conducted at the Electronics and Instrumentation Laboratory, Department of Physics, Faculty of Mathematics and Natural Sciences, Padang State University, starting in April 2024. The research process is divided into three main stages: the preparation stage, the implementation stage, and the final report preparation stage. The research procedure involves several important stages as follows: Ideas and Task Clarity, Conceptual Design, Arrangement, Geometry, and Functioning, Detailed Design, Tool Making, and Testing.

In the design process, the elements that make up the system are geometrically arranged according to their respective functions. The device design stage includes important aspects such as block diagrams, hardware design, and software design. A block diagram depicting the control and monitoring system can be seen in Figure 2.

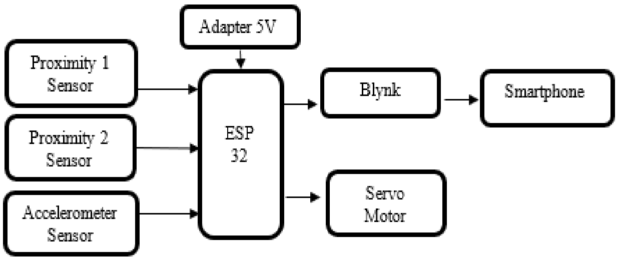

Figure 2. Block Diagram of The System

A 5V adapter is used as the main voltage source for this tool. The first and second proximity sensors serve as triggers to start and stop the timer. The accelerometer sensor is used to measure the tilt angle of the experimental device. The ESP32 is responsible for processing the data generated by the sensors, and the results are sent to the Blynk application, which serves as a medium for displaying measurement data. The servo motor is used to adjust the position of the bar holding the object to be launched on the inclined plane board, while the smartphone is used as a tool to monitor the measurement data in real-time.

The details of the design of this inclined plane experimental tool include both important aspects, namely hardware and software design. The hardware design describes the physical components that make up the system, while the software design serves as an operational guide for the hardware, ensuring that all components work according to their functions. To see the hardware design of this inclined plane experiment, please refer to Figure 3.

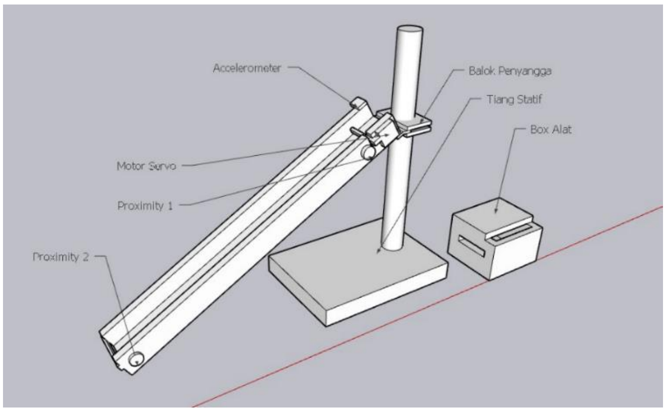

Figure 3. System Hardware Design

The first step is to measure the inclination angle of the track. Once the object is set at the end of the path and the button is pressed, the servo motor will rotate, causing the object to slide. When the object passes the first sensor, the time calculation will start, and the calculation will stop when the object passes the second sensor. The measurement results from the sensors are then sent to the ESP32, which is in charge of processing the input data. After processing, the data will be sent to the Blynk server via a Wi Fi connection.

For the hardware to function optimally and perform its duties efficiently, proper software design is essential. In this research, the software was developed using the Arduino IDE to ensure that the system operates in accordance with the intended purpose. The software design is carefully crafted to support the overall functionality of the system, including the processing of data from sensors and interaction with hardware components. To provide a clearer picture of the structure and workflow of the software, a flow chart illustrating the software design in this system can be seen in Figure 4. The diagram shows the process steps and data flows that are important in software development.

