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Research Article

FREE FALL TEST SYSTEM CONTROLLED BY COMPUTER WITH ARDUINO

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Keywords

*Arduino,
Free Fall,
Laboratory,
Test Set,
Wifi.*

Abstract

This study aims to devise a computer-aided measurement system for students taking a physics course in secondary schools and universities to use in their laboratory applications. Arduino Uno development board is used in the system structure of the system. The free fall time of steel balls of different size released from the adjustable height is measured and shown on the LCD display, also observed in the software on the host computer. The designed device has electromagnet to hold the steel ball, and LDR light sensor and laser diode to measure the time. The transfer of the results to the host computer is carried out by the Wi-Fi module. A free fall test, comprised of bodies with four different weight released from six different heights, has been performed in order to test the measurement accuracy of the test set. The time is measured in milliseconds for each free fall test. 24 different results obtained from the tests are compared with the results of the theoretical calculations. In accord with this result, there is approximately 1 millisecond difference in accuracy. In addition, the system is more advantageous in terms of multiple measurements, Wi-Fi, and price when compared to other free fall test sets.

ARDUINO İLE BİLGİSAYAR KONTROLLÜ SERBEST DÜŞME DENEY SİSTEMİ

Anahtar Kelimeler

*Arduino,
Deney Seti,
Laboratuvar,
Serbest Düşme,
Wifi.*

Öz

Bu uygulama çalışmasında ortaöğretim kurumları ve üniversitelerde fizik dersini alan öğrencilerin laboratuvar uygulamalarında kullanabilecekleri bilgisayar destekli bir ölçüm sistemi tasarlanmıştır. Sistemin donanım yapısında Arduino Uno geliştirme kartı kullanılmıştır. Ayarlanabilir yükseklikten bırakılan farklı boyutlardaki çelik topun serbest düşme zamanı ölçülüp, sonuç LCD ekranda gösterilmektedir. Aynı zamanda ölçülen değerler ana bilgisayardaki yazılımda da görülmektedir. Tasarlanan cihazda; çelik topu tutmak için elektro mıknatıs, süreyi ölçmek için LDR ışık sensörü ve lazer diyot kullanılmıştır. Ayrıca ölçülen değerlerin ana bilgisayara aktarılma işlemi wifi modülü ile gerçekleştirilmiştir. Deney setinin ölçüm hassasiyetinin testi için 6 farklı yükseklikten ve 4 farklı ağırlıktaki cisim ile serbest düşme deneyi yapılmıştır. Her düşme deneyi için milisaniye biriminde süre ölçülmektedir. Deney sonucunda elde edilen 24 farklı süre, teorik hesaplamalarından çıkan sonuçlar ile kıyaslanmıştır. Bu sonuca göre doğruluk hassasiyetinde yaklaşık 1 milisaniyelik farklılık bulunmaktadır. Ayrıca sistem diğer serbest düşme deney setleri ile kıyaslandığında çoklu ölçüm, wifi ve fiyat konusunda avantajlı olduğu görülmektedir.

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1. Introduction

The students can sharpen the knowledge they have learned in theoretical courses with their experiments in the laboratory. The purpose of any experiment is to boost the students' retention, to help them remember the day's learning. Experiments are provided as much as possible. In some of the courses, experiments are simulated in a virtual environment since it is not possible for some institutions to establish laboratories (İbrahim and Onurhan, 2003 ; Boeing and Bräunl,2007 ; Jin,1997 ; Akkağıt and Tekin, 2012 ; Tüysüz, 2010).

The technology is making lives easier; various difficult or time-requiring tasks have been made easier. The physics experiments, once difficult to perform, are no exception to this, which are now easy to perform with computer controlled systems. This, in turn, enables students to easily understand the abstract physics concepts (Caner and Bekiroğlu, 2012). The study conducted by Thornton in 1987 found that the students using these experiments tests were more successful than other students in the study of designing some experimental sets for the microcomputer-based laboratory in physics education (Thornton,1987).

