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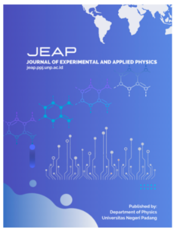

Design of a Free Fall Motion Experiment Using E18-D80NK Proximity and HC-SR04 Ultrasonic Sensors: An IoT-Based Approach

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Abstract: Electronics plays an important role in science, especially in the advancement of school laboratory equipment which is one of the pillars of education. Many laboratories equipment currently still use manual methods. This research aims to develop an IoT-based free fall motion measurement system that displays measurement results automatically. This system uses E18-D0NK proximity sensor and HC-SR04 ultrasonic based on ESP32. This research focuses on engineering a free fall motion measurement tool with the method of dropping objects. Data collection is done through direct and indirect approaches. Direct measurement involves reading the value on the smartphone screen, while indirect measurement is used to evaluate the level of accuracy and precision of the digital measurement system compared to conventional methods. The data obtained was statistically analyzed and represented in graphical form to provide a comprehensive understanding of the performance of the developed system. From the data analysis, there are two important findings. First, the measurement system includes an E18-D0NK proximity sensor for starting and stopping the movement of objects and an HC-SR04 ultrasonic sensor for measuring height, all housed in a toolbox. Second, the system shows excellent average accuracy and average precision.

Keywords: ESP32 Microcontroller, IoT-Based Free-Fall Motion Measurement, Proximity Sensor E18-D80NK, Ultrasonic Sensor HC-SR04.

1. Introduction

Physics experiments play a fundamental role in understanding and exploring natural phenomena [1]. They are essential in many fields, as they form the basis for understanding the laws that govern the universe, from the smallest atoms to the largest galaxies [2]. In addition, physics experiments contribute significantly to the development of new technologies, such as

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computers, airplanes, and medical devices [3]. They also provide solutions to practical problems in various fields, including engineering, environmental science, and biology [4].

As technology continues to develop rapidly, the role of technology in physics experiments is expected to grow in importance in the future [5]. The relationship between physics and technology is very close, where physics provides the scientific basis for technological development, while technology enables more sophisticated physics research [6]. One of the most prominent technology trends in recent years is the Internet of Things (IoT), which connects physical objects to the internet and enables real-time data exchange [7]. This opens up new opportunities in various fields, including physics experiments [8].

Free fall motion is one of the most fundamental physics phenomena and is often studied at various levels of education [9]. This phenomenon occurs when an object falls towards the earth without significant air resistance, following the earth's gravitational acceleration [10]. Conducting and improving free fall experiments is essential to improve students' understanding and skills, as well as supporting the advancement of science and technology.

Conventional free-fall motion experiments generally use stopwatches and meters to measure the time and distance of falling objects [11]. However, these tools have limitations, such as measurement inaccuracies, measurement difficulties at high altitudes, data collection limitations, and lack of data visualization [12]. Recent research has focused on developing sensor-based experimental tools to overcome these limitations [13]. For example, infrared sensors and microcontrollers have been used to improve measurement accuracy, but there are still challenges such as sensor sensitivity to external light interference and limited data display [14]. Design specifications have an important role to ensure that the sensor or system made has good accuracy and accuracy [15], starting from seeing how the characterization of each sensor used and then seeing the accuracy and accuracy of the sensor and system made, so that the resulting tool can function properly and add to the selling value of the tool.

The free fall motion lab tool is a lab tool that uses digital sensors, namely proximity as a Star and stop timer and ultrasonic sensors as a height gauge for the object to be dropped, so that it can freely adjust the height of the object that we will drop with a maximum height of 150 cm, the object to be dropped is attached to the electromagnet then the user can press the button on the tool box to break the flow of electromagnets and the object falls freely. The data will be displayed in the Blynk application after we choose whether the data on the experiment will be saved or not so we can choose the experimental results that we will use or save, so that if there is an error in the measurement then the user can't enter the data so that it is not difficult or does not make the data that has been taken before become messy especially this makes it easy to monitor for educators when the practicum is in progress and there will be a notification if the tool is not used.

The integration of IoT and Blynk offers a promising solution, enabling remote monitoring and control of free-fall motion experiments via mobile devices such as smartphones or tablets. This approach increases user interactivity and convenience, provides attractive data visualization tools and helps users easily understand patterns and relationships between variables in the experiment. Based on these developments, a new experimental system was developed entitled " Design and Construction Experiment for Free Fall Motion Using E18-D80NK Proximity and HC-SR04 Ultrasonic Sensor Based on Internet of Things" which aims to create a more responsive free fall motion experiment system, including time control and real-time data display that can be accessed via smartphone.

