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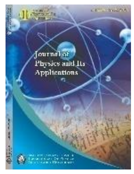

A Real-Time Hooke's Law Experiment using IoT Mobile Application

Agus Sudarmanto[1], Joko Budi Poernomo[1], Jatmiko Endro Suseno[2], Ari Bawono Putranto[3], and Muhammad Abdul Basit[1]

[1]*Department of Physics, Faculty of Sciences and Technology, Walisongo Islamic State University, Semarang, Indonesia*
[2]*Department of Physics, Faculty of Sciences and Mathematics, Diponegoro University, Semarang, Indonesia*
[3]*Vocational School, Diponegoro University, Semarang, Indonesia*

**Corresponding author :* agussudarmanto@walisongo.ac.id

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ABSTRACT

Hooke's Law is one of the topics in physics that can be simplified for better understanding through practical methods. This research aims to design a Real-Time remote Hooke's Law experiment in laboratory with Blynk as IoT Mobile Application, allowing students to experiment more flexibly in terms of time and location. The research methodology is based on Research and Development (R&D), including hardware design, software design, testing and data collection, data analysis, and report writing. This study resulted in the development of a laboratory Hooke's Law experiment and a Blynk application as its controller. The apparatus was tested by conducting experiments with three different loads: 30 grams, 40 grams, and 50 grams. The experiments aimed to obtain the spring constant, k, which were then processed using Hooke's Law formula based determine spring elongation data, Δx. The 30 gram load yielded an average Δx of 0.059 meters with an accuracy of 99.98% and an average k value of 4.90 N/m with an accuracy of 98.75%. The 40 gram load yielded an average Δx of 0.059 meters with an accuracy of 99.93% and an average k value of 5.32 N/m with an accuracy of 95.40%. The 50 gram load yielded an average Δx of 0.089 meters with an accuracy of 99.94% and an average k value of 5.53 N/m with an accuracy of 96.39%. The overall accuracy of the apparatus was 99.95% for Δx and 96.18% for the spring constant. The system can choose the mass, m with control the stepper motor via mobile application and the result of research can be monitored in smartphone display such as such as spring elongation, Δx, and spring constant, k as well as streaming video for monitoring purposes.

1. Introduction

Blended learning is an educational approach that combines traditional face-to-face instruction with online learning components [1]. Blended learning can be applied to both theoretical and practical courses. The implementation of blended learning in practical courses is carried out by combining direct practice in the laboratory with the use of digital media online. The online sessions can be integrated with laboratory practice tools through the Internet of Things (IoT). Through the combination of in-person laboratory work and online learning components, educators can ensure continuity in teaching, even in times of disruption, where many universities adapted their laboratory practices to a blended format to maintain educational quality [2]. Therefore, the development of a practical tool, specifically for the Hooke's Law experiment, based on the Internet of Things, was carried out.

Research conducted highlights the importance of laboratory experiments as a method of learning physics, particularly the spring experiment (Hooke's Law) [3]. This experiment aims to better understand the concepts of physics learning materials through direct experience. The spring constant is an important value in this experiment, which can determine the proportional increase in length of the spring with the force acting on it.

Several studies have attempted to develop spring constant laboratory tools using microcontroller technology and the values on an LCD. The laboratory tool was designed using components such as an Arduino Uno, tranducer, LCD, and jumper cables [4]. However, these studies did not incorporate the concept of the Internet of Things (IoT) in the development of the laboratory equipment. In special cases where researchers do not have experimental equipment or the equipment is in a laboratory in locations with long distances and need to conduct experiments directly, not simulations, the use of distance learning experiments or the Internet of Things (IoT) is very necessary.

The Internet of Things (IoT) represents a transformative paradigm that integrates real-world objects into a cohesive network, enabling enhanced control and monitoring [5]. IoT technology, a concept where objects can connect and interact via the internet, has been a focal point in the development of electronic devices. Muhammad Nurkholis Ramadhani successfully developed an IoT-based laboratory tool for measuring the coefficient of linear expansion using ultrasonic and temperature sensors to monitor temperature changes and elongation of copper pipes, with data displayed directly on a smartphone screen [6].