In the free fall experiment, the basic principle is to know the height between the point at which a body is released and the ground, between the time the free fall begins and the time it ends. In the experiments without computer assistance, the fall time has been measured by devices such as a stopwatch. In such tests that require precision, the person who performs the measurement may have time-dependent faults at the start and stop of the stopwatch that affects the result of the experiment. Another reason why the result of the experiment is erroneous is that the height at which the object is released is not fully determined (Bush and Miles,1996).

In experiments carried out with the computer controlled free fall test set, human errors are eliminated, which, in turn, enables students to better understand the accuracy of the free fall test that they have learned in theory, while performing the test with bodies of different weights and from different heights.

2. Background

This section provides technical information about the materials used in the devised test set.

2.1. Free Fall Movement

The fact that objects released in the air fall down are an ordinary event for people. Until Galileo's work, people thought that heavy objects fell to the ground faster and in less time than light objects. If one of the two A4 size papers of the same weight is crumpled in a ball-like form and two of them are released from the same height, it can be seen that the crumpled paper falls first to the floor. This indicates that the fall times of objects of the same weight are not dependent on weight (Palmerino, 1999).

$$h = \frac{1}{2}gt^2 \qquad (1)$$

In equation 1, h stands for the height from the ground where the free-falling object is released, g for gravity acceleration (9.81 m/s2), and t for the time the object falls to the ground (Lackner and Graybiel, 1986).

2.2. Arduino

When we look at the development cards used in electronic and automation fields in our country in recent years, we see that Arduino development card is preferred in terms of cost, availability, and ease of learning (Ferdoush and Li, 2014). Arduino is an open-source hardware and software development board that provides control of electronic systems in the internet of things, or IoT (Şimşek and Taşdelen,2017). Different Arduino models are available for different areas of use or characteristics. The models that use the Arduino development card are shown in Table 1.

Table 1. Arduino models list (Barbon, et.all,2016)

Arduino Due	Arduino Leonardo	Arduino Yun
Arduino Mega 2560	Arduino LilyPad	Arduino Industrial 101
Arduino Esplora	Arduino Uno	Arduino 101
Arduino Pro Mini	Arduino Mini	Arduino Tian
Arduino BT (Bluetooth)	Arduino Nano	Arduino Zero
Arduino Ethernet	Arduino Pro	Arduino CTC 101
Arduino Mega ADK	Arduino Fio	Arduino YUN Mini
Arduino Mega 2560	Arduino LilyPad	Arduino Materia 101
Arduino MKR WAN 1300	Arduino Uno wifi REV 2	Arduino Gemma
Arduino M0 PRO	Arduino M0	Arduino MKR GSM 1400

2.3. ESP8266 Wifi Module

ESP8266, shown in Figure 1, is used in development boards to provide internet connection from the model of the Internet of things. The ESP8266 Wi-Fi module has an internal antenna. In this way, data packets can be transferred via TCP/IP protocol (Schwartz,2016).

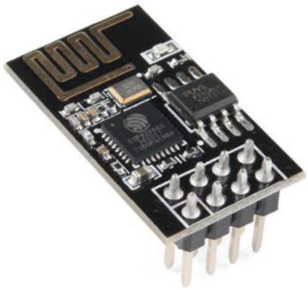

Figure 1. ESP8266 wifi module

The ESP8266 WiFi module uses AT commands to provide access and connection Settings. Sample AT commands used for connection operations in the module are given in table 2 (Singh and Saikia, 2016).

Table 2. General AT commands used in the Wifi module

AT Command	Functions
AT+CWMODE	Wifi mode selection
AT+CWJAP	Connect to a network
AT+CWLAP	Network listing
AT+CIPSTA	Static IP Assignment
AT+CIPSTATUS	Network status information
AT+RST	Restart

2.4. Electro Magnet Module

This module, which is used to hold iron alloyed objects in electronic systems, gains the magnet feature when current is supplied by the system. The electromagnet module can carry loads up to 1 kg. The module also works with DC 5V and draws 400mA current. The increase in the amount of current drawn by the electro-magnet modules increases the amount of charge that can be carried in proportion (Arogbonlo, et.all., 2015).