This research provides innovation in the development of a free-fall motion experiment device by utilizing IoT technology to improve efficiency and accuracy. The system is designed to be fully controlled through a smartphone application without the need for physical buttons to run the device, thus providing a more modern and practical user experience. With real-time monitoring features, users can easily run experiments, save data, monitor experimental results from different places and reset the device without manual intervention, which is a significant improvement over conventional devices and sensor-based devices that have been made before.

One of the main advantages of this device is the use of the E18-D80NK proximity sensor to detect dropped objects. The E18-D80NK proximity sensor's ability to detect very fast-moving objects has high accuracy without being disturbed by ambient light, so the experimental results are more consistent even under non-ideal environmental conditions. In addition, height measurements are made using the HC-SR04 ultrasonic sensor, which provides greater precision than manual measurements. The combination of these two sensors creates an integrated and optimized system to support various experimental scenarios.

With this innovation, the experimental device not only improves the efficiency of the implementation time, but also provides a more relevant learning solution for physics education. Students can focus more on analyzing experimental results rather than on the technical process of data collection. In the context of education, this technology opens up opportunities to integrate technology-based learning with a deep understanding of physics concepts, especially on the phenomenon of free fall motion. The whole system not only demonstrates technological advances in supporting physics practicum, but also contributes to the modernization of learning tools. By removing the limitations of existing devices and replacing them with a more flexible and accurate system, this research is an important step in connecting modern technology with the needs of education in the digital era.

2. Materials and Method

This research is an engineering study focusing on the design and development of an Internet of Things (IoT)-based free-fall motion experimental tool using E18-D0NK proximity sensors and HC-SR04 ultrasonic sensors. Engineering research involves new contributions in the form of processes or products/prototypes, following the outlined stages [16]. The research procedure includes several stages as follows: Ideas and Task Clarity; Conceptual Design; Structure, Geometry, and Functionality; Detailed Design; Prototype Creation; Testing.

The elements that make up the system to be designed are arranged geometrically according to their respective functions. The device design stage encompasses various aspects related to block diagrams, hardware design, and software design. The 5V adapter as the voltage source of the device, the first and second proximity sensors function as triggers for start and stop timers, ultrasonic sensors are used to measure the height of the object to be dropped, ESP32 functions as data processing generated by sensors whose results will be sent to the Blynk application, Blynk is a medium for displaying measurement data and smartphones as measurement data monitors. The details of the design of this free fall experimental tool include hardware and software design. The block diagram of the control and monitoring system is shown in Figure 1.

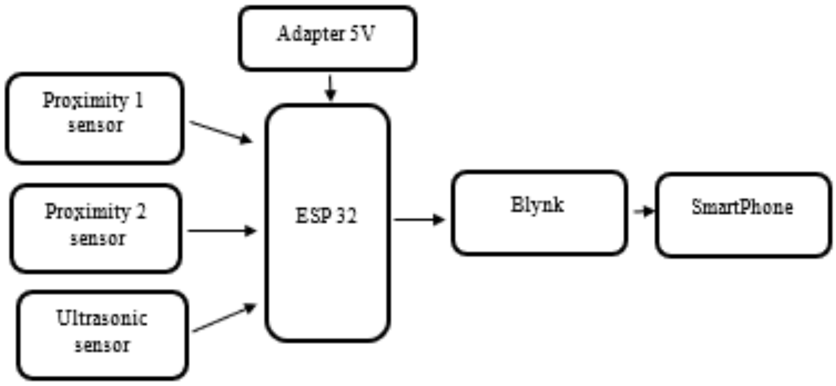

Figure 1. Tool Block Diagram

The hardware design describes the physical components of the system. Meanwhile, the software design acts as a guide for the hardware in carrying out its functions. To see the hardware design of this free fall experiment, see Figure 2.