NodeMCU is an open-source firmware and development kit that facilitates the programming of ESP8266 Wi-Fi modules into these applications exemplifies its role in enhancing automation and connectivity in modern technology [7]. Based on this background, researchers will innovate by developing an IoT-based spring constant laboratory tool. This tool will use NodeMCU microcontrollers connected to the internet, allowing students to conduct laboratory experiments remotely and obtain real-time data. Problem formulation, research objectives, and research benefits have been outlined to provide clear direction in the development of this laboratory tool.

The novelty of this research lies in the development of an Internet of Things (IoT)-based Hooke's Law experimental apparatus that enables real-time measurement of the spring constant and remote access through a mobile application. Unlike previous studies that only displayed data locally using an LCD, the system developed in this research is integrated with a blended learning framework, thereby supporting flexible, interactive, and authentic experiment-based physics laboratory activities.

The main contribution of this manuscript is the development of an IoT-based experimental instrumentation for measuring the spring constant in a Hooke's Law experiment, integrated with a blended learning approach. In addition to instrument development, this study contributes to educational innovation by enabling remote, real-time laboratory experiments that enhance learning flexibility, while also providing experimental validation of Hooke's Law through direct measurement using the developed system.

Compared to conventional laboratory experiments that rely on on-site measurements and manual data recording, the proposed IoT-based Hooke's Law experimental apparatus improves experimental effectiveness by enabling real-time data acquisition, remote accessibility, and efficient repetition of measurements. This approach supports blended learning implementation while maintaining experimental authenticity and enhancing students' understanding of the relationship between force and spring elongation.

Hooke's law is :

$$F = k.\Delta x \qquad 1,$$

which means that in an elastic area of an object, the growth value of its length is proportional to the force acting on the object. The value of :

$$F=W=mg \qquad 2,$$

where *m* is mass load, *g* is acceleration due to gravity, *Δx* is change in length and *k* is spring constant. When an object has reached its elastic limit, the object returns to its original position when it stops (the force is lost). [8].

The Internet of Things (IoT) is a concept where the internet becomes a network infrastructure that can be used anywhere and anytime as long as it is connected to the internet. The IoT communication channel network is a combination of body area networks, personal area networks, local area networks, and wide area networks [9]. Any object of any shape (physical or virtual) can be connected by IoT by capturing data and communicating it using sensors to develop services [10]. The Blynk application is a smartphone application that can be used as part of an electronics research based on the Internet of Things system. Blynk is used as the interface for the conducted research, as it features as a receiver of data that can be displayed and also serves as a controller for the research tool [11].

Fig. 1: *Blynk logo and Interface*

NodeMCU is one of several microcontrollers available. The ESP8266 chip it utilizes is capable of connecting to the internet, making it suitable for Internet of Things (IoT) projects. With its strong capabilities in onboard storage and data processing, the ESP8266 enables NodeMCU to integrate well with sensors and other components via GPIOs, and development is made straightforward, even including file uploading with minimal hassle [12].

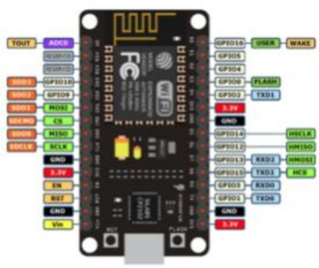

Fig. 2: *Nodemcu Pinout Digram*

A sensor that operates with sound waves ranging from 20 kHz to 2 MHz using the principle of sound wave reflection is called an ultrasonic sensor

[1]. Its function as a converter of electrical quantities into sound and vice versa is one of the uses of the ultrasonic sensor. The sound emitted by the ultrasonic sensor can propagate through a medium, one of which is gas. When the sound propagating through the medium is obstructed, it will be reflected, and the reflection will be received back by the ultrasonic sensor. It has a frequency of 20,000 Hz, making it inaudible to humans [13].

Fig. 3: *Ultrasonic Sensor HC-SR04*

The operating method of an ultrasonic sensor is as follows: first, the transmitter emits ultrasonic waves, then the time required for the waves to reach the target and be reflected back to the receiver is measured. The duration is proportional to twice the distance between the sensor and the target, so the distance from the sensor to the target can be determined using the equation:

$$s = \frac{v\,t}{2} \qquad 3,$$

where s is the distance in meters, v is the speed of sound with a value of 344 m/s, and t is the time traveled in seconds.

