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Author	:	**Toni Kus Indratno**, Ishafit, dan Yoga Dwi Prabowo
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29 November 2022

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Referee: 1

COMMENTS TO THE AUTHOR(S)
I like the idea you present in the paper. However, it requires some edits before consideration for publishing it. I have listed some of the comments directly referring to the sections on the article.

Introduction:
1. References - there can be more references going along with Ref [1] or you can rephrase the text.
2. "Using Archimedes' Principle, we can calculate the density of a liquid [2] through investigation activities" Also, you can find the density of the object using a liquid with a known density -- best if you add that as well.
3. Ref. 3 - is this the correct reference for what you are discussing in the text?
4. 3rd paragraph: "In his research, the motor was used to move three liquids in the container upwards." -- I don't understand what you are trying to say here. Re-write the paragraph in a manner a reader, who hasn't come across Ref. 3, can understand.
5. Last paragraph: "In contrast to previous research, in this study, stepper motors were used to move objects so that they were immersed in liquid ". It is important to mention the types of objects (wood/metal or other), and liquids (water/oil or any other liquid?) you are using in this experiment.
"Data is recorded": what data? heights or depths?
"event with entry": can you be more specific here?
Last paragraph is the most important paragraph in this section; however, it is not explained well. consider re-writing the paragraph.

Archimedes' Principle:
6. "The deeper the object is submerged, the greater the pressure force on the object." Did you mean " deeper the object is, more pressure it experiences"? what is "pressure force"?

7. Equations: 2, 3, and 4 (also marked as 3) somewhere at the beginning you may want to mention "static equilibrium". It is important.

8. Why do you use, "mapp" for the true mass of the object?
What is Wapp ? is that apparent weight? It is important to say so.

Hardware design:
9. "Adjusting the stepper motor's rotation makes it possible to move objects so that they are immersed in liquid every 4 cm3." I don't fully understand this. Explain it better.

10. "Experimental data in the form of the object's gravity, when the object is suspended in the air or submerged in a liquid, was obtained using a Force Sensor from Vernier Technology." Are you discussing the "true and apparent weights" here? please explain it.

11. Ref. [9] - can you change or add another reference that explains the LABVIEW software? Ref. 9 is specific for X-ray spectrometry IAEA beamline end-station at Elettra Sincrotrone Trieste.

12. "offline use is enough to install on a computer, then connect the computer to the apparatus, and the system is ready to use." re-write or explain it better.

13. The remote laboratory system architecture used in this experiment is as written in [10] -- This is an important piece of information. Please include all the details in the paper or set up an external document and include it as a supplementary material

Discussion and conclusion:

14. There is no figure 11 - " Figure 11 shows a graph of the results of fitting the data into a linear equation, with the volume of the immersed object (Vx) as the dependent variable x and the upward pressure force as the independent variable y." where is the figure?

15. What is the equation of the graph?
Can you show the equation, relating Vx and the density of the unknown liquid, where you display the graph?

16. It is important to write about the user feedback? Do you have any feedback from the students, colleagues or any other users who have used the remote?

17. What are the constraints? When someone is doing the experiment remotely, can they change the liquid? When it comes to non-metallic objects - like wood for example, how would you proceed? It may be important to include the experimental constraints as well.

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We notice that the link you've included in your paper leading to the r-phylab site seems to lead to a general website. It is not clear what this link is supposed to lead to, as a lot of this site is in Indonesian, and the obvious links at the bottom (labelled "available courses") are password protected. Please can you check this link leads to your intended site, and add some clarity around what the site adds to the paper. Thank you.

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18 January 2023

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Archimedes' Principles Experimental Apparatus for Remote Physics Laboratory

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Abstract

The latest developments in information technology have made it possible to have experimental activities that can be accessed remotely. This article describes the development of experimental apparatus regarding Archimedes' principle which can be accessed remotely. The apparatus has been developed by adding a stepper motor to control the object so that it is immersed in a liquid. Stepper motors are controlled by Arduino Uno using a graphical user interface (GUI) developed using LabVIEW. The data sampling process is carried out using a force sensor which is controlled using the same GUI. Using the apparatus that has been developed, experiments on Archimedes' principle can be done online through the website. The experimental results show that there is good compatibility with theoretical calculations and with previous research. So it can be concluded that the developed apparatus can be used in online experimental-based physics learning.

Keywords: remote experiment, archimedes principle, remote laboratory

1. Introduction

Archimedes' principle is one of the fundamental topics related to the discussion of fluid mechanics in schools [1]. Students' understanding of Archimedes' concepts will significantly support understanding other fluid mechanics principles [2]. This principle says that if an object is immersed in a liquid, either partially or completely, then the object will experience an upward thrust whose magnitude is equal to the weight of the liquid displaced by the object. Using Archimedes' Principle, we can calculate the density of a liquid [3] through investigation activities. We can also determine the value of the density of an object using a liquid whose density is known. However, in many schools, learning related to this topic is still dominated by discussion in theoretical studies without being accompanied by experimental activities, even though experimental activities are an important aspect of learning, especially in physics [4].

Referring to previous research, experiments related to Archimedes' Principle can be carried out using a spring balance [5] or also a triple beam balance. The load is hung on a balance, then immersed in liquid. Then the value of the buoyant force will be obtained, which is equal to the weight of the displaced liquid. For better results, Concetto Gianino [6] developed an experimental method for determining the density of liquids using a Microcomputer-Based Laboratory (MBL), which consists of a force sensor, a computer, and a data acquisition system. In this case, the load is hung on the force sensor. Then the object is slowly dipped into the liquid. The MBL system will display a graph of the relationship between the volume of a submerged object vs. the buoyant force experienced by the object.

A similar apparatus was also developed by M. Ozvoldová [7], who developed an experimental apparatus for the Archimedes principle based on remote experiments. In his research, objects hung on a dynamometer connected to a computer. The container containing the liquid is then moved (computerized) upward until the object is immersed. The depth data of the immersed object and the buoyancy force are recorded through a data acquisition system developed using Java applets. This system can also be accessed online through an application on the website.

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Referring to research that has been done and things that still need to be done in developing the Archimedes principle experimental apparatus, this article discusses the development of the Archimedes principle experimental apparatus for remote laboratory-based experiments. The novelty of the apparatus being developed lies in the apparatus control and data acquisition systems. The user performs device control and data acquisition through a Graphical User Interface (GUI) developed using LabVIEW. This Archimedes principle experimental apparatus can be used in physics learning experimentally based in a remote laboratory.

2. Materials and Methods

The process of developing the experimental device for Archimedes' Principle was carried out in three steps, including studying the physics concept of Archimedes' Principle, designing hardware, and creating software for control systems and data acquisition.

a. Archimedes' Principle

When an object is immersed in a liquid, the object will experience a buoyant force, F . This buoyant force is the resultant of the compressive force experienced by a submerged object. The deeper the object is submerged, the greater the buoyant force on the object. Thus the direction of the buoyant force will be upward [8]. Figure 1 (adapted from [9]) illustrates the force due to pressure experienced by a partially submerged object.

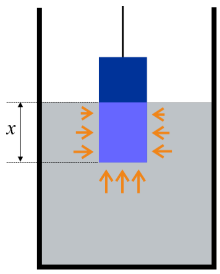

Figure 1. Force due to pressure on a partially submerged object

Mathematically Archimedes' Principle is written as,

$$F_{\text{up}} = \rho g V_x \qquad (1)$$

Where ρ is the density of the liquid, g is the acceleration due to gravity, and V_x is the volume of the object submerged.

When an object is hung on a force sensor and the object is in a state of static equilibrium, the value read is based on the tension in the rope connecting the object to the sensor.

$$W_{\text{app}} = m_{\text{app}} g = T_{\text{wire}} \qquad (2)$$

m_{app} is the object's mass, while W_{app} is the weight of an object when it is suspended in the air. If the suspended object is immersed in a liquid, the tension in the rope will be less than the object's weight because of the buoyant force. So that we can write down the forces acting on objects based on figure 2 (adapted from [9]), it becomes

$$\sum F_y = T_{\text{wire}} + F_{\text{up}} - W_{\text{object}} \qquad (3)$$

W_{object} is the sensor's value when the object is submerged in liquid. Using equations (2) and (3), the value of the buoyant force acting on the object is,

$$F_{\text{up}} = W_{\text{app}} - W_{\text{object}} \qquad (4)$$

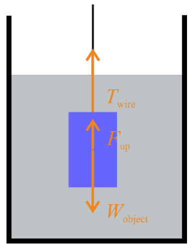

Figure 2. A diagram of the forces acting on a submerged object

b. Hardware design

The main components in developing this apparatus are (1) Arduino Uno as a microcontroller for communication between hardware and software, as well as device controllers; (2) Stepper Motor Nema17 17HS4401 to move objects. Stepper motors are connected vertically using lead screws. The lead screw is the rail on which the object moves up and down. The stepper motor is controlled by Arduino Uno using the circuit in Figure 3 to regulate the motion of objects so they can be immersed in liquid. Limit switches are used as the upper limit for object movement.

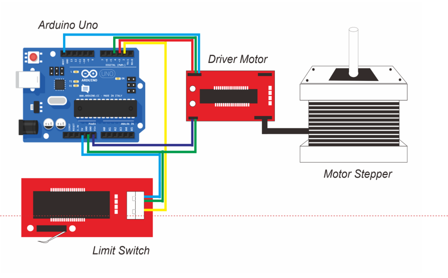

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Figure 3. Stepper motor control circuit schematic

Experimental data in the form of an object's weight, W_{object}, when the object is suspended in the air or submerged in a liquid, was obtained using a Force Sensor product from Vernier Technology. This force sensor can read forces from 0.01 to 50 newtons [10]. The force sensor is connected to the computer via SensorDAQ, which is a data acquisition interface from National Instrument and Vernier. SensorDAQ has three analog and one digital channel with a maximum capacity of up to 48000 samples per second [11]. Diagrammatically the design of the experimental apparatus, Archimedes' Principle, is shown in Figure 4.

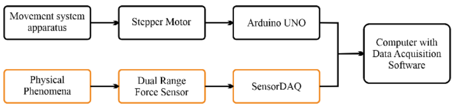

Figure 4. Hardware schematic design

c. Control system development

The control system is made in the form of a Graphical User Interface (GUI) which is quite simple and easy for users to use. The GUI was developed using LabVIEW software. LabVIEW from National Instrument (NI) is a block diagram-based programming language for creating virtual instrumentation. The LabVIEW software has three main parts: the front panel to create a GUI, block diagrams as programming code, and connectors to connect between components that are made [12]. The use of LabVIEW in developing this GUI is because LabVIEW has web publishing tools features. So that the developed GUI can be accessed remotely via the website.

The GUI design of the experimental software Archimedes' Principle is shown in Figure 5 below. There are two main parts to the GUI of the experimental software Archimedes' Principle: the first is for device settings, and the second is for the data acquisition system. The device setting section orders the stepper motor to move down so that the object is immersed in the liquid. The data acquisition system section displays (in tabular and graphical form) data on the upward buoyancy experienced by the object being read by the sensor. Block diagrams for the device settings, and stepper motor control sections are shown in Figure 6, while block diagrams for the data acquisition system and camera display are shown in Figure 7 and Figure 8.