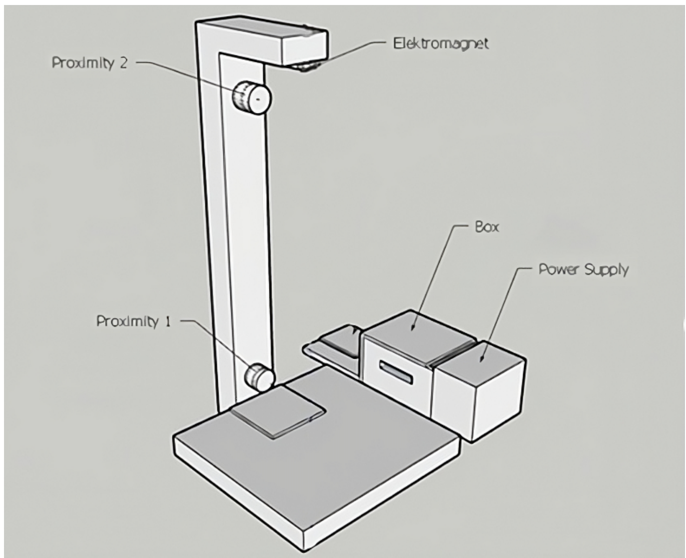

Figure 2. Tool Hardware Design

The design of this tool is shown in Figure 2. After the object is attached to the electromagnet and released, when the object passes the first sensor, the timing will start. When the object passes the second sensor, the time calculation will stop, and the light intensity will be measured. The measurement results from the sensors are then sent to the ESP32 to process the data. The processed data will be sent to the Blynk server via Wi Fi connection. To ensure the hardware can perform its duties effectively, proper software design is required. In this research, the software is designed using Arduino IDE to support the functionality of the system. A flowchart illustrating the software design in this system can be seen in Figure 2.

This design process is carried out using the Arduino IDE application to create a program that is uploaded to the NodeMCU board, as well as the Blynk application to design the system interface.

Programming on NodeMCU starts with system initialization, which aims to declare the pins that will be used. Automatic control is executed through data processing by Arduino. The process starts by detecting the value of the switch button; if the switch button is 0 or off, then the proximity sensor can read the data. This aims to avoid detecting application object that are not relevant to the measurements to be taken. When an object is detected by the first proximity sensor (value 1), the time calculation starts, and the calculation will stop when the second proximity sensor detects the object. All measurement data by the sensors is then displayed on an Android smartphone device using the Blynk.

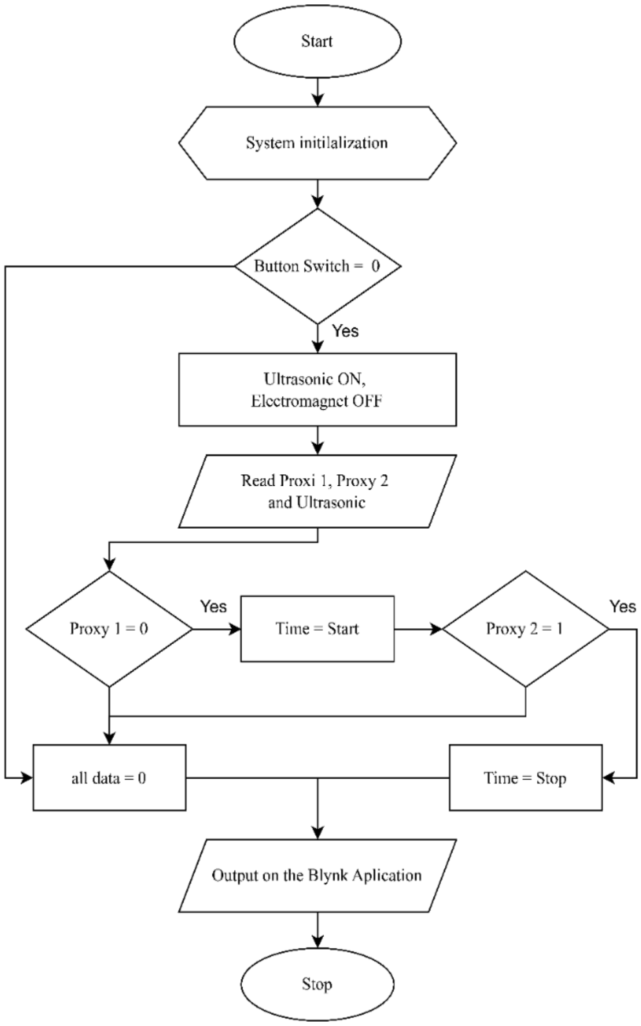

Figure 3. Software design / flowchart

The manufacture of the Internet of Things (IoT)-based free fall experiment tool will be carried out in accordance with the previously planned design. After the system is assembled, testing will be carried out to ensure that the tool is functioning properly. This test is the first step before experiments are carried out in research. The last stage in engineering research is thorough testing of the system that has been developed. This. testing aims to ensure that all components in the system are working properly and to identify potential errors that may occur. The accuracy of the system will be evaluated by comparing the measurement results of the system with existing theoretical calculations [17]. The level of measurement accuracy of a system can be determined using the following Equation (1):

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

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

Prescision measures the system's ability to provide consistent and similar measurement results. Accuracy can be calculated using 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. Results and Discussion

The performance specifications of this tool include the sensor circuit, application design and mechanical manufacture of the tool. This sensor circuit will be controlled by the Node MCU ESP32 microcontroller. This tool is equipped with two E18-D80NK proximity sensors to detect objects and calculate travel time, and one HC-SR04 ultrasonic sensor to measure distance. The sensor circuit can be seen in Figure 4.