Table 1 Ultrasonic Sensor Spesification

Parameter	Spesification
Size	24 mm x 20 mm x 12 mm
Workflow	30-50 mA
Voltage	3,3 DCV – 5 DCV
Distance Detection	3 cm – 3 m
Sensitivity	Detection object with diameter 3 cm distance > 1 m

Stepper motors are a type of DC motor that can be controlled by digital pulses. Operating a stepper motor is done by converting input pulses into discrete mechanical movements. Therefore, to drive a stepper motor, a stepper motor controller is required to generate periodic pulses [14].

A relay is an electronic component used as a switch in electronics-based projects. Serving as an automatic voltage-to-electricity switch, the relay consists of two electromechanical components: a coil serving as the electromagnetic component and a set of contacts serving as its mechanical function [15].

LCD (Liquid Crystal Display) is a component used to display the output results of an electronic circuit.

Fig. 4: *Motor Stepper*

Fig. 5: *Relay*

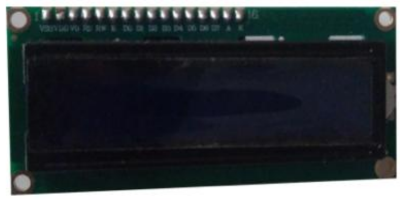

Fig. 6: *LCD (Liquid Crystal Display)*

Since the LCD has many pins, the I2C module is a solution that can be used to reduce the number of pins required. The features of this LCD screen include: (a) It can display 16 characters and 2 lines (16x2 LCD), (b) It has a total of 192 characters, (c) It features a pre-programmed character generator, (d) Both 4-bit and 8-bit modes can be used, and (e) It can be used with backlight.

Due to the LCD's numerous pins, the I2C module is a solution that can be used to reduce the usage of these pins. With just 4 pins, the LCD can be connected to a NodeMCU or other microcontrollers. Here are the 4 pins found on this I2C module: (a) GND Pin: Ground pin, connected to GND on the NodeMCU, (b) VCC Pin: Vin pin, connected to 5V on the NodeMCU, (c) SDA Pin: I2C data pin, connected to an analog pin on the NodeMCU, and (d) SCL Pin: I2C clock pin, connected to an analog pin on the NodeMCU.

2. Methods

Design

Fig. 7 shown a block diagram of A Real-Time Hooke's Law Experiment using IoT Mobile Application.

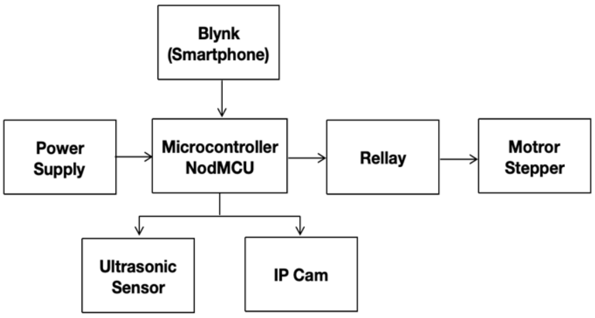

Fig. 7: Block diagram of A Real-Time Hooke's Law Experiment using IoT Mobile Application

The smartphone sends commands to the NodeMCU microcontroller via the Blynk application. Then, the NodeMCU microcontroller sends a command to the relay to turn on the stepper motor so that it rotates to the right, unwinding the rope until the spring stretches to its maximum due to the load. After that, the ultrasonic sensor will detect the change in the spring's length before stretching and after reaching its maximum stretch. Once the change in spring length is detected, the stepper motor rotates to the left to wind the rope back until the spring returns to its original position. The results of the spring length change readings will be displayed on the LCD and on the smartphone. The IP camera functions to monitor the Hooke's Law experimental device, and the results are displayed on the smartphone via live streaming.