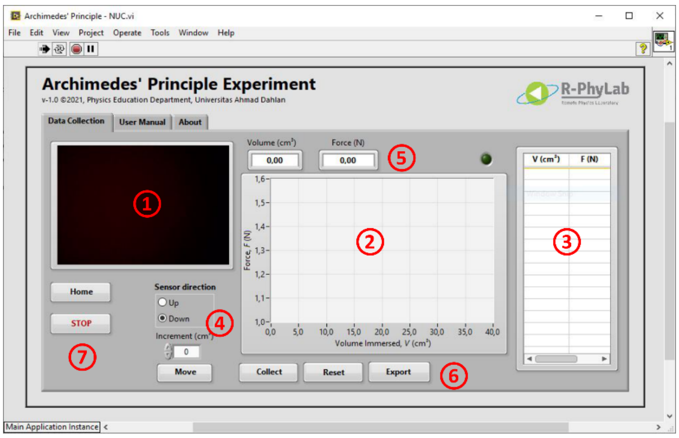

Figure 5. Archimedes principle experiment GUI display

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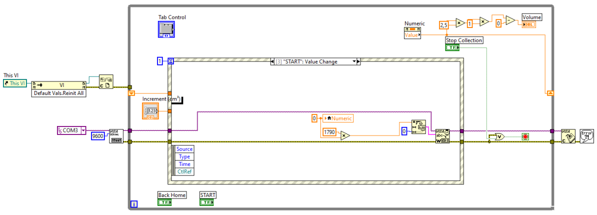

Figure 6. Block diagram for device setup and stepper motor control

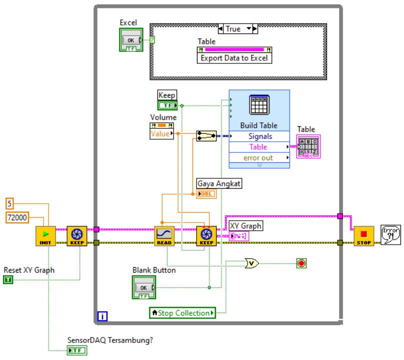

Figure 7. Data acquisition system block diagram

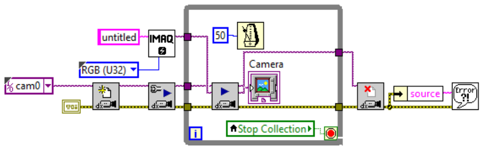

Figure 8. Camera panel block diagram

There are at least 7 (seven) main elements contained in the Archimedes principle experimental GUI with different functions, including: (1) an Apparatus monitor to display experimental apparatus, (2) a graphic panel to display data in graphical form, (3) a table panel, displays data in tabular form, (4) switch to adjust the direction of motion of the sensor, (5) Current monitor, displays data in real-time, (6) Button to retrieve data in the form of object volume and buoyant force experienced by the object, and (7) buttons to start and end the experiment.

This Archimedes principle experimental system can be used offline or online. In offline use, the user installs the GUI of the Archimedes Principle Experiment that has been developed, then connects the experimental apparatus to a computer via a USB connection. Meanwhile, for remote experimental online use, this system needs to be published first into HTML code via the web publishing tools feature available in LabVIEW. After publishing, users can access the system and its apparatus via the website. The remote laboratory system architecture (see figure 9) used in this experiment is as written in [13] . The experimental apparatus is connected to a computer on the lab server. Through the lab server computer, the data acquisition system is published as HTML to be accessed by users via the internet network.

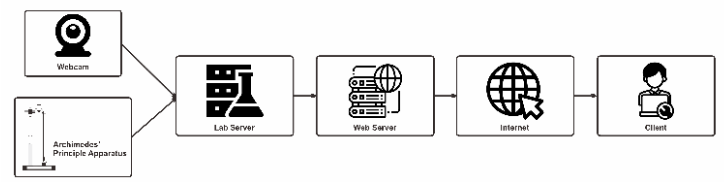

Figure 9. Remote laboratory architecture diagram

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3. Result and Discussion

Result

The real form of the development of the experimental apparatus for the Archimedes principle in this study is shown in Figure 10. The novelty of this study, when compared to research [6], lies in the computerization of the hardware control system. The stepper motor is computerized and controlled to insert objects into the liquid. Meanwhile, compared to research [7], the difference lies in the type of sensor used and the data collection process. In this study, a Dual-Range Force Sensor from Vernier Technology was used, and data collection was carried out by event with entry.

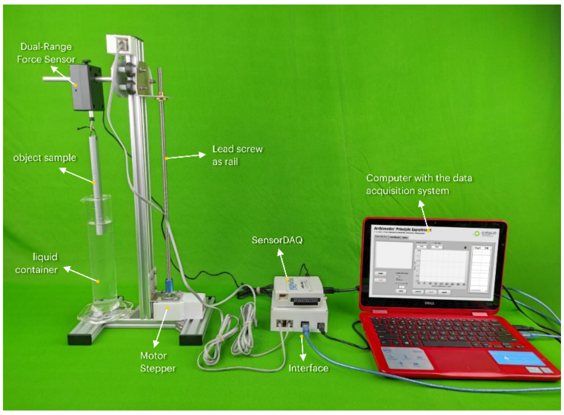

Figure 10. Photo of Archimedes principle experimental apparatus for remote laboratory

The apparatus developed can be used for learning physics with remote laboratory-based online experiment methods. Using the camera installed in the system, students can observe the experimental apparatus, control the apparatus, and control the data collection process. This apparatus can be accessed remotely using a GUI embedded in the remote laboratory web portal, rphylab.pf.uad.ac.id/sistem/. Users can create accounts independently and confirm experimental activities to the administrator via email rphylab@pfis.uad.ac.id. Figure 11 below shows access to the apparatus and the results of the Archimedes principle experiment remotely via the website.

In this study, the experimental apparatus of the Archimedes principle was used to verify the density value of liquids. In this case, water and alcohol were used. Objects (in the form of blocks of 2.5 x 1 x 18 cm) are immersed from 4 cm3 to 40 cm3. Users can observe the movement of objects when immersed through video streaming from the camera installed in the apparatus. the object can be determined. Table 1 shows the experimental results of the relationship between the volume of a submerged object and the buoyant force experienced by the object.

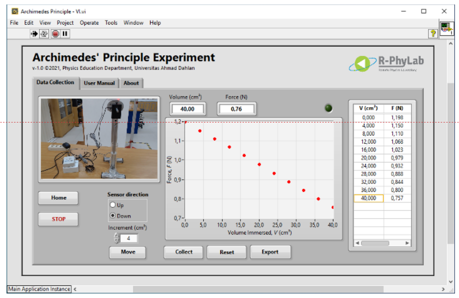

Figure 11. Archimedes' principle experiment online with a remote laboratory

Discussion

Based on the remote experimental results, from Figure 11, data is obtained that there is a linear relationship between the volume of the immersed object and the force read on the sensor. The force that is read on this sensor is the object's gravity. Using equation (3), the buoyant force experienced by

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Table 1. Experimental result

Volume (m^3)	Buoyant Force (N)	
	Water	Ethanol
0.000004	0.033	0.038
0.000008	0.079	0.076
0.000012	0.122	0.114
0.000016	0.165	0.153
0.000020	0.209	0.192
0.000024	0.250	0.230
0.000028	0.292	0.267
0.000032	0.336	0.306
0.000036	0.378	0.344
0.000040	0.420	0.384

Figure 12 shows a graph of the results of fitting the data into a linear equation, with the volume of the immersed object (v_x) as the dependent variable x and the upward pressure force as the independent variable y.

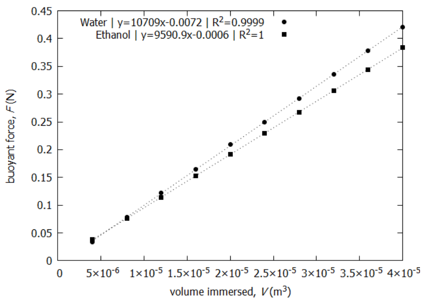

Figure 12. Grafik hubungan volume benda yang tercelup dengan gaya tekan ke atas yang dialami benda

Using equation (1), the density value of the liquid can be calculated from the gradient of the line on the graph divided by the acceleration value due to gravity of $g = 9{,}8$ m/s^2 [4]. The calculation results show that water and ethanol density values are obtained, as shown in Table 2.

Table 2. The results of calculating the value of the density of liquids

Liquid	Slope	R^2	ρ (Kg/m^3)	% Error
Water	10709	0,9999	1092.76	0.09
Ethanol	9590.9	1	980.66	0.18

The relative error is obtained by comparing the experimental results with the reference values contained in the reference [3]. The experimental results in this study showed results that were as good as similar studies that had been conducted by [3], [5] and [6]. So it can be said that the apparatus that has been developed is capable of verifying the density value of a liquid with good results.

The experimental apparatus for the Archimedes principle (and also for the GUI) that has been developed is not equipped with components to measure the temperature of liquids. The operator measures the temperature of the liquid during the experiment and notifies the user through the remote laboratory portal. In addition, users cannot change liquids themselves when using online. Replacement liquids are carried out by operators based on user requests. In terms of accuracy and precision, the data generated from this apparatus is very good, so it can be used for physics learning with online experimental methods.

User feedback is obtained using the USE Questionnaire (Usefulness, Satisfaction, and Ease of use). After conducting an online experiment using a remote laboratory, the user is asked to fill out a questionnaire. The feedback results show that the use of remote physics laboratories in physics experiments gets a very good response. The score that still needs to be improved is the ease of use aspect. This is because the use of remote laboratories requires the support of fast and stable internet access. During implementation, some users experienced internet connection problems when conducting experiments because the users were in several places with unstable internet infrastructure support.

4. Conclusion

Archimedes' principle experimental apparatus for remote physics laboratories have been successfully developed. This apparatus and its data acquisition system succeeded in demonstrating a linear relationship between the volume of an immersed object and the upward force that the object experiences very well. So that it can be said that the apparatus developed for the remote laboratory is feasible to be used for experiments to verify the density value of a liquid through the application of the Archimedes principle.

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Toni Kus Indratno has a master's degree in physics education. He is a lecturer in the physics education department at Universitas Ahmad Dahlan in Yogyakarta. His current research interest focuses on the application of ICTs (smartphones/computers) in learning physics. Besides, he and his team are developing a remote-based laboratory (R-Phylab) for distance physics learning.

Ishafit is an Associate Professor in the Department of Physics Education at Universitas Ahmad Dahlan. He received his doctoral degree at Universitas Negeri Yogyakarta in 2021 and has taught physics for over 25 years. His current research interests are laboratory-based physics instruction and ICT-based physics experiments.

Yoga Dwi Prabowo is a laboratory assistant at the Ahmad Dahlan University Science Learning Technology Laboratory (LTPS). He obtained a master's degree in physics education at Ahmad Dahlan University. Currently he is actively part of the team that developed the Remote Physics Laboratory (R-Phylab).

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COMMENTS TO THE AUTHOR(S)

I like the idea you present in the paper. However, it requires some edits before consideration for publishing it. I have listed some of the comments directly referring to the sections on the article.

Introduction:

1. References - there can be more references going along with Ref [1] or you can rephrase the text.

   New sentences have been added that support the statement of the previous sentence.

2. "Using Archimedes' Principle, we can calculate the density of a liquid [2] through investigation activities" Also, you can find the density of the object using a liquid with a known density -- best if you add that as well.

   It has been added according to the reviewer's suggestion.