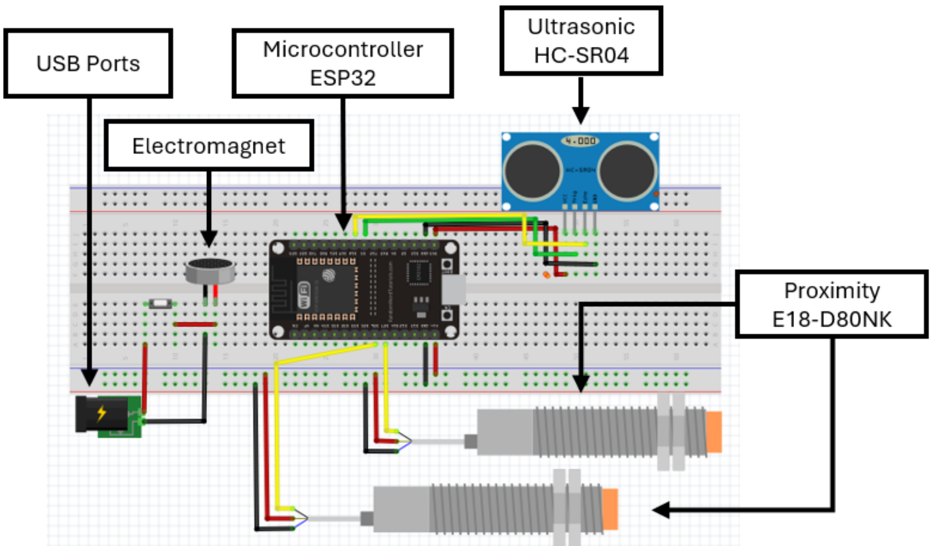

Figure 4. Electronic Circuit System

The circuit consists of 2 proximity sensors connected to pins D27 and D28 respectively. The ultrasonic sensor is connected to pin D5 for echo and D18 for trigger. The three sensors get a voltage supply from the VIN pin and GND pin on the ESP32. There is an electromagnet with a voltage source from the power supply and can be controlled by a switch.

The HC-SR04 sensor is an ultrasonic proximity sensor that uses digital signals to measure distance. This sensor works by sending out an ultrasonic signal and then receiving its reflection. The HC-SR04 provides a digital output in the form of a pulse with a duration proportional to the distance of the detected object. You can measure the duration of this pulse to calculate the distance with a specific formula.

To use this sensor, we need to trigger the sending of ultrasonic waves through the 'Trigger' pin. After that, the sensor measures the time taken by the sound waves to return to the sensor and generate a pulse on the 'Echo' pin. The duration of the pulse on the 'Echo' pin is what is used to determine the distance to the object.

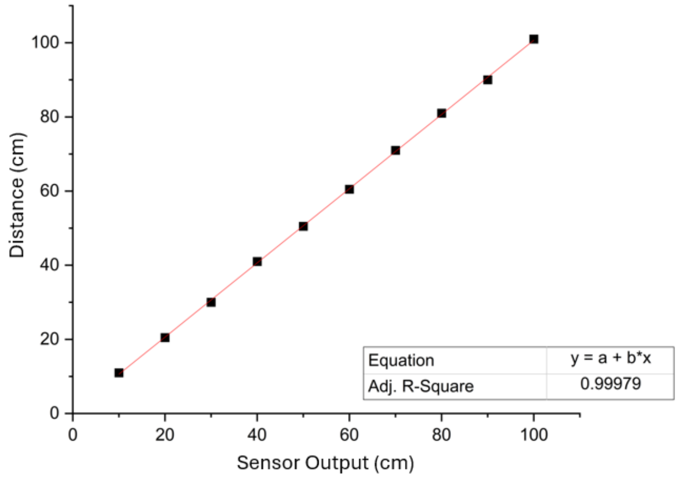

Figure 5. Ultrasonic Sensor Characteristics

Based on Figure 5, the y-axis can be seen the sensor output and the x-axis is the actual distance so it can be seen that the relationship between distance and HC-SR04 sensor output is directly proportional. The R^2 value of the sensor is 0.99979, which indicates that the data generated by the sensor is quite good and accurate. The equation that connects the HC-SR04 sensor output to the distance is y = a + b * x. The Blynk interface design was created using the Android Blynk IoT software. It displays all measured parameters such as travel time and distance. The use of the Blynk application as an interface and microcontroller connector in this IoT-based free fall experiment tool is because Blynk offers an intuitive interface, making it easier for users to design displays, add widgets, and set tool functions without having to write interface code from scratch.