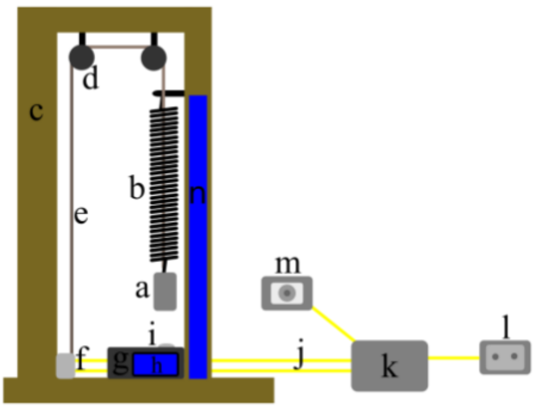

Fig. 8: *Design Hooke's Law*

The design of the Hooke's Law laboratory apparatus shown in Fig 8 can be explained as follows: (a) is the hanging mass with a hook and a link. This mass is used to elongate the spring, thereby obtaining data on the increase in length of the spring, (b) is the spring. The spring is the main component to generate data on the increase in length and the spring constant, which will be analyzed using the formula of Hooke's Law, (c) is the static rod. The static rod serves as the support for the entire apparatus. The static rod used is made of wood, (d) is the pulley. The pulley is used to assist in hoisting/pulling the string attached to the hanging mass, (e) is the rope/string. The rope/string used in this apparatus is mattress cord. The mattress cord can withstand a maximum variation of the hanging mass load in the apparatus, which is 100 grams, (f) is the stepper motor. The stepper motor is used to pull the hanging mass, (g) is the equipment box. The equipment box contains several essential items for the apparatus, such as the NodeMCU, circuit cables, and others, (h) is an I2C LCD. The I2C LCD is used to display the device's work results, thus facilitating analysis of laboratory experiment outcomes, (i) is an ultrasonic sensor. The Ultrasonic Sensor is used to measure the increase in length that occurs in the spring (j) is a circuit cable. Several circuit cables are located outside the device box, (k) is a relay. The relay is used to interrupt the flow of electricity in the circuit, (l) is a power source (power plug). The power source is useful for powering the device, so it can operate properly, (m) is a camera. The camera is used to monitor the operation of the device, whether it is functioning properly or not, (n) is a cloth ruler used as a comparison for the ultrasonic sensor.

Data Analysis and Report Preparation

The final step involved testing the core components of the developed experimental system, including the ultrasonic distance sensor, stepper motor, relay, and control unit, to ensure proper functionality and measurement reliability. For each applied mass, measurements were repeated five times to evaluate repeatability and improve the precision of the developed instrumentation. The change in spring length measured by the ultrasonic sensor was then used to calculate the spring constant (k) based on Hooke's Law. This method provides a reliable means of determining the spring constant, essential for understanding the mechanical properties of different springs, which detail the calculation of spring constants using similar principles [16].

The calibration process of ultrasonic sensors is critical for ensuring accurate thickness measurements in various applications. This process typically involves the establishment of a reference standard against which the sensor's measurements are compared [17]. Calibration of the ultrasonic sensor was performed by comparing the measured distance values with reference measurements obtained using a ruler. Measurement uncertainty was evaluated from repeated measurements, and statistical analysis was conducted by calculating the mean value and standard deviation for each mass variation. The uncertainty in distance measurement and mass loading was propagated into the calculation of the spring constant to assess the overall experimental uncertainty. The analyzed results were then used to evaluate the performance and presicion of the developed IoT-based experimental system, and conclusions were drawn accordingly.

3. Result and Discussion

The value of the spring constant is influenced by temperature, spring material, diameter, and number of windings. Variations in wire diameter and coil diameter of the spring have an effect on the spring constant. The greater the number of windings and the diameter of the spring, the smaller the value of the spring constant [18]. The research on the creation of a prototype apparatus for spring constant (Hooke's Law) based on Blynk was successfully conducted.