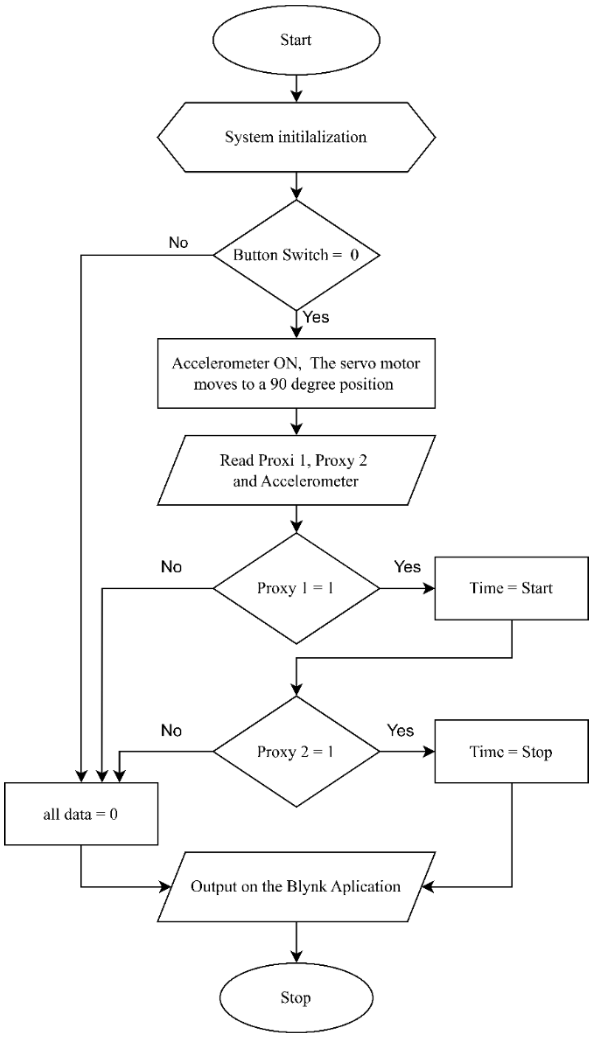

Figure 4. Software Design / Flowchart

Measurement data analysis is a process to determine the level of accuracy and precision of a measurement system. Accuracy is the level of conformity or closeness of a measurement result to the actual price or result. System accuracy is determined by comparing the results of system measurements with the results of theoretical calculations (Febriana et al., 2017). Accuracy is the level of conformity or closeness of a measurement result to the actual price. The measurement accuracy of a measurement system can be determined in the following Equation (1).

$$Accuracy = \left[1 - \left|\frac{Y_n - X_n}{Y_n}\right|\right] \times 100\% \qquad (1)$$

Y_n is the travel time measured with a stopwatch and Xn is the travel time measured on the experimental device.

Precision is a measure of the ability to get similar measurement results. Accuracy can be determined in the following equation.

$$Prescision = \left[1 - \left|\frac{X_n - \bar{X}_n}{\bar{X}_n}\right|\right] \times 100\% \qquad (2)$$

Where X_n is the value of the nth data, n is the total number of measurements and $\bar{X}_n$ is the average value of the measurements.

3. RESULT AND DISCUSSION

Tool performance specification involves the process of identifying or describing the function of each system component, including testing and analysis to ensure optimal system performance. In the context of this research, the specifications include sensor settings (proximity sensor E18-D80NK and accelerometer MPU6050), user interface design with the Blynk application, and the manufacture of the mechanical mechanism of the tool.

This sensor suite will be integrated with the Node MCU ESP32 microcontroller. The microcontroller will be programmed to optimize the sensor function. This tool is equipped with three sensors, namely two E18-D80NK proximity sensors to detect objects and calculate travel time, and one MPU6050 accelerometer sensor to measure tilt angle. The sensor circuit on the microcontroller according to the research results can be seen in Figure 5.