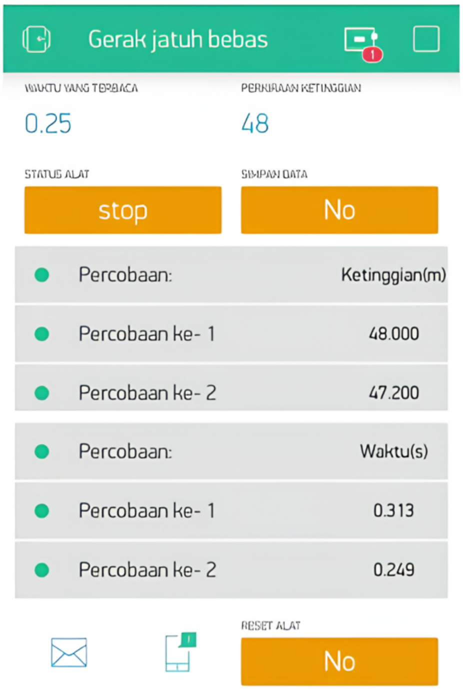

Figure 6. Blynk Application Display

In addition, Blynk enables real-time data monitoring and control, such as displaying fall time or altitude directly on mobile devices. With cloud-based support, the app provides high portability, allowing users to access and control the device from anywhere as long as it is connected to the internet. Sensor integration is also made simpler thanks to the various widgets available, such as buttons, tables, graphs, and virtual LCDs, which simplify the display and analysis of data from proximity and ultrasonic sensors. Experimental data can be stored in the app, sent via email, or further processed on the user's device. In addition, Blynk can provide automatic notifications regarding the status of the device, such as running, saving data, or resetting, so that users are always up to date. The Blynk interface design used can be seen in Figure 6.

The next step is to configure the virtual pins in the Blynk application. The travel time parameter is connected to virtual pin 0 (V0), while the distance parameter uses virtual pin 7 (V7). The app is equipped with control buttons: to run the device using virtual pin 2 (V2), save data using virtual pin 3 (V3), and reset the app using virtual pin 4 (V4). Time data will be displayed in a table using virtual pin 1 (V1), while distance data will be displayed using virtual pin 8 (V8). The interface of the app used in this free-fall experiment is designed to provide intuitive data visualization and control. It displays travel time and altitude with two digits behind the comma, ensuring high accuracy in measurement and data analysis. This display helps users get clear and easy-to-read information, which is very important in experiments that require precision. The LCD on the app displays the status of the device, such as 'running,' 'data reset,' and 'save data,' providing users with real-time feedback on the condition of the device. This status information helps in monitoring the experimental process and ensuring that all necessary steps are taken before and after the measurement.

The app also comes with functional buttons, such as buttons to run the tool, save data, and reset the system. These buttons are designed to be responsive and easy to access, allowing users to operate the tool quickly and efficiently. The 'save data' and 'reset' buttons ensure that data can be saved correctly and the system can be restored to its initial state easily. In addition, there is an in-app table used to store altitude and time data with three digits behind the comma. This provides enough space to store more detailed data, which is useful for more in-depth analyses. The table also makes it easier for users to systematically track and compare experimental results. The app comes with widgets to send data to email and provide notifications on mobile phones. This feature is very useful to ensure that experimental data is not only stored locally but can also be accessed from other devices or sent to those who need it. Notifications on mobile phones make it easy for users to stay informed about the status of experiments, even when not near the main device. The mechanism of the device is made using acrylic as the frame of the experimental box and stative pole. This tool is 175 cm high, 10 cm wide and 20 cm long. The mechanics of the tool can be seen in Figure 7.