3. Free Fall Test System

The developed test system measures the time the object falls from a certain height to the floor. The general use of the system is as follows: Press the first button in the measurement box. The system thus powers the electromagnet and laser. The selected object (iron ball) is then attached to the electromagnet. With the second button pressed, the system cuts off the power of the magnet and starts the measurement. The measurement is terminated as soon as the passage of the falling object through the laser is detected. The measured time is displayed in milliseconds on the LCD monitor and on the computer transmitted via Wi-Fi.

The free fall test system was carried out in two parts as hardware and software. In the hardware section, the measurement box for the test is designed. In the software section, two separate modules have been developed that allow the measurement box to operate and the measured values to be displayed on the instructor's computer.

3.1. Design of Measurement Box

The pins used for connection of the circuit elements and Wi-Fi module used in the measurement box to the Arduino Uno development board are given in Table 3 and Table 4.

Table 3. Connection pins of the WiFi module with Arduino Uno

Arduino Pin	ESP8266 Pin
RX (A0)	TX
TX (A1)	RX
GND	GND
3V3	EN
3V3	RST
3V3	3V3

Table 4. Connection pins of other elements with Arduino Uno

Parts	Arduino Pin
Elektro Magnet	D5
LDR	A2
Lazer	A3
Button 1	D3
Button 2	D4
Buzzer	D2
LCD	D7,D8,D9,D10

The system motherboard has been produced for the connection of the Arduino Uno to other circuit elements for the hardware integrated operation of the system. The system motherboard is designed with *fritzing* and the printing circuit board of Figure 2 (b) is created.

As a measurement box, a box is used that provides IPS65 standards of 17cmx12cmx6cm dimensions as shown in Figure 2 (a).

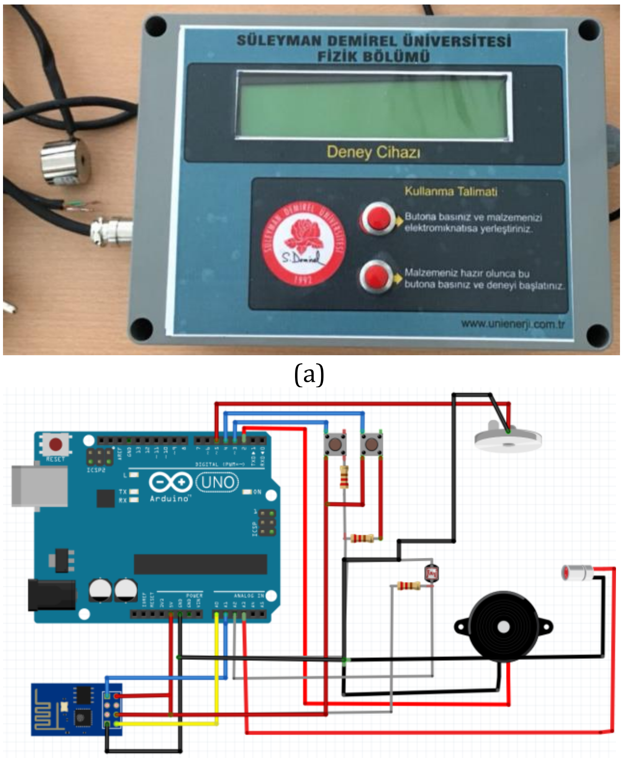

Figure 2. a) Test system control box, b) circuit diagram view

3.2. Software Development

The test system application consists of the software of the control box and the interface software showing the incoming data.

The Arduino IDE encodes the software required to perform input and output checks and measurements in the control box designed using the Arduino Uno development board. Pin definitions and pin mode selection have been made in order to receive and send the data from the circuit elements in the control box. After the identification process, the threshold value must be found from the LDR used to determine if the object has reached the desired point in the experiment. The threshold value is used to determine if an object passes through the LDR and the laser. In order to find this, values have been observed and measured when the rays coming out of the laser fall on the LDR and when they do not. As a result, the threshold value to be used in the experiment set is determined to be 20.