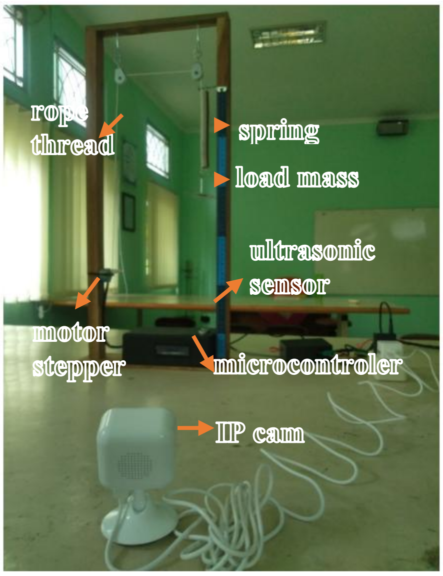

Fig. 9: Practical apparatus prototype for Hooke's Law with Blynk

The prototype assembly was carried out using tools and materials that had been collected and adjusted according to the needs based on the literature obtained according to the picture 9. Before the overall assembly was done, testing was conducted on several components including testing of the ultrasonic sensor, stepper motor, relay, and IP camera, tested according to the prepared comparison. Testing of each main component of the prototype one by one resulted in these components functioning properly, thus they could be used to create the prototype apparatus for spring constant experiments.

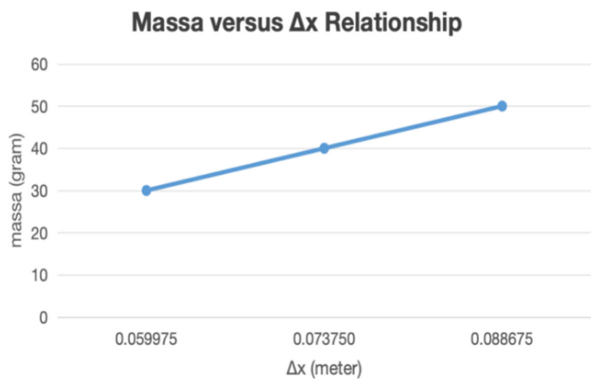

Fig. 10: Mass versus Δx Relationship Diagram

The Fig. 10 showing indicates that mass affects the elongation of the spring, thus affecting the value of the spring constant. The experimental results were in good agreement with the theoretical predictions of Hooke's Law "the amount of increase in spring length is proportional to the force applied".

Fig. 11: View on Applicattion Blynk and LCD with massa 30, 40 and 50 gram

The magnitude of the force is proportional to the mass according to equation 1 and 2. Hooke's law posits a linear relationship between the force applied to a spring and its extension, a hypothesis that has been widely supported through experimental data. The cognitive understanding of spring elongation functions similarly to Hooke's law, reinforcing the theoretical framework. Ultimately, the consistency between empirical results and theoretical predictions underscores the robustness of Hooke's law as a foundational principle in the study of elasticity [19].

The Fig. 11 showing advantages of this prototype spring laboratory apparatus are its automatic system and its Blynk based system, enabling access to the apparatus from anywhere using an internet connection, making laboratory activities easier and more engaging. Despite its advantages, the developed system still has several limitations. The limitations of this prototype laboratory apparatus include the manual process of changing mass loads, the use of only one spring in data collection which needs manual replacement if a different one is desired, and the IP camera used does not have a fixed IP address, thus requiring reconfiguration each time the apparatus is used. This prototype laboratory apparatus can serve as additional literature for the development of modern laboratory equipment, which continues to evolve at present. The system also relies on stable internet connectivity for real-time data transmission, which may degrade its performance under poor network conditions.

4. Conclusion

Based on the research results, a Blynk-based Hooke's Law laboratory prototype was successfully developed using a NodeMCU microcontroller, an ultrasonic distance sensor, a stepper motor, an I2C LCD, and a smartphone as the controller and real-time monitoring interface with blynk. Experimental testing using three mass variations (30 g, 40 g, and 50 g) showed high measurement precision. The experimental results were in good agreement with the theoretical predictions of Hooke's Law within the elastic limit of the spring. The measured spring elongation (Δx) achieved an average precision of 99.95%, while the calculated spring constant (k) showed an average precision of 96.18%. Minor discrepancies between experimental and theoretical values were attributed to sensor resolution, mechanical friction, dynamic loading effects, and slight spring nonlinearity. Overall, the developed IoT-based laboratory apparatus is reliable for experimental validation of Hooke's Law and effective for physics learning applications in a blended learning environment.