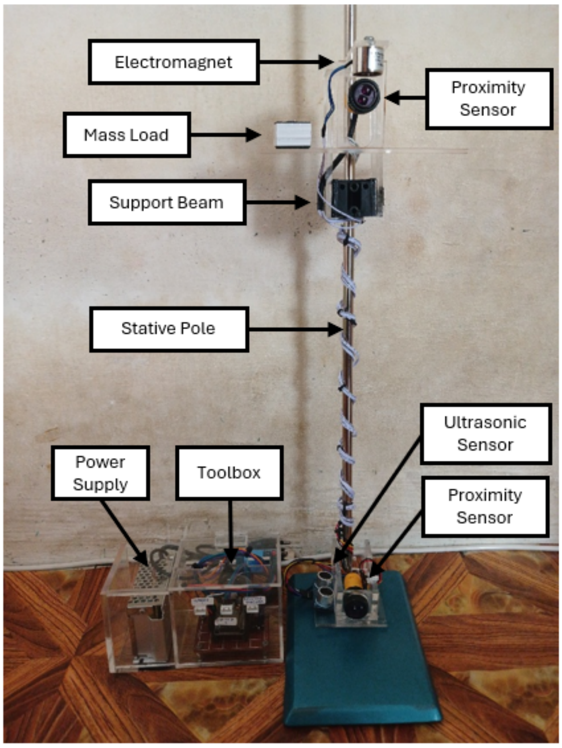

Figure 7. System Mechanics

The design specifications of the IoT-based Fall Motion Experiment Tool consist of the rigor of the experimental tool and the accuracy of the experimental tool. To see the accuracy of the IoT-based free fall experiment tool. The accuracy of a system is determined by comparing the measurement data with the data taken using a standard tool, the height variation will affect the travel time of objects in free fall. The accuracy of the ultrasonic sensor can be seen in Table 1.

Table 1. Display The Height Measurement Accuracy Data of The Free Fall Experiment.

No	Experiment tools (cm)	Standard tools (cm)	Accuracy	Error percentage (%)
1	10.20	10.00	98.000	2.000
2	20.30	20.00	98.500	1.500

3	30.50	30.00	98.333	1.667
4	40.50	40.00	98.750	1.250
5	50.50	50.00	99.000	1.000
6	61.00	60.00	98.333	1.667
7	71.00	70.00	98.571	1.429
8	81.00	80.00	98.750	1.250
9	91.00	90.00	98.889	1.111
10	101.00	100.00	99.000	1.000
Average			98.613	1.387

Based on the data shown in Table 1, a more in-depth analysis of the accuracy of the height measurements from the free fall experiments revealed some important findings. The data obtained from the experimental equipment used is recorded in the first column, showing varying degrees of accuracy compared to the standard measurement equipment recorded in the second column. The accuracy is calculated as a percentage, while the percentage error reflects the deviation from the standard measurement. Overall, the experimental apparatus showed an excellent average accuracy of 98.61%, indicating a high degree of precision in measuring height during the freefall experiment. The relatively small difference between the experimental device and the standard measurement indicates that the measurement system was well calibrated and functioned properly in most cases. The recorded average percentage error of 1.39% is very low, which further reinforces the reliability of the instrument.

Although there were fluctuations in the accuracy results throughout the measurement range, the errors were smaller at larger distances. For example, measurements at a distance of 10 cm had the highest error of 2,000%, while measurements at a distance of 100 cm showed the lowest error of 1,000%. These fluctuations are likely due to factors such as the characteristics of measurements at shorter distances, environmental influences such as air temperature and humidity, and limitations in the accuracy of the measuring instrument itself. Nevertheless, the results remained consistent, with accuracy ranging from 98.0% to 99.0% for all measurements. This consistency shows that the experimental system is highly reliable, giving confidence that it is capable of providing accurate data at various heights. The small errors that occur at shorter distances (e.g., 10 cm and 20 cm) can be resolved with more thorough sensor calibration. The results obtained were within acceptable limits for experimental and educational purposes. The accuracy of the experimental tool can be seen in Table 2.

Table 2. Displays Data on the Accuracy of Travel Time Measurements from the Free Fall Experiment.

No	Height (cm)	Experiment tools (s)	Standard tools (s)	Accuracy
1	60	0.360	0.350	97.143
2	70	0.390	0.378	96.825
3	80	0.400	0.404	99.010
4	90	0.440	0.428	97.196
5	100	0.450	0.451	99.778

6	110	0.480	0.474	98.734
7	120	0.500	0.495	98.990
8	130	0.520	0.515	99.029
9	140	0.540	0.535	99.065
10	150	0.560	0.554	98.917
		Average		98.469

The measurement results of the accuracy of the experimental device have an average precision of 99.46%. The accuracy results obtained show that the accuracy of the experimental tool is very good because it has a value that is close to the actual value measured on a standard measuring instrument [18]. The precision of the distance measurement was tested by re-measuring 10 times, by setting the height value to be measured. Data on the results of measuring the precision of the ultrasonic sensor can be seen in Table 3.

Table 3. Displays Data on the Precision of Height Measurements from the Free Fall Experiment.