The measurement software from the Arduino Uno development board controls the value from a button every 1 millisecond within the *loop ()* function to see if the command required for the preparation of the experiment has been received. After the button is pressed, the software powers the laser and the electromagnet with the *digitalWrite (pin, HIGH)* command. After the second button is pressed, the system time information is assigned to the *start_time* variable. At the same time, the power of the electromagnet is cut and the experiment is started. The *analogRead ()* function is used to read the value from the LDR. The time value when measured analog value passes the threshold value is assigned to the *end_time* variable. The calculated measurement time is displayed on the LCD monitor and sent to the interface software via the *WifiSend()* function.

In order to measure the free fall test and to show the measured times and send them to the interface software, the rough code block is used in Table 5. In addition, the flow chart showing the general operation of the system is given in Figure 3.

Table 5. Coarse code used in measurement

```
if (reading_sensor_value>peak_value)
  {
    end_time=millis();
    men_time= end_time –start_time;
    Buzzer();
    String
reading_value="Time:"+String(men_time)+"ms";
    ClearScreen();
    PrintScreen(reading_value);
    WifiGonder(men_time, ex_number);
}
```

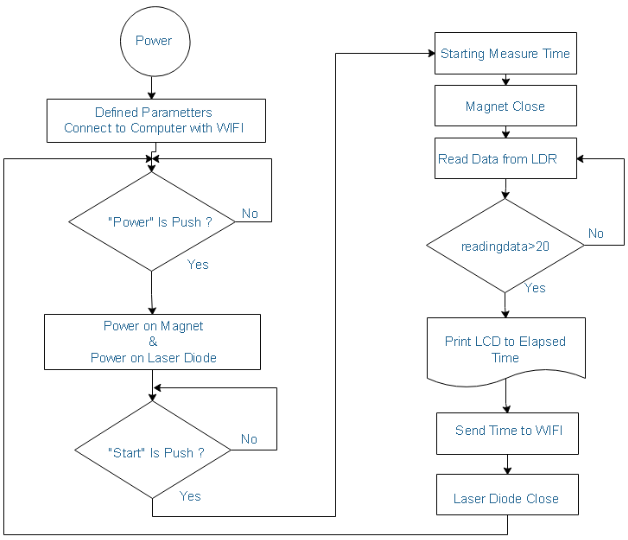

Figure 3. System working diagram

In order to monitor the measurement data from the experiment sets in the laboratory by the trainer, the interface software running on the computer has been developed. The interface software was implemented using the C# 6.0 programming language on the Visual Studio 2017 platform. Values from the experiment set are taken with *serialprint* control. The received values are displayed to the instructor via the *listview* control in the interface. The interface software can be connected to more than one test system as shown in Figure 4.

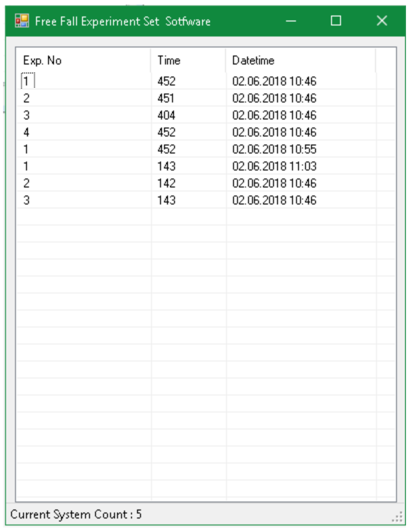

Figure 4. Interface software data list form

4.Results

In order to determine the stability of the free fall test set, measurement tests were carried out with bodies with 4 different weights and from 6 different heights. In addition, based on the experiments conducted with the computer-controlled test system, the formulas for free fall motion and theoretical times under the same conditions. The measured and calculated times are compared at different weights and heights as shown in Table 6,7,8,9. The results indicate a maximum of 1 millisecond difference between the calculated times and measured times.

In the measurements, it is observed that the falling times of the bodies of different weight and from the same height are the same. The theoretical information is also supported by this data obtained from the experimental system.