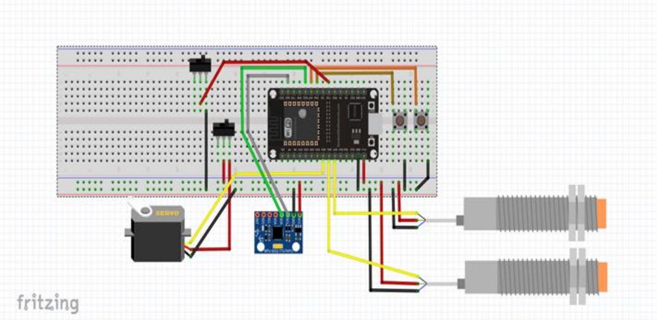

Figure 5. Sensor Circuit

Figure 5 shows the configuration of the sensors connected to the microcontroller in this system. The E18-D80NK proximity sensor, which is installed has three pinouts: power pin (VCC) connected to the 5V pin on the ESP32, ground pin connected to the ground pin on the ESP32, and the data pin of the first proximity sensor connected to pin D26, while the data pin of the second proximity sensor connected to pin D27 on the ESP32. The accelerometer sensor has four pins, namely VCC for power (5V), GND for ground, SCL for sending accelerometer signals connected to pin D5, and SDA for receiving signals used to calculate the tilt angle connected to pin D18. The Servo Motor has three pins, namely VCC for the voltage source, GND for ground and the signal pin connected to pin D25 on the ESP32.

The Blynk interface design was created using the Android Blynk IoT software. In this system, there are several interfaces including a table view, a virtual LCD display, and a notification widget. Each interface displays all the measured parameters such as travel time and tilt angle. The design of the Blynk interface used in this system can be seen in Figure 6.

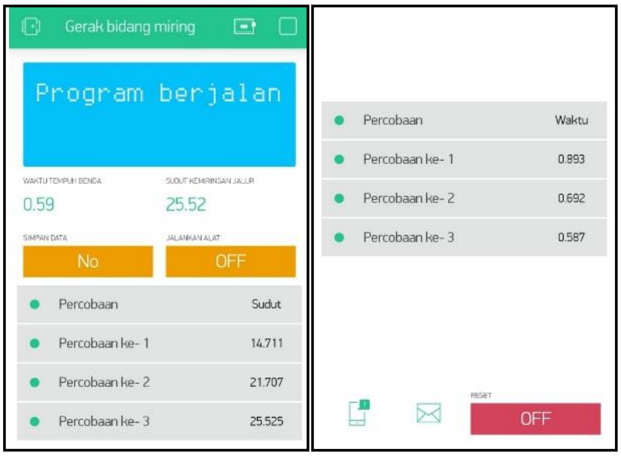

Figure 6. Blynk Interface

Figure 6 shows how the Blynk display will be used to monitor the results of the practicum which displays the travel time and tilt angle, the application made is also equipped with an LCD that will display information on the condition of the tool such as the tool is ready to use, the data has been saved and so on. The application is also equipped with a table as an experimental data storage, so that when the next measurement is made the previous data is not lost. This application is equipped with control buttons to run the tool, save data and reset the application display. There is also a widget to send notifications to the user's email and smartphone.

The travel time parameter will be connected to virtual pin 1 (V1), while the tilt angle parameter will use virtual pin 2 (V2). The control button to run the device uses virtual pin 4 (V4), the control button to save data uses virtual pin 0 (V0), and resets the application using virtual pin 6 (V6). Time data is displayed in a table using virtual pin 5 (V5), while tilt angle data is displayed using virtual pin 3 (V3).

The mechanical device is made using acrylic as the frame of the experimental device. The shape of the device can be seen in the following figure. The Figure 6 shows the shape of the tilted plane experiment mechanism. This tool has a length of 100 cm, a width of 10 cm, a height of 5 cm and a stative pole length of 75 cm.