3. Ref. 3 - is this the correct reference for what you are discussing in the text?

   The reference is replaced. The reference here explains that experimentation is an important aspect of learning, especially learning physics.

4. 3rd paragraph: "In his research, the motor was used to move three liquids in the container upwards." -- I don't understand what you are trying to say here. Re-write the paragraph in a manner a reader, who hasn't come across Ref. 3, can understand.

   It has been rewritten in the third paragraph.

5. Last paragraph: "In contrast to previous research, in this study, stepper motors were used to move objects so that they were immersed in liquid ". It is important to mention the types of objects (wood/metal or other), and liquids (water/oil or any other liquid?) you are using in this experiment.

   "Data is recorded": what data? heights or depths?

   "event with entry": can you be more specific here?

   Last paragraph is the most important paragraph in this section; however, it is not explained well. consider re-writing the paragraph.

   According to the suggestion, paragraph rewriting has been done.

Archimedes' Principle:

6. "The deeper the object is submerged, the greater the pressure force on the object." Did you mean " deeper the object is, more pressure it experiences"? what is "pressure force"?

   The sentence has been replaced, becomes "The deeper the object is submerged, the greater the buoyant force on the object. Thus the direction of the buoyant force will be upward."

7. Equations: 2, 3, and 4 (also marked as 3) somewhere at the beginning you may want to mention "static equilibrium". It is important.

   The sentence has been changed to "When an object is hung on a force sensor and the object is in a state of **static equilibrium**, the value read is based on the tension in the rope connecting the object to the sensor,"

8. Why do you use, "mapp" for the true mass of the object?

   What is Wapp ? is that apparent weight? It is important to say so.

   Sentence changes have been made: "mapp" is the object's mass, while "Wapp" is the object's weight when it is suspended in the air.

Hardware design:

9. "Adjusting the stepper motor's rotation makes it possible to move objects so that they are immersed in liquid every 4 cm3." I don't fully understand this. Explain it better.

   The sentence has been changed to "The stepper motor is controlled by Arduino Uno using the circuit in Figure 3 to regulate the motion of objects so they can be immersed in liquid."

10. "Experimental data in the form of the object's gravity, when the object is suspended in the air or submerged in a liquid, was obtained using a Force Sensor from Vernier Technology." Are you discussing the "true and apparent weights" here? please explain it.

    Yes, what we mean is the weight of the object. In the manuscript, we have corrected it to "Experimental data in the form of an object's weight, W_{object} , when the object is suspended in the air or submerged in a liquid was obtained using a Force Sensor product from Vernier Technology.

11. Ref. [9] - can you change or add another reference that explains the LABVIEW software? Ref. 9 is specific for X-ray spectrometry IAEA beamline end-station at Elettra Sincrotrone Trieste.

    Yes, it's been replaced with a more appropriate reference that describes LabVIEW.

12. "offline use is enough to install on a computer, then connect the computer to the apparatus, and the system is ready to use." re-write or explain it better.

    The sentence has been rewritten.

13. The remote laboratory system architecture used in this experiment is as written in [10] -- This is an important piece of information. Please include all the details in the paper or set up an external document and include it as a supplementary material

    Explanations and pictures have been added.

Discussion and conclusion:

14. There is no figure 11 - " Figure 11 shows a graph of the results of fitting the data into a linear equation, with the volume of the immersed object (Vx) as the dependent variable x and the upward pressure force as the independent variable y." where is the figure?

    The figure has been added.

15. What is the equation of the graph?

    Can you show the equation, relating Vx and the density of the unknown liquid, where you display the graph?

    Yes, the equation for the relationship between Vx and buoyancy is in the image that has been added.

16. It is important to write about the user feedback? Do you have any feedback from the students, colleagues or any other users who have used the remote?

    User feedback is obtained using the USE Questionnaire (Usefulness, Satisfaction, and Ease of use). It's been added to the script.

17. What are the constraints? When someone is doing the experiment remotely, can they change the liquid? When it comes to non-metallic objects - like wood for example, how would you proceed? It may be important to include the experimental constraints as well.

    It has been added according to suggestions from reviewers.

Additional comments from the editorial team:

We notice that the link you've included in your paper leading to the r-phylab site seems to lead to a general website. It is not clear what this link is supposed to lead to, as a lot of this site is in Indonesian, and the obvious links at the bottom (labelled "available courses") are password protected. Please can you check this link leads to your intended site, and add some clarity around what the site adds to the paper. Thank you.

R-PhyLab is a remote-based experimental portal with several experimental apparatuses, one of which is an experiment related to the Archimedes principle so that the first display that appears is the general portal view. The user selects the desired experiment topic. Users can coordinate with the admin for experimental activities via email at rphylab@pfis.uad.ac.id.

Letter reference: DEC:MajRev:S

5. Permissions request for manuscript

24 January 2023

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Yours sincerely,

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REVIEWER REPORT(S):

Referee: 1

COMMENTS TO THE AUTHOR(S)
Dear Editor,

I spent a considerable amount of time reading the edited article. While I admire the authors' research on the remotely operable Archimedes lab, the paper is still challenging to read. I strongly advise the authors to have a native English speaker proofread the document before submission.

You have accepted our previous suggestions, and inserted in some places interrupting the flow of the article. I have quoted some (not all) sections below as examples,

"Referring to research that has been done and things that still need to be done in developing the Archimedes principle experimental apparatus, this article discusses the development of the Archimedes principle experimental apparatus for remote laboratory-based experiments."

"This Archimedes principle experimental apparatus can be used in physics learning experimentally based in a remote laboratory."   - It is hard to understand

"The deeper the object is submerged, the greater the buoyant force on the object. Thus the direction of the buoyant force will be upward." (??) I don't see any relationship between the two lines.

" Experimental data in the form of an object's weight, Wapp,
when the object is suspended in the air or submerged in a liquid, was obtained using a Force Sensor product from Vernier Technology. -- Not very clear

"The use of LabVIEW in developing this GUI is because LabVIEW has web publishing tools features." -- Not very clear

"Based on the remote experimental results, from Figure 11, data is obtained that there is a linear relationship between the volume of the immersed object and the force read on the sensor." -- Not very clear

"The feedback results show that the use of remote physics laboratories in physics experiments gets a very good response. The score that still needs to be improved is the ease of use aspect." -- What did you get as feedback? What was in the questionnaire? What did the users like the most/least about the experiment? -- please be specific

In addition, if you consider resubmitting the paper, Figures 6, 7 and 8 can go into supplementary material.

Material and Method: The section can be replaced by "Physics behind the Experiment" and "Experimental details" or something along those lines.

Additional comments from the editorial team:
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8. Second revision submitted

10 March 2023

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Archimedes' Principles Experimental Apparatus for Remote Physics Laboratory

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Abstract

The latest developments in information technology have made it possible to have experimental activities that can be accessed remotely. This article explains the development of experimental tools regarding the principle of Archimedes that can be accessed remotely. Equipment has been developed by adding a stepper motor to control the object to submerge it in a liquid. Stepper Motors is controlled by Arduino Uno using the Graphic User Interface (GUI) developed using LabView. The data sampling process uses a force sensor that is controlled using the same GUI. Based on equipment that has been developed, experiments on the principle of Archimedes can be done online through websites. The experimental results show that there is good compatibility with theoretical calculations and with previous research. So, the developed apparatus can be used in online experimental-based physical learning.

Keywords: remote experiment, archimedes' principle, remote laboratory

1. Introduction

The principle of Archimedes is one of the fundamental topics related to the discussion of fluid mechanics in schools [1]. Student understanding of the concept of Archimedes will significantly support understanding of other fluid mechanical principles [2]. This principle says that if an object is soaked in a liquid, either wholly or partially, then the object will experience an upward push equal to the weight of the liquid transferred by the object. Using Archimedes' principle, we can calculate fluid density [3] through investigation activities. We can also determine the density of an object using a liquid whose density is known. However, in many schools, learning related to this topic is still dominated by discussions in theoretical studies without being accompanied by experimental activities, even though experimental activities are an essential aspect of learning, especially in physics [4].

Based on the previous studies, experiments on the principle of Archimedes can be done using spring balance [5] or the beam three balance. The load is hung on the balance, then soaked in the liquid. Then the buoyant force value will be obtained, the same as the weight of the liquid being moved. Gianino [6] developed an experimental method to determine fluid density using a Microcomputer-Based Laboratory (MBL) consisting of a force sensor, computer, and data acquisition system for better results. In this case, the load is hung on the force sensor. Then the object is slowly dipped in the liquid. The MBL system will display the relationship graph between the object's submerged volume vs. the buoyant force experienced by the object.

A similar apparatus was also developed by Ozvoldová et al. [7], which developed an experimental apparatus for Archimedes' principle based on remote experiments. They reported the object was hung on the dynamometer connected to the computer. The container containing liquid is then transferred (computerized) until the object is immersed. Data of the object's soaked depth and buoyancy force is recorded through a data acquisition system developed using Java Applet. This system can also be accessed online through applications on websites.

Based on the previous studies, the development of Archimedes' experimental apparatus is needed. Therefore, this article discusses the development of the Remote Laboratory experimental apparatus on Archimedes' principle. The

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2. Materials and Methods

Developing the experimental apparatus for Archimedes' Principle was carried out in three steps, including studying the physics concept of Archimedes' Principle, designing hardware, and creating software for control systems and data acquisition.

a. Archimedes' Principle

When an object is immersed in a liquid, the object will experience a buoyant force, F. This buoyant force is the resultant of the compressive force experienced by a sinking object, and the buoyant force has an upward direction [8]. The deeper the object sinks, the greater the buoyant force experienced by the object. Figure 1 (adapted from [9]) illustrates the force due to pressure experienced by a partially submerged object.

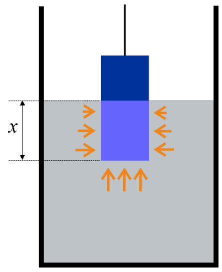

Figure 1. Force due to pressure on a partially submerged object

Mathematically Archimedes' Principle is written as,

$$F_{\text{up}} = \rho g V_x \tag{1}$$

Where ρ is the density of the liquid, g is the acceleration due to gravity, and V_x is the volume of the object submerged.

When an object is hung on a force sensor, and the object is in a state of static equilibrium, the value read is based on the tension in the rope connecting the object to the sensor,

$$W_{\text{app}} = m_{\text{app}} g = T_{\text{wire}} \tag{2}$$

m_{app} is the object's mass, while W_{app} is the weight of an object when it is suspended in the air. If the suspended object is immersed in a liquid, the tension in the rope will be less than the object's weight because of the buoyant force. So that we can write down the forces acting on objects based on figure 2 (adapted from [9]), it becomes

$$\sum F_y = T_{\text{wire}} + F_{\text{up}} - W_{\text{object}} \tag{3}$$

W_{object} is the sensor's value when the object is submerged in liquid. Using equations (2) and (3), the value of the buoyant force acting on the object is

$$F_{\text{up}} = W_{\text{app}} - W_{\text{object}} \tag{4}$$

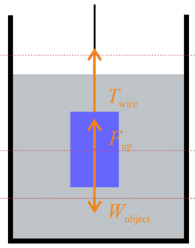

Figure 2. A diagram of the forces acting on a submerged object

b. Hardware design

The main component in developing this apparatus is (1) Arduino Uno as a microcontroller for communication between hardware and software, as well as a device controller; (2) Stepper Motor Nema17 17HS4401 to move the object. The Stepper motor is connected vertically using the lead screw. The lead screw is the rail where the object moves up and down. The stepper motor is controlled by Arduino Uno using a circuit in Figure 3 to adjust the object's moves so that it can be soaked in liquid. The limit switch is used as an upper limit for object movements.