Table 6. Measurements results for 10 gr object

	Height (cm)	Time (ms)	Measurements (ms)										AVG	%±
			1	2	3	4	5	6	7	8	9	10		
10 Gr	100	451,523641	452	451	452	452	452	451	452	452	451	452	451,7	0,04
	80	403,855022	404	404	403	404	404	404	404	404	404	404	403,9	0,01
	60	349,748708	349	349	349	349	349	349	349	348	349	349	348,9	0,24
	40	285,568625	286	286	286	286	285	286	286	286	286	286	285,9	0,12
	20	201,927511	202	202	203	202	202	202	202	203	202	202	202,2	0,13
	10	142,784312	143	143	143	143	143	143	143	143	144	144	143,2	0,29

***Time (ms):** The result of a mathematical formula. ***%±:** Difference between formula and average test result.

Table 7. Measurements results for 20 gr object

	Height (cm)	Time (ms)	Measurements (ms)										AVG	%±
			1	2	3	4	5	6	7	8	9	10		
20 Gr	100	451,523641	452	452	452	452	453	452	452	452	453	452	452,2	0,15
	80	403,855022	403	404	403	403	403	403	403	403	403	403	403,1	0,19
	60	349,748708	350	349	350	350	350	350	350	349	350	350	349,8	0,01
	40	285,568625	286	286	286	286	288	286	286	286	286	286	286,2	0,22
	20	201,927511	201	201	201	201	201	201	201	201	200	201	200,9	0,51
	10	142,784312	142	142	143	142	142	142	142	143	142	142	142,2	0,41

***Time (ms):** The result of a mathematical formula. ***%±:** Difference between formula and average test result.

Table 8. Measurements results for 30 gr object

	Height (cm)	Time (ms)	Measurements (ms)										AVG	%±
			1	2	3	4	5	6	7	8	9	10		
30 Gr	100	451,5236	451	450	451	451	451	451	451	451	451	451	450,88	0,14
	80	403,855	402	401	402	402	402	402	402	402	401	402	401,77	0,51
	60	349,7487	350	350	350	350	351	350	350	350	350	350	350,11	0,10
	40	285,5686	285	285	286	285	285	285	285	285	285	286	285,22	0,12
	20	201,9275	201	201	201	201	202	201	201	201	201	201	201,11	0,40
	10	142,7843	142	142	142	142	142	142	142	143	142	142	142,11	0,47

***Time (ms):** The result of a mathematical formula. ***%±:** Difference between formula and average test result.

Table 9. Measurements results for 50 gr object

	Height (cm)	Time (ms)	Measurements (ms)										AVG	%±
			1	2	3	4	5	6	7	8	9	10		
50 Gr	100	451,5236	450	450	450	451	450	450	450	450	450	450	450,1	0,32
	80	403,855	404	404	404	405	404	404	405	404	404	403	404,1	0,06
	60	349,7487	348	348	348	348	348	348	349	348	348	348	348,1	0,47
	40	285,5686	285	285	285	285	285	285	286	285	285	285	285,1	0,16
	20	201,9275	202	202	202	202	202	202	202	202	202	202	202	0,04
	10	142,7843	141	140	141	141	140	141	141	141	142	141	140,9	1,32

***Time (ms):** The result of a mathematical formula. ***%±:** Difference between formula and average test result.

5. Conclusions

In this study, low-cost free fall test system has been developed for physics laboratories. Students can measure free fall movements of objects of different weights and from different heights. Simultaneous measurements with multiple test systems are monitored and recorded by the interface software on the instructor's computer. As a result of the tests of the developed system, there is a maximum of 1 millisecond difference between the theoretical data and the measured data.

Compared to other commercial products (Table 10), the Computer Controlled Free Fall Test System has the advantage of having multiple measurement monitoring and Wi-Fi features. The measurement accuracy is the same as other commercial products. When compared with other commercial products, it is cheaper.