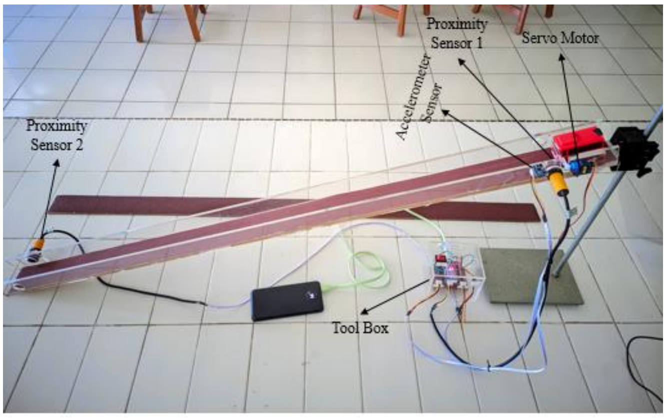

Figure 7. Tool Mechanics

Figure 7 displays the mechanical form of the tool, this experimental tool uses a servo motor as an object holder so as not to slide directly, when the button on the tool is pressed, the servo motor will rotate 900, so that the object barrier will open and the object will immediately slide on a 100 cm long track. Then there is a proximity sensor used as a detector of objects that slide, the sensor is placed at the starting point and end point of the path, with a fairly fast sensor response of less than 2ms the sensor can detect objects well so that data on the object's travel time is obtained. In addition, this tool uses an accelerometer sensor installed at the top of the path to calculate the slope of the path used.

The accuracy sought is the accuracy of the MPU6050 sensor and the accuracy of the inclined plane experimental tool. The following is the accuracy value of the sensor and the experimental tool. Tilt angle accuracy data is obtained by comparing the measurement results of the tools in the system with the standard tools used. The following is the tilt angle accuracy data obtained, which can be seen in Table 1.

Table 1. Tilt Angle Accuracy Data

No	Experiment Tools (degree)/(°)	Standard Tools (degree)/(°)	Accuracy	Error Percentage (%)
1	5.06	5.00	98.800	1.200
2	10.13	10.00	98.700	1.300
3	15.08	15.00	99.467	0.533
4	19.90	20.00	99.500	0.500
5	25.20	25.00	99.200	0.800
6	28.13	28.00	99.536	0.464
7	30.15	30.00	99.500	0.500
8	34.30	34.00	99.118	0.882
9	38.40	38.00	98.947	1.053
10	40.20	40.00	99.500	0.500
Average			99.227	0.773

Furthermore, it determines the accuracy data obtained from the comparison between the tools in the system and the standard tools used. To see the level of accuracy of the MPU6050 accelerometer sensor used, it is done by comparing the angle measured by the sensor with the actual angle measured using an inclinometer, 10 tilt angle data are taken starting from 5 degrees to 40° angle. The lowest accuracy value on the tool is 98.7% at an angle of 10 degrees and the highest speed is at an angle of 5 degrees which is 98.8% and the average accuracy of the 10 data is 99.27% with an average relative error percentage of 0.773% this indicates that the sensor has a good speed characterized by a high percentage of accuracy and a low percentage of relative error.

Table 2. Accuracy Data of Experimental Tools Inclined plane (slippery)

Angle (°)	Experiment Tools (s)	Standard Tools (s)	Accuracy	Error Percentage (%)
15	0.877	0.860	98.023	1.977
17	0.851	0.830	97.470	2.530
20	0.784	0.800	98.000	2.000
22	0.756	0.770	98.182	1.818
25	0.708	0.690	97.391	2.609
28	0.649	0.670	96.866	3.134
30	0.621	0.640	97.031	2.969
32	0.606	0.620	97.742	2.258
35	0.571	0.590	96.780	3.220
38	0.563	0.540	95.741	4.259
Average			97.323	2.677

Table 2 shows the results of the comparison between the travelling time measured using the experimental device and the standard device at various inclination angles, ranging from 15° to 38°. Each row presents the travelling time of the two devices, the accuracy of the measurement results which shows how close the experimental device is to the standard device, and the percentage error of the experimental device compared to the standard device. The average measurement accuracy of the experimental device is 97.323%, with an average percentage error of 2.677%.