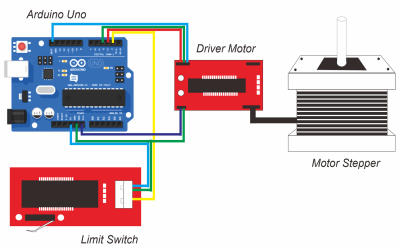

Figure 3. Stepper motor control circuit schematic

Experimental data on the weight of an object when it is suspended in the air or submerged in a liquid is obtained using a Force Sensor product from Vernier Technology. The force sensor can read forces from 0.01 to 50 newtons [10]. The force

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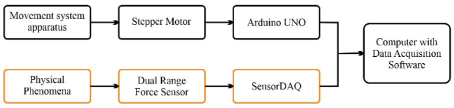

Figure 4. Hardware schematic design

c. Control system development

The control system is made with a Graphical User Interface (GUI), which is simple and easy for users to use. The GUI is developed using LabVIEW software. LabVIEW, originally from National Instrument (NI), is a block diagram-based programming language for creating virtual instrumentation. LabVIEW software has three main parts: the front panel for creating GUIs, block diagrams as programming code, and connectors for connecting between components made [12]. LabVIEW is used for GUI development because it features web publishing tools so that the developed GUI can be accessed remotely via the website.

The GUI design of Archimedes' Principle experimental software is shown in Figure 5. The two main parts of the GUI of Archimedes' Principle experimental software are device settings and data acquisition systems. The tool setting section instructs the stepper motor to move downwards to submerge the object in the liquid. The data acquisition system section displays (in the form of tables and graphs) the object buoyancy data that is read by the sensor. Block diagrams for device settings and stepper motor control sections can be seen in Appendix 1, while block diagrams for data acquisition systems and camera displays can be seen in Appendices 2 and 3.

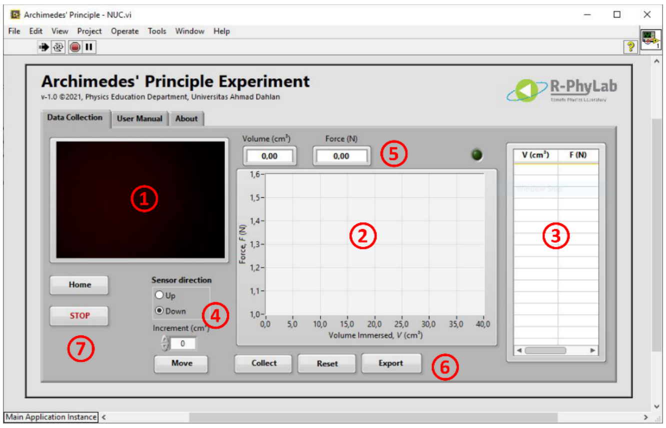

Figure 5. Archimedes principle experiment GUI display

There are seven main elements contained in Archimedes' principle experimental GUI with different functions, including (1) an Apparatus monitor to display experimental apparatus, (2) a graphic panel to display data in graphical form, (3) a table panel, which displays data in tabular form, (4) switch to adjust the direction of motion of the sensor, (5) Current monitor, displays data in real-time, (6) Button to retrieve data in the form of object volume and buoyant force experienced by the object, and (7) buttons to start and end the experiment.

This Archimedes principle experimental system can be used offline or online. In offline use, the user installs the GUI of the Archimedes' Principle Experiment that has been developed, then connects the experimental apparatus to a computer via a USB connection. Meanwhile, this system must first be published into HTML code via the web publishing tools feature available in LabVIEW for remote experimental online use. After publishing, users can access the system and its apparatus via the website. The remote laboratory system architecture (see Figure 6) used in this experiment is as written in [13]. The experimental apparatus is connected to a computer on the lab server. Through the lab server computer, the data acquisition system is published as HTML to be accessed by users via the internet network.

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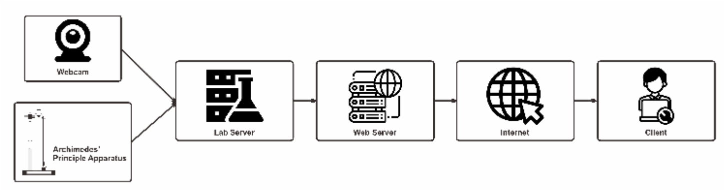

Figure 6. Remote laboratory architecture diagram

3. Result and Discussion

Result

The real form of the development of an experimental apparatus for Archimedes' principle in this study is shown in Figure 7. The novelty of this study, when compared to the research [6], lies in the computerization of hardware control systems. The stepper motor is computerized and controlled to insert the object into the liquid. Meanwhile, compared to research [7], the difference lies in the type of sensor used and the data collection process. The Dual-Range Force Sensor from Vernier Technology was used in this study, and the event collected data by entering.

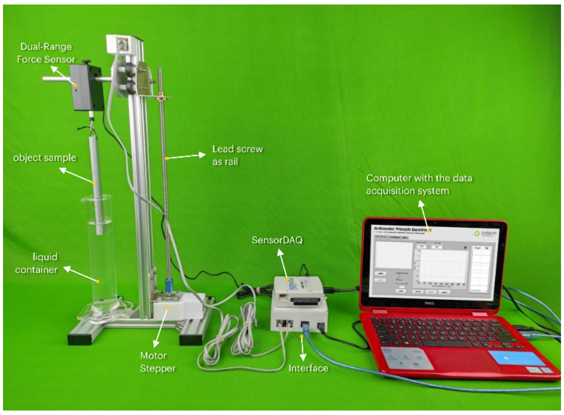

Figure 7. Photo of Archimedes principle experimental apparatus for remote laboratory

The apparatus developed can be used for learning physics with remote laboratory-based online experiment methods. Using the camera installed in the system, students can observe the experimental apparatus, control the apparatus, and control the data collection process. This apparatus can be accessed remotely using a GUI embedded in the remote laboratory web portal, http://rphylab.pf.uad.ac.id/sistem/. Users can create accounts independently and confirm experimental activities to the administrator via e-mail at rphylab@pfis.uad.ac.id. Figure 8 shows access to the apparatus and the results of Archimedes' principle experiment remotely via the website.

In this study, the experimental apparatus of Archimedes' principle was used to verify the density of liquids. In this case, water and alcohol were used. Objects (in the form of blocks of 2.5 × 1 × 18 cm) are immersed from 4 cm^3 to 40 cm^3. Users can observe the movement of objects when immersed through video streaming from the camera installed in the apparatus.

Discussion

Based on the results of remote experiments (see Figure 8), data were obtained for a linear relationship between the volume of a submerged object and the force read on the sensor. The force read on this sensor is the object's gravitational force. The buoyant force experienced by an object can be determined using equation (3). Table 1 shows the relationship between the volume of a sinking object and the buoyant force experienced by the object based on the experimental results.

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In this study, the experimental apparatus of the Archimedes principle was used to verify the density value of liquids. In this case, water and alcohol were used. Objects (in the form of blocks of 2.5 x 1 x 18 cm) are immersed from 4 cm3 to 40 cm3. Users can observe the movement of objects when immersed through video streaming from the camera installed in the apparatus.

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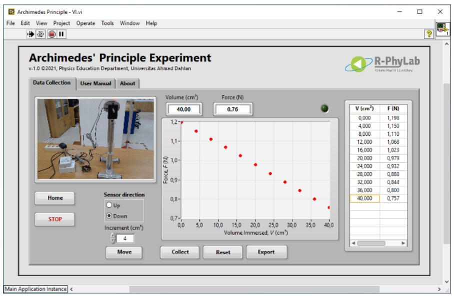

Figure 8. Archimedes' principle experiment online with a remote laboratory

Table 1. Experimental result

Volume (m^3)	Buoyant Force (N)	
	Water	Ethanol
0.000004	0.033	0.038
0.000008	0.079	0.076
0.000012	0.122	0.114
0.000016	0.165	0.153
0.000020	0.209	0.192
0.000024	0.250	0.230
0.000028	0.292	0.267
0.000032	0.336	0.306
0.000036	0.378	0.344
0.000040	0.420	0.384

Figure 9 shows a graph of the results of fitting the data into a linear equation, with the volume of the immersed object (V_x) as the dependent variable x and the upward pressure force as the independent variable y.

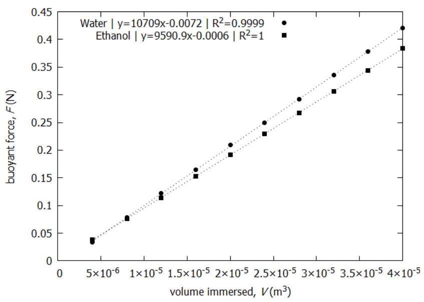

Figure 9. The graph of the relationship between the volume of objects infected with buoyant force on objects

Based on equation (1), the density of a liquid can be determined using the ratio of the line gradient to the acceleration due to gravity (g = 9.8 m/s^2) [4]. The results of calculating the density of water and ethanol are shown in Table 2.

Table 2. The results of calculating the value of the density of liquids

Liquid	Slope	R^2	ρ (Kg/m^3)	% Error
Water	10709	0.9999	1092.76	0.09
Ethanol	9590.9	1	980.66	0.18

The relative error is obtained by comparing the experimental results with reference [3]. The experimental results in this study are the same as similar studies that have been conducted in previous studies [3], [5] and [6]. So the apparatus that has been developed can verify the fluid density value with good results.

The experimental apparatus (and also for GUI) developed needs to be equipped with a liquid temperature measuring component. The operator still carries out liquid temperature measurements, which the operator will convey to the user through the Remote Laboratory Portal. In addition, users cannot replace automatic liquids during experiments online. Fluid replacement is carried out by the operator based on user requests. However, the accuracy and precision resulting from the apparatus approach the value theoretically, so it can be used for learning physics with the online experimental method.

After experimenting with R-PhyLab, users fill out feedback questionnaires using the USE Questionnaire [14], including Usefullnes, Easy to Use, Easy of Learning, and Satisfaction. Usefulness describes the benefits of R-PhyLab for users. Easy to Use illustrates the ease of using R-PhyLab for users. Ease of learning illustrates the ease of operating R-PhyLab by the user. At the same time, Satisfaction describes user satisfaction after using R-PhyLab.

The feedback results show that using R-PhyLab gets a positive response from the user. According to the user, aspects of R-PhyLab operation that cannot be done at any time must be considered. This is because using R-PhyLab still depends on the operator's role. In addition, some users face the stability of internet connection stability because some users are in a location with the support of infrastructure for internet connection that is less stable [15]. The use of R-PhyLab requires fast and stable internet access support.

For future research, we recommend developing an R-PhyLab system that minimizes the operator's role so that R-PhyLab access can be done anytime.

4. Conclusion

Archimedes' principle experimental apparatus for remote physics laboratories have been successfully developed. This apparatus and its data acquisition system demonstrated a linear relationship between the volume of an immersed object and the buoyant force that the object experiences. So that the

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The experimental apparatus for the Archimedes principle (and also for the GUI) that has been developed is not equipped with components to measure the temperature of liquids. The operator measures the temperature of the liquid during the experiment and notifies the user through the remote laboratory portal. In addition, users cannot change liquids themselves when using online. Replacement liquids are carried out by operators based on user requests. In terms of accuracy and precision, the data generated from this apparatus is very good, so it can be used for physics learning with online experimental methods.