Measurement to-	Experiment tools (cm)	Precision	Degree of precision
1	75.50	0.991	0.009
2	76.00	0.998	0.002
3	74.50	0.978	0.022
4	74.00	0.972	0.028
5	77.00	0.989	0.011
6	78.00	0.976	0.024
7	77.50	0.982	0.018
8	77.80	0.978	0.022
9	76.50	0.996	0.004
10	74.80	0.982	0.018
Average	76.160	0.984	0.016

Based on the data shown in Table 3, an in-depth analysis of the precision of the travel time measurements from the free fall experiment revealed some important findings. The experimental tools used, listed in the first column, showed varying degrees of precision, which was calculated based on their proximity to the mean value of the measurements. The precision is calculated based on the values obtained in the experiment, while the degree of precision reflects how small the difference is between the individual measurement values and the average measurement value. Overall, the measurement results showed an average precision of 0.984, which indicates a very good level of consistency in the measurements. The average degree of precision value of 0.016

indicates that the differences between measurements are very small, with most of the measurement values being very close to the average value. This shows that the instrument can provide consistent and stable results in every measurement.

The fluctuations seen in the measurement results, such as in measurement number 3 (74.50 cm) which has an accuracy degree of 0.022 or measurement number 4 (74.00 cm) with an accuracy degree of 0.028, are still very small. These small fluctuations can be caused by unavoidable measurement factors in the experiment, such as variations in the experimental environment or possible small errors in the measurement technique. Nonetheless, the degree of precision recorded is still very good, given that the degree of precision of all measurements is within a very narrow range. With an average precision of 0.984, these results show that the experimental apparatus is reliable in producing data that is consistent and close to the mean value. The small variations observed could be addressed by further calibration of the experimental apparatus, but the results are still within excellent limits for experimental applications. The precision of the experimental tool can be seen in Table 4.

Table 4. Displays Data on the Precision of Travel Time Measurements from the Free Fall Experiment.

Measurement to-	Experiment Tool (s)	Precision	Degree of precision
1	0.455	0.9941	0.022
2	0.460	0.9950	0.002
3	0.453	0.9897	0.002
4	0.455	0.9941	0.012
5	0.462	0.9906	0.007
6	0.461	0.9928	0.002
7	0.468	0.9775	0.012
8	0.452	0.9875	0.017
9	0.455	0.9941	0.002
10	0.456	0.9963	0.012
Average	0.458	0.9912	0.01

The measurement results of the precession of the free fall experiment tool have an average accuracy of 0.9993 and a precision level of 0.01. The precision results obtained show that the precision of the tool is very good, because all measured values are close to the average value [18].

The higher the height of the falling object, the longer the gravitational acceleration acts on the object, so the final velocity increases. The percentage relative error (%SR) between the measured and calculated final velocities is small, indicating that the measured results are close to the theoretical calculations. This small deviation could be due to factors such as air resistance or errors in measurement. Overall, the change in height is directly proportional to the increase in final velocity, in accordance with the underlying physical theory.

In free fall motion, the velocity of an object increases as its height decreases. This happens because the gravitational potential energy that the object has when it is at a height turns into kinetic energy when the object moves down [19]. The higher the initial position of the object, the greater its potential energy, which then contributes to an increase in speed as it approaches the surface. In conditions without air resistance, the speed of the object will continue to increase until it reaches the ground.

Straight line movement (GLBB) graph generated from the travelling time data against altitude also forms a parabolic pattern. This happens because the relationship between travel time and altitude in free fall motion is influenced by gravitational acceleration, where travel time is proportional to the square root of altitude. As the height increases, the travelling time increases, following the parabolic pattern of GLBB. The following figure will show the parabolic graph generated based on the travel time data that has been obtained from this experiment.