This means that overall, the experimental device performed well, although there were slight differences with the standard device, especially at higher inclinations, where the percentage error tended to increase. Furthermore, the accuracy of the inclined plane experimental device on the track with fine sandpaper is shown in Table 3.

Table 3. Accuracy Data of Experimental Tools Inclined plane (fine sandpaper)

Angle (°)	Experiment Tools (s)	Standard Tools (s)	Accuracy	Error Percentage (%)
10	0.991	0.980	98.878	1.122
15	0.738	0.730	98.904	1.096
20	0.675	0.670	99.254	0.746
23	0.621	0.610	98.197	1.803
25	0.589	0.580	98.448	1.552
28	0.558	0.550	98.545	1.455
30	0.534	0.530	99.245	0.755
32	0.516	0.510	98.824	1.176
35	0.483	0.480	99.375	0.625
38	0.476	0.470	98.723	1.277
Average			98.839	1.161

Table 3 displays the accuracy data from the experimental tool on a path with a smooth roughness level taken 10 different data with angle variations. The average speed of 98.83% and an average percentage of relative error of 1.16% Based on this data, the tool has good accuracy. Next is the accuracy of the inclined plane experimental tool on the track with coarse sandpaper shown in Table 4.

Table 4. Accuracy Data of Inclined Plane (Coarse Sandpaper) Experimental Tools

Angle (°)	Experiment Tools (s)	Standard Tools (s)	Accuracy	Level of Accuracy (%)
10	1.320	1.300	98.462	1.538
15	1.012	1.000	98.800	1.200
20	0.805	0.790	98.101	1.899
23	0.518	0.510	98.431	1.569
25	0.679	0.670	98.657	1.343
28	0.661	0.650	98.308	1.692
30	0.610	0.600	98.333	1.667
32	0.527	0.520	98.654	1.346
35	0.476	0.470	98.723	1.277
38	0.455	0.450	98.889	1.111
Average			98.536	1.464

Table 4 shows the accuracy data of the experimental tool on a rough track, by taking 10 data by varying the angle and what will be seen is the travel time of the object that slides compared to the standard tool, namely the stopwatch and the highest percentage accuracy is obtained, namely 98.88% and the lowest accuracy is 98.1%. The average accuracy of the experimental tool is 98.53% and the average percentage of relative error is 1.46%. The measurement results show that the tool has high accuracy, because the value is very close to the results obtained from standard measuring instruments (Mahmood Ali, 2020). The precision of the experimental tool is tested by measuring a parameter that has been determined, then measured using the tool system 10 times. The data of the sensor precision results for the tilt angle parameter is presented in the Table 5.

Table 5. MPU6050 Accelerometer Sensor Precision

Th Measurement	Experiment Tools (degree)	Precision	Level of Precision
1	19.60	0.9776	
2	20.10	0.9975	
3	20.00	0.9975	
4	19.80	0.9875	
5	19.90	0.9925	
6	20.10	0.9975	0.01
7	20.30	0.9875	
8	20.40	0.9825	
9	20.00	0.9975	
10	20.30	0.9875	
Average	20.05	0.9905	

Table 5 displays the precision of the MPU6050 sensor in measuring the angle after 10 data are taken with the same treatment, namely at an angle of inclination of 20 degrees, the average of 10 measurements of the same angle is 20.05 ° then the average tool precision is 0.9905 with a sensor precision level of 0.01. Based on the average precision obtained, we can know that the sensor has good precision.

Table 6. Precision of the Inclined Plane Experiment Tool (Slippery Path)

Th Measurement	Experiment Tools (s)	Precision	Level of Precision
1	0.502	0.9984	
2	0.503	0.9996	
3	0.505	0.9956	
4	0.501	0.9964	
5	0.505	0.9956	
6	0.499	0.9924	0.01
7	0.504	0.9976	
8	0.501	0.9964	
9	0.506	0.9936	
10	0.502	0.9984	
Average	0.503	0.9964	

Table 6 shows the results of measuring the travelling time (in seconds) of an object sliding on an inclined plane with an angle of inclination of 25 degrees. There are 10 measurements of travel time using the experimental device, with the accuracy of the measurement results in each experiment also recorded. The average travel time obtained from the ten measurements was 0.503 seconds, with an average accuracy of 0.9964. The variation in travel time was quite small, indicating the consistency of the experimental results, and the precision value was close to 1, indicating that the measuring device provided highly accurate results in this measurement. Furthermore, the precision of the inclined plane experimental tool on the track with fine sandpaper is shown in Table 7.