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apparatus developed for the remote laboratory is feasible to be used for experiments to verify the density value of a liquid through the application of Archimedes' principle.

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Ishafit is an Associate Professor in the Department of Physics Education at Universitas Ahmad Dahlan. He received his doctoral degree at Universitas Negeri Yogyakarta in 2021 and has taught physics for over 25 years. His current research interests are laboratory-based physics instruction and ICT-based physics experiments.

Yoga Dwi Prabowo is a laboratory assistant at the Ahmad Dahlan University Science Learning Technology Laboratory (LTPS). Currently he is actively part of the team that developed the Remote Physics Laboratory (R-Phylab).

Moh. Irma Sukarelawan is a lecturer in the Department of physics education, Universitas Ahmad Dahlan, Indonesia. He is a Ph.D. Candidate in Department of Educational Science, Graduate School, Universitas Negeri Yogyakarta, Indonesia. His research focuses on physics education, misconception, mobile learning, and the Rasch model.

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APPENDIX

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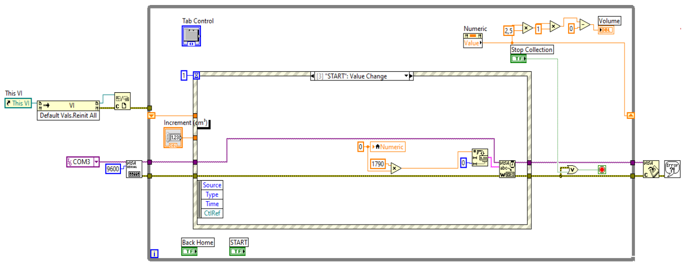
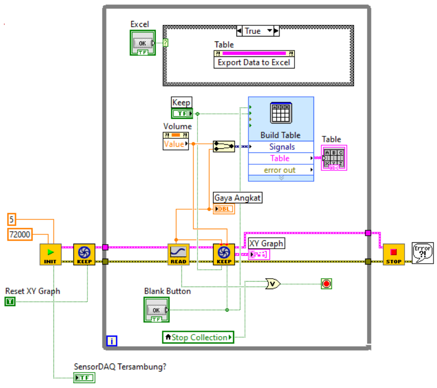
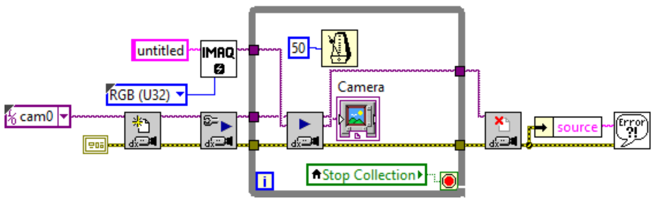
Appendix 1. Block diagram for device setup and stepper motor control



Appendix 2. Data acquisition system block diagram



Appendix 3. Camera panel block diagram



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20 September 2023

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Re: "Archimedes' Principles Experimental Apparatus for Remote Physics Laboratory"

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REVIEWER REPORT(S):

Referee: 1

COMMENTS TO THE AUTHOR(S)
Dear Authors,

This time, I had a more comprehensive understanding of the paper as I read through it. I did notice some language issues that required attention. I provided several suggestions for rephrasing certain sections. Accepting them or not, is completely up to you.

Abstract:

"So, the developed apparatus can be used in online experimental-based physical learning. "

Do you want to say, " So, the developed apparatus can be used as an experimental-based learning tool in an online platform?

Introduction:
first page, first column 42:
The sentence is still confusing – think about re-writing or changing it to something like "A strong comprehension of Archimedes' principles can significantly enhance a student's grasp of various other fluid mechanical concepts."

44: Change "soaked" to "immersed."

50-54 "However, in many schools, learning related to this topic is still dominated by discussions in theoretical studies without being accompanied by experimental activities, even though experimental activities are an essential aspect of learning, especially in physics [4]."

Consider re-writing it: "Due to the lack of physical resources in certain schools, lessons pertaining to the aforementioned principle are often confined to theoretical discussions, devoid of any practical hands-on experience."

57 What is "beam three balance"? Is it "triple beam balance?
59. Soaked -- It's incorrect - should be "immersed."

first page, second column

You used "load is hung," and the object is dipped." Are you referring to the same?

"The container containing liquid is then transferred (computerized) until the object is immersed." -- Sorry, I am lost here.
Was the container with liquid lifted until the hanging object was immersed? And was the setup operated remotely with the aid of computers?

"Based on the previous studies, the development of Archimedes' experimental apparatus is needed."

As I understand, you are trying to say there is a clear need to develop an experimental apparatus based on Archimedes' principles. But you never mentioned a flaw in the previous research. Discuss what flaws you observe in the previously reported studies.

page 2
21 "resultant of the compressive force" did you mean a resistive force?

26. "the force due to pressure experienced by a partially submerged object." Did you mean pressure-induced force?

46 "Vx is the volume of the object submerged" - Not correct! It would be best if you said displaced fluid or the volume of the fraction of the submerged object. -- The way you wrote it, the reader might misunderstand it as the total volume of the object. As I understood, you are slowly immersing the object while taking data - right? Not submerging different objects, right? you mentioned the following on the paper, "Users can observe the movement of objects when immersed through video streaming from the camera installed in the apparatus"

49. "..... the value read is based on the tension in the rope connecting the object to the sensor."
It would read better if you wrote it like " ......the sensor directly reads the tension on the string as shown in equation (2)."

Page 2, column 2
"........ can write down the forces acting on objects based on figure 2 "
The net force on the object can be expressed by equation (3)

"W-object is the sensor's value when the object is submerged in liquid. "
Is W-object the sensor's reading? Then, what is Fnet?

page 3

7-8 "Diagrammatically, the experimental apparatus Archimedes' Principle's design is shown in Figure 4."
Change to something like: The hardware schematics of the experiment are given in Figure 4

In the seven steps 47-54, you are using upper case letters for some and lower case for others - please consider using one type (simple or capital letters - pick one)

Page 3: PLEASE CHECK THE TWO COLUMNS ON THE UPPER HALF AND THE LOWER HALF [below the figure]. The columns don't run from top to bottom, maybe because of the figure in between. I haven't seen the columns broken the way they are in this article --> This could be an error on MSW. If the editors decide to replace the image, the text may not read correctly. Please check with the editorial board.

PAGE 4: PLEASE CHECK THE TWO COLUMNS ON THE UPPER HALF AND THE LOWER HALF [below the figure] -- Please check with the editorial board

Page 4:
" The real form of the development of an experimental ......
in Figure 7." Please reword this: suggestion - " Figure 7 displays the apparatus used in the Archimedes experiment, including all the associated hardware.

Discussion:
"Based on the results of remote experiments (see Figure 8), data were obtained for a linear relationship between the volume of a submerged object and the force read on the sensor."

As shown in Fig. 8, Vx and the sensor reading, Fnet, show a linear relationship.
page 5
56-58 " ...... determined using the ratio of the line gradient to the
acceleration due to gravity (g = 9.8 m/s2)..... "

consider the below change,
F = V(rho) g
y = mx
Thus, the slope, m, of the graph = (rho)g, and by using this, one can find the density of the unknown liquid.

Please re-read the paper and make sure there are no physics related mistakes.

Good Luck!

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22 September 2023

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Toni Kus Indratno <tonikus@staff.uad.ac.id>

Your submission to Phys. Educ.: PED-103593.R3

1 pesan

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Dear Mr Indratno,

Re: "Archimedes' Principle Experimental Apparatus for Remote Physics Laboratory"

Manuscript reference: PED-103593.R3

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Archimedes' Principle Experimental Apparatus for Remote Physics Laboratory

T K Indratno, Ishafit, and Y D Prabowo

Physics Education Department, Universitas Ahmad Dahlan, Yogyakarta, Indonesia

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Received xxxxxx
Accepted for publication xxxxxx
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Abstract

The latest developments in information technology have made it possible to have experimental activities that can be accessed remotely. This article offers an explanation abou the development of experimental tools that can be accessed remotely based on Archimedes' principle that can be accessed remotely. The equipment has been developed by adding a stepper motor to control the object to submerge in liquid. The stepper motor is controlled by Arduino Uno using the graphic user interface (GUI) developed using LabVIEW. Data sampling process uses a force sensor that is controlled using the same GUI. Based on the equipment that has been developed, experiments on the principle of Archimedes can be done online through websites. The experimental results agree with theoretical calculations and with previous research. Therefore, the developed apparatus can be used as an experimental-based learning tool in an online platform.

Keywords: remote experiment, Archimedes' principle, remote laboratory

1. Introduction

Archimedes' principle is one of the fundamental topics of fluid mechanics in school [1]. A strong comprehension of Archimedes' principles can significantly enhance a student's grasp of various fluid mechanical concepts [2]. This principle states that if an object is immersed in a liquid, either wholly or partially, it is buoyed up equal to the weight of the liquid transferred by the object. Using Archimedes' principle, fluid density can be calculated [3] through several investigations. The density of an object can also be determined from the known density of the liquid. Due to lack of physical resources in certain schools, lessons pertaining to the aforementioned principle are often confined to theoretical discussions, devoid of any practical hands-on experience [4].

Based on previous studies, experiments of Archimedes' principle can be done using spring balance [5] or triple beam balance. The load is hung on the balance, then immersed in liquid. The buoyant force value is then obtained, which equals the weight of the liquid being moved. Gianino [6] developed an experimental method to determine fluid density using a microcomputer-based laboratory (MBL), which consists of a force sensor, computer, and data acquisition system for better results. In this case, the load is hung on the force sensor. Then the object is slowly dipped into the liquid. The MBL system will display the relationship graph between the object's submerged volume vs. the buoyant force experienced by the object.

A similar apparatus was also developed by Ozvoldová et al. [7], who developed an experimental apparatus based on Archimedes' principle for remote experiments. They reported that the object was hung on a dynamometer connected to a computer. The container with liquid was lifted by the setup operated remotely until the hanging object was immersed. Data on the object's immersed depth and buoyancy force is recorded through a data acquisition system developed using Java Applet. This system can also be accessed online through certain applications on websites.

Previous studies have shown that a software control to submerge the object in the liquid is not yet available. This software control allows full control of the data acquisition process to support remote experimentation. In research [7],

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software control was carried out in a container with liquid. Shocks may occur in the liquid, interfering in the data obtained. Therefore, the development of an experimental apparatus based on Archimedes' principle is needed. This article discusses the development of experimental apparatus for remote laboratory based on Archimedes' principle. The novelty of the device being developed lies in the device control and the data acquisition system. Users can perform device control and data acquisition through a graphical user interface (GUI) created using LabVIEW. This experimental tool, which uses Archimedes' principle and is based on this remote laboratory, can be used for learning physics.

2. Materials and Methods

The experimental apparatus based on Archimedes' principle was developed in three steps: studying Archimedes' principle in physics, designing hardware, and creating software for control systems and data acquisition.

a. Archimedes' Principle

When an object is immersed in a liquid, it experiences a buoyant force, *F*. This buoyant force is the net upward force on the object by the liquid [8]. The deeper the object sinks, the greater the buoyant force experienced by the object. Figure 1 (adapted from [9]) shows forces due to pressure acting on the surface of a partially immersed body.