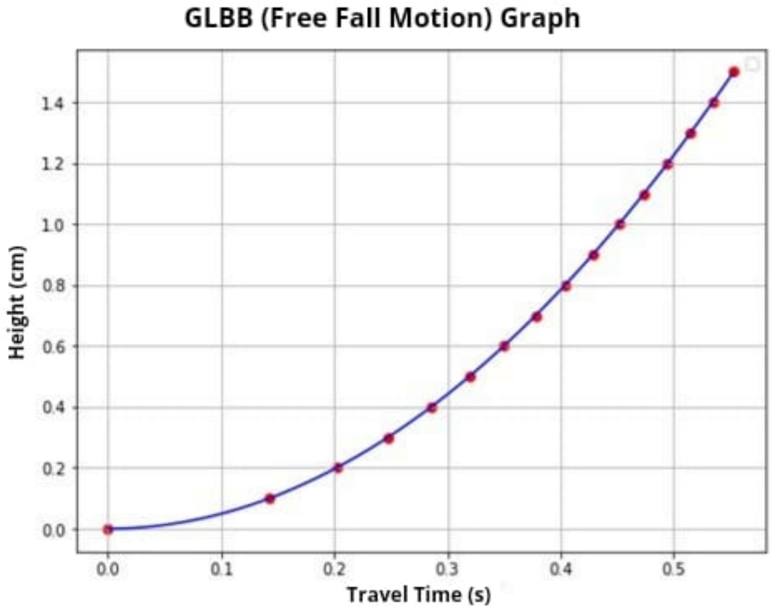

Figure 7. Graph of Uniformly Accelerated Rectilinear Motion in Free Fall Motion

The graph illustrates the relationship between height (meters) and time (seconds) in straight line motion (GLBB) for objects in free fall. The curve shows that the distance travelled by the object increases quadratically with time, which is characteristic of motion affected by a constant acceleration, namely gravity [20]. At time zero, the distance travelled by the object is also zero, and as time increases, the distance travelled increases at an accelerating rate. This is consistent with the equation

$$h = \frac{1}{2} g t^2 \tag{3}$$

The drastic decrease in height illustrates how the acceleration of gravity affects the motion of a free-falling object, where the change in height increases faster as time increases [21]. While the relationship of the data that has been obtained in finding the value of gravity and compared with the theoretical value of gravity can be seen in Table 5.

Table 5. Comparison of Gravity Values from Experiments and Theory

No	Height (cm)	Gravity Measurement (m/s2)	Gravity Theory (m/s2)	Error percentage (%)
1	1	9.22	9.81	6.014
2	1.1	9.74	9.81	0.714
3	1.2	10.22	9.81	4.179
4	1.3	10.52	9.81	7.238
5	1.4	10.96	9.81	11.723

Based on the data presented in Table 5, the comparison between the values of acceleration of gravity obtained through experiments and the theoretical values shows a significant variation. The theoretical gravity acceleration value used is 9.81 m/s^2, which is a common value. Meanwhile, the value of gravity obtained from the experimental results varies at each measured height. In general, the higher the height of the falling object, the greater the measured value of gravitational acceleration. For example, at a height of 1 cm, the gravity value obtained is 9.22 m/s^2, which has an error difference of 6.014%. However, as the height increases, the measured gravity value gets closer to the theoretical value of 9.81 m/s^2, such as at a height of 1.1 cm which obtained a gravity value of 9.74 m/s^2 with an error of 0.714%.

An increase in the value of gravity measured at a lower altitude may be due to various factors, including instability in time measurement or minor influences from external factors such as wind, air humidity, or errors in the measurement device. The smaller the fall distance, the faster the time required to reach terminal velocity, which may cause errors in the measurement of gravitational acceleration. In addition, at higher altitudes, the time taken to fall is longer, providing an opportunity for the measurement to be more accurate and close to the theoretical value. Nonetheless, the difference in error recorded at larger heights, such as at 1.4 cm (11.723% error), still suggests that other factors such as limitations of the experimental method may affect the results obtained. Overall, despite the fluctuations in the gravity measurement results obtained, the data shows an interesting trend where the gravity value is getting closer to the theoretical value of 9.81 m/s^2. These results suggest that this experiment can be used to understand the movement of objects in free fall, although there are variations that need to be considered and studied further.

As the distance an object falls decreases, the time it takes for the object to reach the ground will also decrease, and this has a direct impact on its final velocity. In free fall motion, the acceleration experienced by an object is due to gravity, with a constant value of about 9.8 m/s^2 on earth. When an object falls from a lower height, the time for the object to be accelerated by gravity is shorter. Thus, its final velocity will be lower than that of an object falling from a higher height. Based on the equation:

$$v^2 = 2gh \qquad (4)$$

It can be seen that the final velocity of the object is directly proportional to the root of the falling height. The lower the height, the smaller the final velocity. However, the acceleration of gravity (g) remains unchanged as it is a constant property of the Earth's gravitational field. So, even if the distance, time and velocity change, gravity remains the main factor accelerating objects in free fall motion and is always a constant value [22].

4. Conclusion

The results of the design of the free fall experiment using IoT-based proximity and ultrasonic sensors include performance specifications and design specifications. From a technical point of view, the performance specifications in this system are able to operate properly in accordance with their respective functional objectives. The design specifications of the IoT-based free fall experiment tool were successfully designed and tested with a high level of accuracy and precision. Therefore, this tool is reliable for use in testing and research that requires accurate measurement of speed and time in free fall motion. The success of this design shows that proximity and ultrasonic sensor technology integrated with IoT-based systems can provide effective and efficient solutions in supporting physics experiments

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