Table 7. Precision of Experimental Tools Inclined Plane (Fine Sandpaper)

Th Measurement	Experiment Tools (s)	Precision	Level of Precision
1	0.588	0.9988	
2	0.583	0.9927	
3	0.591	0.9937	
4	0.585	0.9961	
5	0.583	0.9927	
6	0.585	0.9961	0.01
7	0.588	0.9988	
8	0.591	0.9937	
9	0.589	0.9971	
10	0.590	0.9954	
Average	0.587	0.9955	

Table 7 displays the precision data of the experimental tool on a track with a smooth roughness The precision data is taken by taking 10 times the data at an angle of 25 ° and what will be taken is the travel time data, the average travel time of the 10 trials is 0.587 seconds and the average precision is 0.9955 with a precision level of 0.01 Based on this data it can be seen that the tool has a good level of precision. Next is the precision of the inclined plane experimental tool on the track with coarse sandpaper shown in Table 8.

Table 8. Precision of the Inclined Plane Experiment Tool (Coarse Sandpaper)

Th Measurement	Experiment Tools (s)	Precision	Level of Precision
1	0.678	0.9993	
2	0.682	0.9948	
3	0.680	0.9978	
4	0.681	0.9963	
5	0.675	0.9948	
6	0.675	0.9948	0.01
7	0.675	0.9948	
8	0.680	0.9978	
9	0.678	0.9993	
10	0.681	0.9963	
Average	0.679	0.9966	

Based on Table 8 to obtain data on the accuracy of the experimental tool on a rough track, 10 data were taken with the same slope angle of 25 degrees and the average time the object slides is 0.679 while the accuracy is 0.9966 with an accuracy level of 0.01 so Based on these data we can see that the experimental tool has a good level of accuracy. The findings indicate that the monitoring system has very good precision, because all measurement values are close to the average (Mahmood Ali, 2020).

Based on the data obtained in the accuracy and precision tables of the sensors and experimental tools, it can be seen that both the MPU6050 sensor used to measure angles and the experimental tools used to measure the travel time of gliding objects, have good accuracy and good accuracy characterized by a percentage of accuracy that reaches 98% or more and a fairly good level of accuracy of the tool which is at 0.01. While the difference in time obtained between the experimental tool with smooth and rough trajectories is caused by different friction coefficients where the coefficient of friction on the track with smooth roughness is smaller which causes faster travel time than the path with a rough trajectory.

Based on the accuracy data obtained, it can be seen that the greater the launch angle of the object, the faster the object's travel time will be, this is in accordance with the theory because when an object slides on an inclined plane, its travel time is influenced by the angle of inclination of the plane. The greater the angle of inclination, the greater the component of the gravitational force acting parallel to the inclined plane, so that the acceleration of the object increases (Hochberg et al., 2018). With greater acceleration, the object will reach a higher speed in a shorter time. As a result, the time taken to travel a certain distance on the inclined plane will be smaller as the angle of inclination increases. This applies as long as there is no significant friction or other obstacles that slow down the movement of the object (Fitrianingrum & Pawarangan, 2024).

The accuracy data obtained shows that there is a difference in travel time on each path with the same angle, the more slippery the path, the smaller the travel time, this is in accordance with the theory, when the rougher the track, the travel time of the gliding object will be longer because the rough surface produces a greater friction force between the object and the track. This friction force works against the direction of motion of the object, thus reducing the speed and slowing the acceleration of the object (Gideon, 2016). With a smaller acceleration, the object takes longer to travel the same distance compared to a smoother track, where the friction force is smaller. Friction converts some of the kinetic energy into heat, so the motion of the object is not as fast as if the track is smoother (Muhammad, 2022).