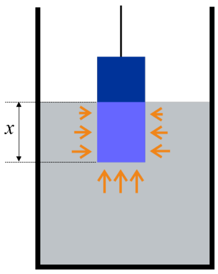

Figure 1. Forces due to pressure acting on the surface of a partially immersed body.

Archimedes' principle is mathematically written as,

$$F_{\text{up}} = \rho g V_x \tag{1}$$

where ρ is the density of the liquid, g is the acceleration due to gravity, and V_x is the volume of the fraction of the submerged object.

When an object is hung on a force sensor, and the object is in a state of static equilibrium, the sensor directly reads the tension on the string as shown in equation (2).

$$W_{\text{app}} = m_{\text{app}} g = T_{\text{wire}} \tag{2}$$

where m_{app} is the object's mass, while W_{app} is the weight of an object when it is suspended in the air. If the suspended object is immersed in a liquid, the tension in the rope will be less than the object's weight because of the buoyant force. The formula of the forces acting on objects is shown in Figure 2 (adapted from [9]). The net force on the object can be expressed by equation (3).

$$\sum F_y = T_{\text{wire}} + F_{\text{up}} - W_{\text{object}} \tag{3}$$

W_{object} is the force sensor value when the volume of the fraction of the submerged object. Using equations (2) and (3), the value of the buoyant force acting on the object is,

$$F_{\text{up}} = W_{\text{app}} - W_{\text{object}} \tag{4}$$

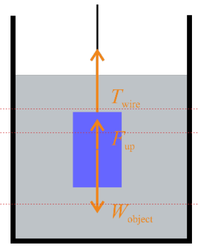

Figure 2. A Forces acting on a submerged object

b. Hardware design

The main component in developing this apparatus is (1) Arduino Uno as a microcontroller for communication between hardware and software, as well as a device controller, (2) Nema17 17HS4401 stepper motor to move the object. The stepper motor is connected vertically using a lead screw, which is a rail where the object moves up and down. The stepper motor is controlled by the Arduino Uno using a circuit (Figure 3) to adjust the object's moves, so it can be immersed in liquid. The limit switch is used as an upper limit for object movements.

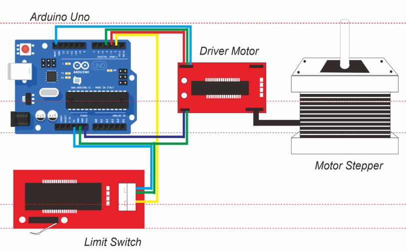

Figure 3. Schematic diagram of stepper motor control circuit

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Experimental data on the weight of an object suspended in the air or submerged in liquid is obtained using a Force Sensor from Vernier Technology. This apparatus can read forces from 0.01 to 50 newtons [10]. The Force Sensor is connected to the computer via SensorDAQ, a data acquisition interface from National Instrument and Vernier. SensorDAQ has three analogs and one digital channel with a maximum capacity of up to 48,000 samples per second [11]. The hardware schematic diagram of the experiment is displayed in Figure 4.

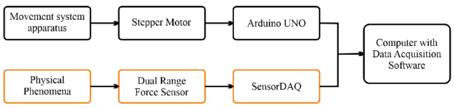

Figure 4. Hardware schematic design

c. Control system development

The control system is made with a graphical user interface (GUI), which is simple and easy to use. The GUI is developed using LabVIEW software. LabVIEW, originally from National Instrument (NI), is a block diagram-based programming language for creating virtual instrumentation. LabVIEW software has three main parts: a front panel for creating GUIs, a block diagram as programming code, and a connector for connection between components made [12]. LabVIEW is used for GUI development because it features web publishing tools, so the developed GUI can be accessed remotely via the website.

The experimental software's graphical user interface (GUI) design based on Archimedes' principle is shown in Figure 5. The two main parts of this experimental software are device settings and data acquisition systems. The tool setting instructs the stepper motor to move downwards to submerge the object in the liquid. The data acquisition system displays the object buoyancy data that is read by the sensor. The data is in tables and graphs. Block diagrams for device settings and stepper motor control can be seen in Appendix 1, while the block diagrams for data acquisition systems and camera displays can be seen in Appendices 2 and 3.

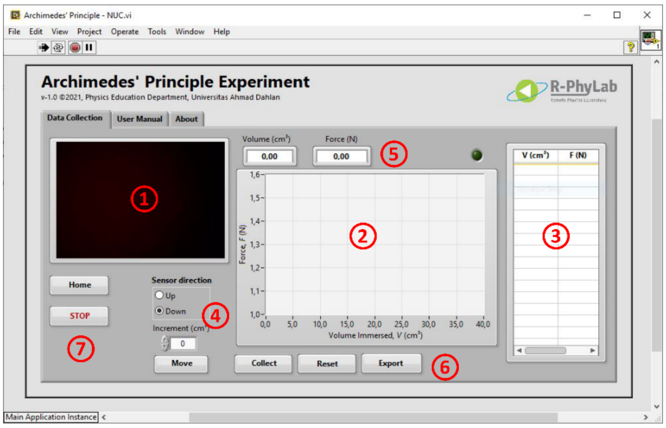

Figure 5. The experimental software's GUI based on Archimedes' principle

There are seven main elements in the experimental software's GUI based on Archimedes' principle with different functions: (1) an apparatus monitor to display experimental apparatus, (2) a graphic panel to display data in graphic form, (3) a table panel, which displays data in tabular form, (4) switch to adjust the direction of motion of the sensor, (5) current monitor, which displays real-time data, (6) buttons to retrieve data of object volume and buoyant force experienced by the object, and (7) buttons to start and end the experiment.

This experimental system can be used offline or online. In offline use, the user installs it, then connects the experimental apparatus to a computer via a USB connection. Meanwhile, this system must first be published into HTML code via the web publishing tools available in LabVIEW for remote experimental online use. After publishing, users can access the

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system and its apparatus via the website. The architecture of remote laboratory system (see Figure 6) used in this experiment is as described in [13]. The experimental apparatus is connected to a computer on a lab server. Through the lab server computer, the data acquisition system is published as HTML to be accessed by users via the internet.

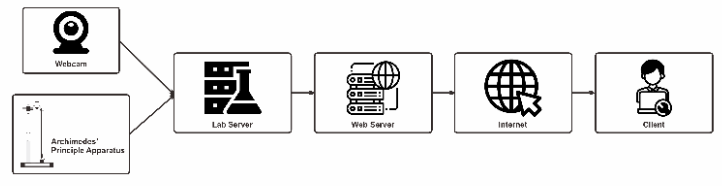

Figure 6. The architecture of remote laboratory system

3. Results and Discussion

Result

Figure 7 displays the apparatus used in the Archimedes' principle experiment, including all associated hardware. The novelty of this study, when compared to the research [6], lies in the computerization of hardware control systems. The stepper motor is computerized and controlled to immerse the object into the liquid. Meanwhile, compared to research [7], the difference is in the type of sensor used and the data collection process. The Dual-Range Force Sensor from Vernier Technology was used in this study, and the event collected data by entering.

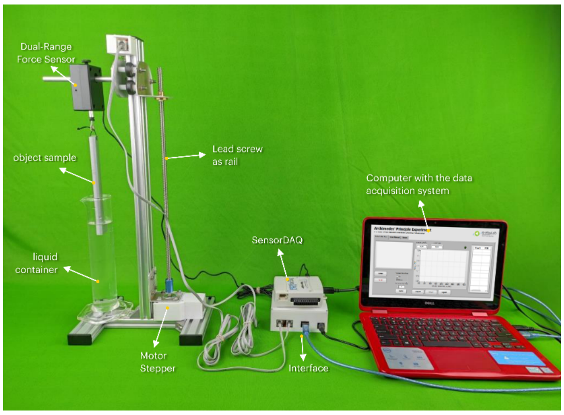

Figure 7. Image of the experimental apparatus based on Archimedes' principle for remote laboratory

The apparatus developed can be used for learning physics with remote laboratory-based experiment methods. Using the camera installed in the system, students can observe the experimental apparatus, control the apparatus, and control the data collection process. This apparatus can be accessed remotely using a GUI embedded in the remote laboratory web portal, http://rphylab.pf.uad.ac.id/sistem/. Users can create an account independently and confirm experimental activities to the administrator via e-mail to rphylab@pfis.uad.ac.id. Figure 8 shows the results of Archimedes' principle experiment and access to the apparatus remotely via the website.

In this study, the experimental apparatus involving Archimedes' principle was used to verify the density of liquids. In this case, water and alcohol were used. Blocks of dimensions 2.5 × 1 × 18 cm were immersed from 4 cm^3 to 40 cm^3. Users can observe the movement of the objects when immersed through video streaming from the camera installed in the apparatus.

Discussion

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As shown in Figure 8, V_x and the sensor reading, show a linear relationship. The force read on this sensor is the object's gravitational force. The buoyant force experienced by an object can be determined using equation (3). Table 1 shows the relationship between the volume of a sinking object and the buoyant force experienced by the object based on the experimental results.

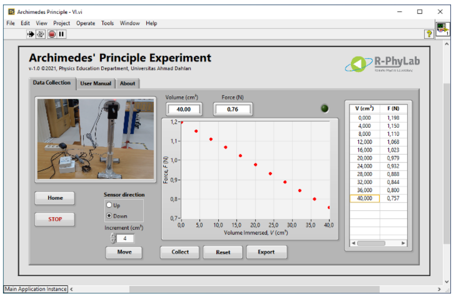

Figure 8. Archimedes' principle experiment with an online remote laboratory

Table 1. Experimental result

Volume (m^3)	Buoyant Force (N)	
	Water	Ethanol
0.000004	0.033	0.038
0.000008	0.079	0.076
0.000012	0.122	0.114
0.000016	0.165	0.153
0.000020	0.209	0.192
0.000024	0.250	0.230
0.000028	0.292	0.267
0.000032	0.336	0.306
0.000036	0.378	0.344
0.000040	0.420	0.384

Figure 9 shows the results of fitting the data into a linear equation, with the volume of the immersed object (V_x) as the dependent variable x and the upward pressure force as the independent variable y.

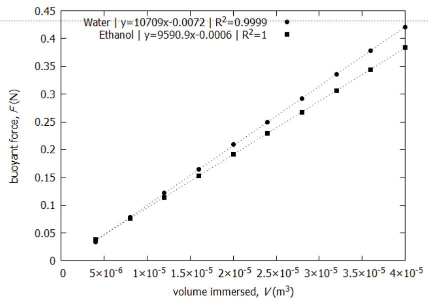

Figure 9. The graph of the relationship between the volume of objects infected with buoyant force on objects

By using equation (1) and comparing it with the equation of a straight line, $y = mx$, the gradient of a line is $m = \rho g$. Using this, one can find the density of the unknown liquid (g = 9.8 m/s^2 [4]). The results of the calculation of the density of water and ethanol are shown in Table 2.

Table 2. Results of the calculation of the value of the density of liquids

Liquid	Slope	R^2	ρ (Kg/m^3)	% Error
Water	10709	0.9999	1092.76	0.09
Ethanol	9590.9	1	980.66	0.18

The relative error is obtained by comparing the experimental results with reference [3]. The experimental results in this study confirm the results of similar previous studies [3], [5] and [6]. Therefore, the apparatus that has been developed can verify the fluid density value with good results.