Table 10. Comparison of experimental systems

Product Name	1	2	3	4
Computer Controlled Free Fall Testing System	1	Yes	Yes	300
Free Fall Test Set K30060 (Kayra Mühendislik, 2018)	1	No	No	750
Free Fall Test Set 3B (3B Scientific, 2018)	2	No	No	850
Free Fall and Atwood Machine Experiment Set (Rentech, 2018)	1	No	No	1.000

1- Measurement accuracy (ms)
2- Multiple measurement monitoring
3- Wifi
4- Price (Turkish Lira)

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Conflict of Interest

No conflict of interest was declared by the authors.

References

3B Scientific, Access: 13.08.2018, Link: https://www.3bscientific.com.tr/

Akkağıt, ş. F., & Tekin, a. (2012). Simülasyon Tabanlı Öğrenmenin Ortaöğretim Öğrencilerinin Temel Elektronik ve Ölçme Dersindeki başarılarına etkisi. Ege eğitim dergisi, 13(2).

Arogbonlo, A., Usma, C., Kouzani, A. Z., Gibson, I., (2015). "Design and fabrication of a capacitance based wearable pressure sensor using e-textiles", Procedia Technology, 20, 270-275.

Barbon, G., Margolis, M., Palumbo, F., Raimondi, F., Weldin, N., (2016)."Taking Arduino to the Internet of Things: the ASIP programming model", Computer Communications, 89, 128-140.

Boeing, A., & Bräunl, T. (2007). Evaluation of real-time physics simulation systems. In Proceedings of the 5th international conference on Computer graphics and interactive techniques in Australia and Southeast Asia (pp. 281-288). ACM.

Bush, G. A., Miles, F. A., (1996). "Short-latency compensatory eye movements associated with a brief period of free fall", Experimental brain research, 108(2), 337-340.

Caner, F.,Bekiroğlu, F., (2012)."Implementation of microcomputer based laboratory in physics class: students' perceptions", INTED2012 Proceedings, 3163-3166.

Ferdoush, S., & Li, X. (2014). Wireless sensor network system design using Raspberry Pi and Arduino for environmental monitoring applications. Procedia Computer Science, 34, 103-110.

İbrahim, D., Onurhan, E., (2003). "Uzaktan Mühendislik Eğitiminde Laboratuvar Kullanımı", I.

Elektrik Elektronik Bilgisayar Mühendislikleri Eğitimi Sempozyumu, Ankara.

Jin, H. (1997). Behavior-mode simulation of power electronic circuits. IEEE Transactions on Power Electronics, 12(3), 443-452.

Kayra Mühendislik, Access: 13.08.2018, Link: http://www.kayramuhendislik.com.tr/

Lackner, J. R., & Graybiel, A. (1986). Head movements in non-terrestrial force environments elicit motion sickness: implications for the etiology of space motion sickness. Aviation, space, and environmental medicine, 57(5), 443-448.

Palmerino, C. R., (1999). “Infinite Degrees of Speed Marin Mersenne and the Debate Over Galileo's Law of Free Fall”, Early Science and Medicine, 4(4), 269-328.

Rentech, Access: 13.08.2018 Link : https://www.rentech.com.tr

Schwartz, M.,(2016). “Internet of Things with ESP8266”, Packt Publishing Ltd.

Şimşek, M. A., Taşdelen, K., “Arduino ile Tasarlanmış Sistemlerin İnternet Tabanlı Kontrolü ve İzlenmesi”, Süleyman Demirel Üniversitesi Uluslarası Teknolojik Bilimler Dergisi, 8(1), 20-33, 2017.

Singh, P., Saikia, S.,(2016). “Arduino-based smart irrigation using water flow sensor, soil moisture sensor, temperature sensor and ESP8266 WiFi modüle”, In Humanitarian Technology Conference (R10-HTC), 2016 IEEE Region 10 (pp. 1-4). IEEE.

Thornton, R.K., (1987). “Tools for scientific thinking-microcomputer-based laboratories for physics teaching”, Physics Education, 22(4), 230.

Tüysüz, C. (2010). The Effect of the Virtual Laboratory on Students' Achievement and Attitude in Chemistry. International Online Journal of Educational Sciences, 2(1).