References

[1] Arsada, Bakhtiyar, and B. Suprianto, "Ultrasonic Sensor Application for Distance Position Detection in Space Using Arduino Uno" State Univ. of Surabaya, 6(2), 137-145, (2017).

[2] K. A. Gamage, D. I. Wijesuriya, S. Y. Ekanayake, A. E. Rennie, C. G. Lambert, and N. Gunawardhana, "Online delivery of teaching and laboratory practices: Continuity of university programmes during COVID-19 pandemic" Educ. Sci., 10(10), 291, (2020).

[3] H. S. Wattimena, A. Suhandi, and A. Setiawan, "Indonesian Physics Education Journal" Indones. Phys. Educ. J., 10(2), 128–139, (2014).

[4] B. K. Prahani, E. Hariyono, H. V. Saphira, I. Zakhiyah, S. Eliezanatalie, and M. H. Ismail, "Digitalization of Physics Laboratory Tools: Increase Undergraduate Students Learning Motivation and Problem-Solving Skills" TEM J., 14(3), 2371–2380, (2025).

[5] S. Madakam, R. Ramaswamy, and S. Tripathi, "Internet of Things (IoT): A Literature" J. Comput. Commun., 3, 164–173, (2015).

[6] M. N. Ramadhani, "Real Laboratory Praktikum Kefisien Muai Panjang Berbasis Internet of Things dan Aplikasi Android" S1 Thesis, Universitas Islam Negeri Walisongo Semarang, (2021).

[7] Z. Wan, Y. Song, and Z. Cao, "Environment dynamic monitoring and remote control of greenhouse with ESP8266 NodeMCU" in Proc. 2019 IEEE 3rd Inf. Technol., Netw., Electron. Autom. Control Conf. (ITNEC), 377–382, (2019).

[8] D. C. Giancoli, Physics, Vol. 1, Jakarta: Erlangga, (2001).

[9] N. Azman, Internet of Things dan Komputasi Edge: Pengenalan Hingga Keamanan, Jakarta: CV. Tampuniak Mustika Edukarya, (2020).

[10] A. Kusumaningrum, A. Pujiastuti, and M. Zeny, "Pemanfaatan Internet of Things pada Kendali Lampu" Compiler, 6(1), 53–59, (2017).

[11] T. Juwariyah, S. Prayitno, and A. Mardhiyya, "Perancangan Sistem Deteksi Dini Pencegah Kebakaran Rumah Berbasis ESP8266 dan Blynk" J. Transistor EI, 3(2), 120–126, (2018).

[12] I. Setiawan and D. Sutarno, "Pembuktian Eksperimental Pengaruh Jumlah Lilitan Pegas dan Diameter Pegas terhadap Konstanta Pegas" in Conf. Proc. Sci., (2011).

[13] P. F. Yudha and R. A. Sani, "Implementasi sensor ultrasonik HC-SR04 sebagai sensor parkir mobil berbasis Arduino" Einstein E-J., 5(3), 19–26, (2019).

[14] G. N. Prakasa, "Prototipe Kunci Pintu Menggunakan Motor Stepper Berbasis Arduino Mega 2560 Dengan Perintah Suara Pada Android" S1 Thesis, Universitas Lampung, (2017).

[15] Y. Efendi, "Internet of Things (IoT) Light Control System Using Mobile-Based Raspberry Pi" Sci. J. Comput. Sci., 4(1), 19–26, (2018).

[16] C. Dziuban, C. R. Graham, P. D. Moskal, A. Norberg, and N. Sicilia, "Blended learning: the new normal and emerging technologies" Int. J. Educ. Technol. High. Educ., 15(1), 3, (2018).

[17] C. Dziuban, C. R. Graham, P. D. Moskal, A. Norberg, and N. Sicilia, "Blended learning: the new normal and emerging technologies" Int. J. Educ. Technol. High. Educ., 15(1), 3, (2018).

[18] M. R. Hidayat, S. Christiono, and S. S. Budi, "Design of IoT-Based Home Security System with NodeMCU ESP8266 Using PIR HC-SR501 Sensor and Smoke Detector Sensor" Kilat J., 7(2), 140–141, (2018).

[19] A. Cocco and S. C. Masin, "The Law of Elasticity" Psicologica, 31(3), 647–657, (2010).