The experimental apparatus (and also for GUI) developed needs to be equipped with a liquid temperature sensor, as liquid temperature measurements is still performed manually by an operator who will convey the results to the user through the remote laboratory portal. In addition, users cannot replace automatic liquids during experiments online. Fluid replacement is carried out by an operator based on user's requests. However, the accuracy and precision resulting from the apparatus are close to the value theoretically expected, so it can be used for learning physics with the online experimental method.

After experimenting in R-PhyLab, users fill out a questionnaire, created based on the USE Questionnaire [14], including usefullnes, easy to use, easy of learning, and satisfaction. Usefulness refers to the benefits of R-PhyLab for users. Easy of use examines how easy it is to use R-PhyLab, Ease of learning shows how easy it is to learn to operate R-PhyLab, while satisfaction examines user's satisfaction after using R-PhyLab.

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The results of the questionnaire survey show that R-PhyLab gets a positive response from users. According to the users, some aspects of R-PhyLab operation that cannot be done at any time must be considered. This is because the use R-PhyLab typically depends on the role of an operator. In addition, the use of R-PhyLab requires a fast and stable internet connection, and this may not be possible for some users who have unstable or inconsistent internet access due to geographical location [15].

Future research, could develop an R-PhyLab system that minimizes the operator's role so that R-PhyLab can be accessed anytime.

4. Conclusion

An experimental experimental apparatus for remote physics laboratories based on Archimedes' principle has been successfully developed. This apparatus and its data acquisition system have demonstrated a linear relationship between the volume of an immersed object and the buoyant force that the object experiences. Thus, the apparatus is feasible to be used for experiments to verify the density value of a liquid through the application of Archimedes' principle.

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Toni Kus Indratno is a lecturer in the physics education department at Universitas Ahmad Dahlan. His current research interest focuses on the application of ICTs (smartphones/computers) in learning physics. Besides, he and his team are developing a remote-based laboratory (R-Phylab) for distance physics learning.

Ishafit is an Associate Professor in the Department of Physics Education at Universitas Ahmad Dahlan. He received his doctoral degree at Universitas Negeri Yogyakarta in 2021 and has taught physics for over 25 years. His current research interests are laboratory-based physics instruction and ICT-based physics experiments.

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Yoga Dwi Prabowo is a laboratory assistant at the Ahmad Dahlan University Science Learning Technology Laboratory (LTPS). Currently he is actively part of the team that developed the Remote Physics Laboratory (R-Phylab).

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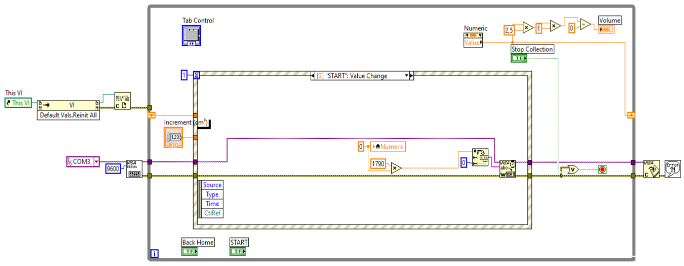
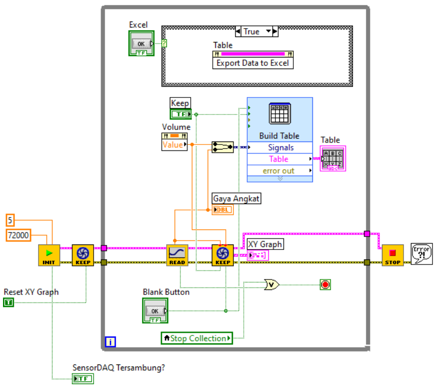
APPENDIX

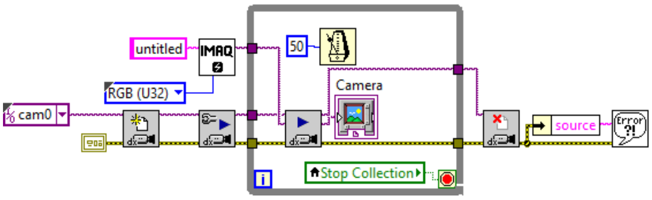
Appendix 1. Block diagram for device setup and stepper motor control



Appendix 2. Data acquisition system block diagram



Appendix 3. Camera panel block diagram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14. The Fourth revision submitted

19 October 2023

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Archimedes' Principle Experimental Apparatus for Remote Physics Laboratory

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Abstract

The latest developments in information technology have made it possible to have experimental activities that can be accessed remotely. This article offers an explanation about the development of experimental tools that can be accessed remotely based on Archimedes' principle. The equipment has been developed by adding a stepper motor to control the object to submerge in liquid. The stepper motor is controlled by Arduino Uno using the graphic user interface (GUI) developed using LabVIEW. Data sampling process uses a force sensor that is controlled using the same GUI. Based on the equipment that has been developed, experiments on the principle of Archimedes' can be done online through websites. The experimental results agree with theoretical calculations and with previous research. Therefore, the developed apparatus can be used as an experimental-based learning tool in an online platform.

Keywords: remote experiment, Archimedes' principle, remote laboratory

1. Introduction

Archimedes' principle is one of the fundamental topics of fluid mechanics in school [1]. A strong comprehension of Archimedes' principles can significantly enhance a student's grasp of various fluid mechanical concepts [2]. This principle states that if an object is immersed in a liquid, either wholly or partially, it is buoyed up equal to the weight of the liquid transferred by the object. Using Archimedes' principle, fluid density can be calculated [3] through several investigations. The density of an object can also be determined from the known density of the liquid. Due to lack of physical resources in certain schools, lessons pertaining to the aforementioned principle are often confined to theoretical discussions, devoid of any practical hands-on experience [4].

Based on previous studies, experiments on Archimedes' principle can be done using spring balance [5] or triple beam balance. The load is hung on the balance, then immersed in liquid. The buoyant force value is then obtained, which equals the weight of the liquid being moved. Gianino [6] developed an experimental method to determine fluid density using a microcomputer-based laboratory (MBL), which consists of a force sensor, computer, and data acquisition system for better results. In this case, the load is hung on the force sensor. Then the object is slowly dipped into the liquid. The MBL system will display the relationship graph between the object's submerged volume vs. the buoyant force experienced by the object.

A similar apparatus was also developed by Ozvoldová et al. [7], who developed an experimental apparatus based on Archimedes' principle for remote experiments. They reported that the object was hung on a dynamometer connected to a computer. The container with liquid was lifted by the setup operated remotely until the hanging object was immersed. Data on the object's immersed depth and buoyancy force is recorded through a data acquisition system developed using Java Applet. This system can also be accessed online through certain applications on websites.

Previous studies have shown that a software control to submerge the object in the liquid is not yet available. This software control allows full control of the data acquisition process to support remote experimentation. In research [7], software control was carried out in a container with liquid. Shocks may occur in the liquid, interfering in the data obtained. Therefore, the development of an experimental apparatus based on Archimedes' principle is needed. This article discusses the development of experimental apparatus for remote laboratory based on Archimedes' principle. The novelty of the device being developed lies in the device control and the data acquisition system. Users can perform device control and data acquisition through a graphical user interface (GUI) created using LabVIEW. This experimental tool, which uses Archimedes' principle and is based on this remote laboratory, can be used for learning physics.

2. Materials and Methods

The experimental apparatus based on Archimedes' principle was developed in three steps: studying Archimedes' principle in physics, designing hardware, and creating software for control systems and data acquisition.

a. Archimedes' Principle

When an object is immersed in a liquid, it experiences a buoyant force, *F*. This buoyant force is the net upward force on the object by the liquid [8]. The deeper the object sinks, the greater the buoyant force experienced by the object. Figure 1 (adapted from [9]) shows forces due to pressure acting on the surface of a partially immersed body.

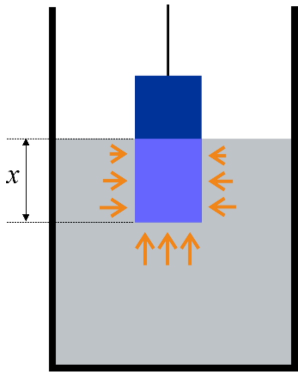

Figure 1. Forces due to pressure acting on the surface of a partially immersed body

Archimedes' principle is mathematically written as,

$$F_{\text{up}} = \rho g V_x \tag{1}$$

where ρ is the density of the liquid, g is the acceleration due to gravity, and V_x is the volume of the fraction of the submerged object.

When an object is hung on a force sensor, and the object is in a state of static equilibrium, the sensor directly reads the tension on the string as shown in equation (2).

$$W_{\text{app}} = m_{\text{app}} g = T_{\text{wire}} \tag{2}$$

where m_{app} is the object's mass, while W_{app} is the weight of an object when it is suspended in the air. If the suspended object is immersed in a liquid, the tension in the rope will be less than the object's weight because of the buoyant force. The formula of the forces acting on objects is shown in Figure 2 (adapted from [9]). The net force on the object can be expressed by equation (3).

$$\sum F_y = T_{\text{wire}} + F_{\text{up}} - W_{\text{object}} \tag{3}$$

where W_{object} is the weight of the object that is read on the sensor when the volume of the object is submerged. Using equations (2) and (3), the value of the buoyant force acting on the object is,

$$F_{\text{up}} = W_{\text{app}} - W_{\text{object}} \tag{4}$$

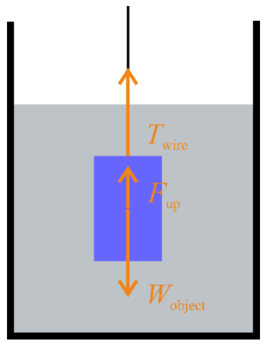

Figure 2. A Forces acting on a submerged object

b. Hardware design

The main component in developing this apparatus is (1) Arduino Uno as a microcontroller for communication between hardware and software, as well as a device controller, (2) Nema 17HS4401 stepper motor to move the object. The stepper motor is connected vertically using a lead screw, which is a rail where the object moves up and down. The stepper motor is controlled by the Arduino Uno using a circuit (Figure 3) to adjust the object's moves, so it can be immersed in liquid. The limit switch is used as an upper limit for object movements.

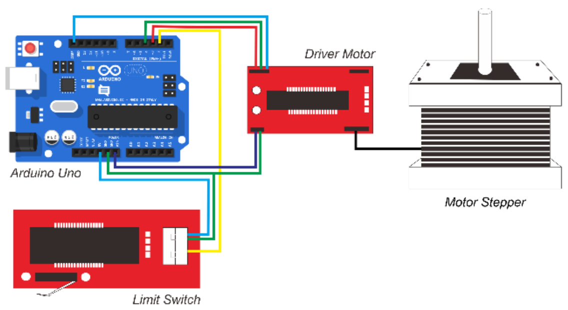

Figure 3. Schematic diagram of stepper motor control circuit

Experimental data on the weight of an object suspended in the air or submerged in liquid is obtained using a Force Sensor from Vernier Technology. This apparatus can read forces from 0.01 to 50 newtons [10]. The Force Sensor is connected to the computer via SensorDAQ, a data acquisition interface from National Instrument and Vernier. SensorDAQ has three analogs and one digital channel with a maximum capacity of up to 48,000 samples per second [11]. The hardware schematic diagram of the experiment is displayed in Figure 4.