The phenomenon that occurs is GLBB, so the square relationship between distance travelled and time travelled on an object sliding on an inclined plane is related to accelerated motion. When an object slides on an inclined plane with constant acceleration, the distance travelled (s) is directly proportional to the square of the travel time (s) (Hari, 2019). This means that the longer the travel time, the greater the distance travelled, and this increase in distance occurs quadratically, not linearly. In the context of physics, the constant acceleration on an inclined plane results from the component of gravitational force acting along the inclined plane. This relationship shows that if the travel time increases, the distance travelled will increase exponentially according to the square of the measured time (Trianiza et al., 2022). Table 8 shows the travelling time of an object sliding on a slippery inclined plane.

Table 9. Table of Distance and Time Travelled on Gliding Objects

No	Distance (cm)	Time Travelled (s)
1	10	0.239
2	20	0.338
3	30	0.415
4	40	0.478
5	50	0.533
6	60	0.538
7	70	0.628
8	80	0.671
9	90	0.711
10	100	0.756

Based on Table 9, it can be seen the relationship between distance and travel time of objects sliding on an inclined plane.

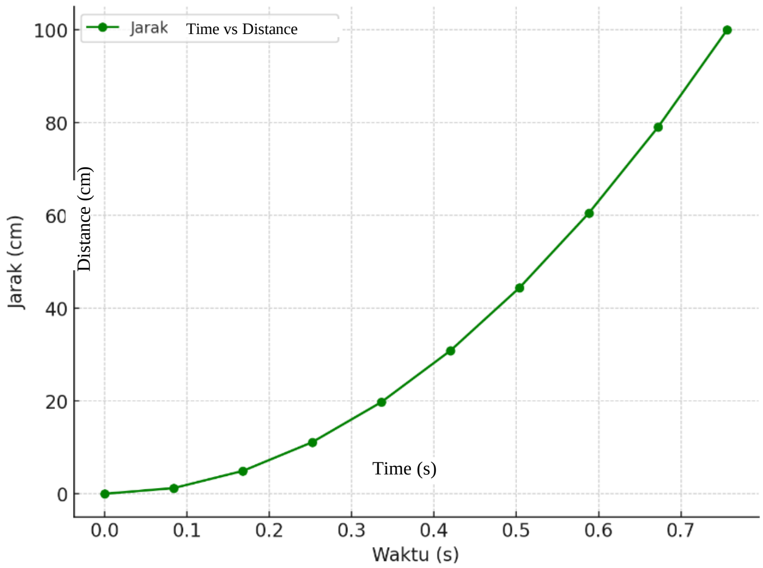

Figure 8. Relationship of Distance to the Square of Time

The graph shown illustrates the parabolic relationship between distance travelled and time on an inclined plane, where was the time travelled increases, the distance travelled also increases significantly. This reflects that object moving on an inclined plane experience constant acceleration, which causes the distance travelled to be proportional to the square of time. In other words, the increase in time spent moving contributes exponentially to the distance travelled, so this pattern shows the characteristics of regular motion and is influenced by the force of gravity and the angle of inclination of the plane.

4. CONCLUSION AND RECOMMENDATION

The results of designing an inclined plane experimental tool using IoT-based proximity and accelerometer sensors are performance specifications and design specifications. Performance specifications in this system, from a technical point of view, can operate properly in accordance with their respective functional purposes. The design specifications of the IoT-based inclined plane experimental tool were successfully designed and tested with high accuracy and precision results. Thus, this tool can be relied upon to be used in testing and research that requires accurate measurement of tilt angle and velocity on an inclined plane. The success of this design shows that proximity sensor and accelerometer technology, integrated with an IoT-based system, can provide effective and efficient solutions in supporting physics experiments.

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