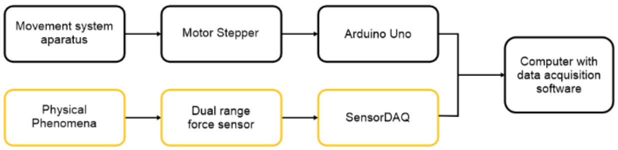

Figure 4. Hardware schematic design

c. Control system development

The control system is made with a graphical user interface (GUI), which is simple and easy to use. The GUI is developed using LabVIEW software. LabVIEW, originally from National Instrument (NI), is a block diagram-based programming language for creating virtual instrumentation. LabVIEW software has three main parts: a front panel for creating GUIs, a block diagram as programming code, and a connector panel for connection between components made [12]. LabVIEW is used for GUI development because it features web publishing tools, so the developed GUI can be accessed remotely via the website.

The experimental software's graphical user interface (GUI) design based on Archimedes' principle is shown in Figure 5. The two main parts of this experimental software are device settings and data acquisition systems. The tool setting instructs the stepper motor to move downwards to submerge the object in the liquid. The data acquisition system displays the object buoyancy data that is read by the sensor. The data is in tables and graphs. Block diagrams for device settings and stepper motor control can be seen in Appendix 1, while the block diagrams for data acquisition systems and camera displays can be seen in Appendices 2 and 3.

There are seven main elements in the experimental software's GUI based on Archimedes' principle with different functions: (1) an apparatus monitor to display experimental apparatus, (2) a graphic panel to display data in graphic form, (3) a table panel, which displays data in tabular form, (4) switch to adjust the direction of motion of the sensor, (5) current monitor, which displays real-time data, (6) buttons to retrieve data of object volume and buoyant force experienced by the object, and (7) buttons to start and end the experiment.

This experimental system can be used offline or online. In offline use, the user installs it, then connects the experimental apparatus to a computer via a USB connection. Meanwhile, this system must first be published into HTML code via the web publishing tools available in LabVIEW for remote experimental online use. After publishing, users can access the system and its apparatus via the website. The architecture of remote laboratory system (see Figure 6) used in this experiment is as described in [13]. The experimental apparatus is connected to a computer on a lab server. Through the lab server computer, the data acquisition system is published as HTML to be accessed by users via the internet.

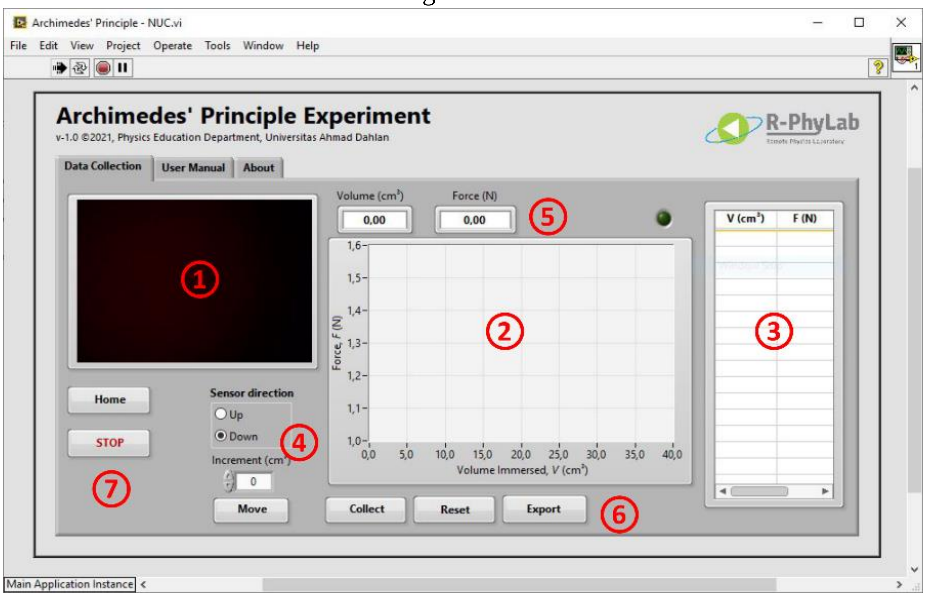

Figure 5. The experimental software's GUI based on Archimedes' principle

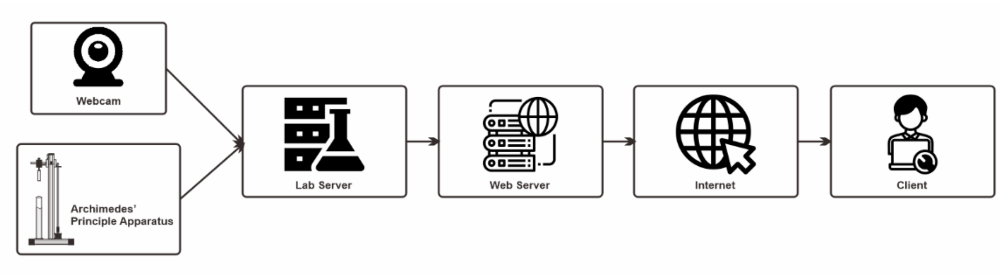

Figure 6. The architecture of remote laboratory system

3. Results and Discussion

Result

Figure 7 displays the apparatus used in the Archimedes' principle experiment, including all associated hardware. The novelty of this study, when compared to the research [6], lies in the computerization of hardware control systems. The stepper motor is computerized and controlled to immerse the object into the liquid. Meanwhile, compared to research [7], the difference is in the type of sensor used and the data collection process. The Dual-Range Force Sensor from Vernier Technology was used in this study, and the event collected data by entering.

The apparatus developed can be used for learning physics with remote laboratory-based experiment methods. Using the camera installed in the system, students can observe the experimental apparatus, control the apparatus, and control the data collection process. This apparatus can be accessed remotely using a GUI embedded in the remote laboratory web portal, http://rphylab.pf.uad.ac.id/sistem/. Users can create an account independently and confirm experimental activities to the administrator via e-mail to rphylab@pfis.uad.ac.id. Figure 8 shows the results of Archimedes' principle experiment and access to the apparatus remotely via the website.

In this study, the experimental apparatus involving Archimedes' principle was used to verify the density of liquids. In this case, water and alcohol were used. Blocks of dimensions 2.5 × 1 × 18 cm were immersed from 4 cm^3 to 40 cm^3. Users can observe the movement of the objects when immersed through video streaming from the camera installed in the apparatus.

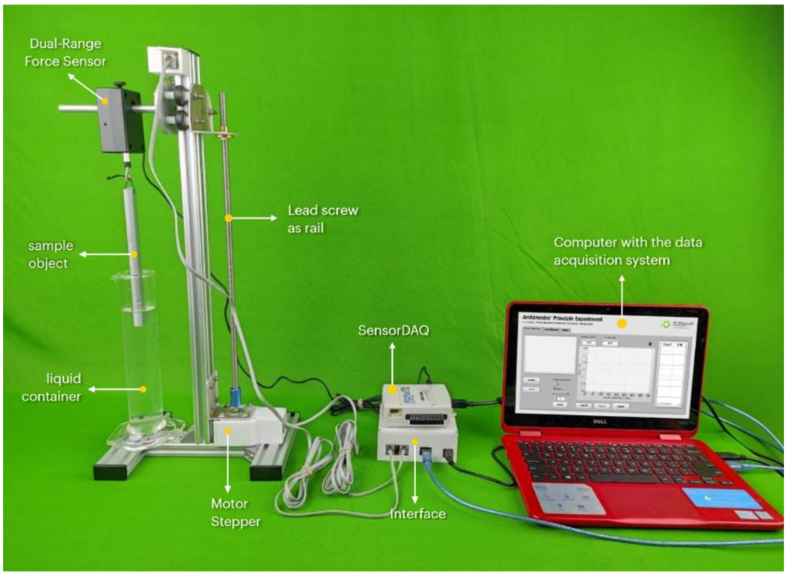

Figure 7. Image of the experimental apparatus based on Archimedes' principle for remote laboratory

Discussion

As shown in Figure 8, V_x and the sensor reading, show a linear relationship. The force read on this sensor is the object's gravitational force. The buoyant force experienced by an object can be determined using equation (3). Table 1 shows the relationship between the volume of a sinking object and the buoyant force experienced by the object based on the experimental results.

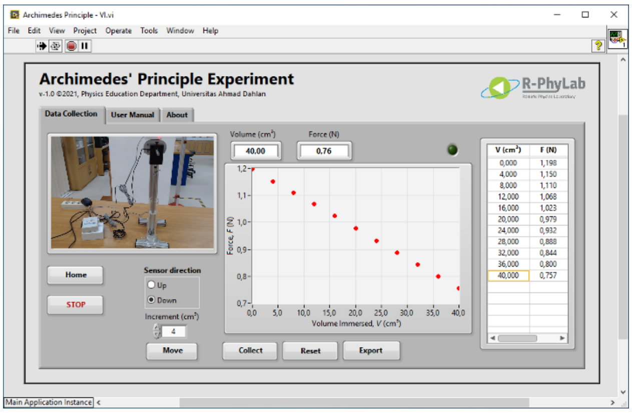

Figure 8. Archimedes' principle experiment with an online remote laboratory

Table 1. Experimental result

Volume ($\times 10^{-5}$ m^3)	Buoyant Force (N)	
	Water	Ethanol
4	0.033	0.038
8	0.079	0.076
12	0.122	0.114
16	0.165	0.153
20	0.209	0.192
24	0.250	0.230
28	0.292	0.267
32	0.336	0.306
36	0.378	0.344
40	0.420	0.384

Figure 9 shows the results of fitting the data into a linear equation, with the volume of the immersed object (V_x) as the dependent variable x and the upward pressure force as the independent variable y.

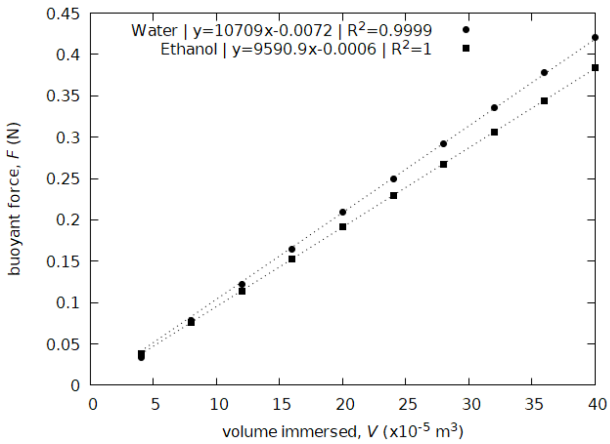

Figure 9. The graph of the relationship between the volume of objects infected with buoyant force on objects

Using equation (1) and comparing it with the equation of a straight line, $y = mx$, the slope of a line is $m = \rho g$. Using this slope, one can find the density of the unknown liquid (g = 9.8 m/s^2 [4]). The results of the calculation of the density of water and ethanol are shown in Table 2.

Table 2. Results of the calculation of the value of the density of liquids

Liquid	Slope	R^2	ρ (Kg/m^3)	% Error
Water	10709	0.9999	1092.76	0.09
Ethanol	9590.9	1.0000	980.66	0.18

The relative error is obtained by comparing the experimental results with reference [3]. The experimental results in this study confirm the results of similar previous studies [3], [5] and [6]. Therefore, the apparatus that has been developed can verify the fluid density value with good results.

The experimental apparatus (and also for GUI) developed needs to be equipped with a liquid temperature sensor, as liquid temperature measurements are still performed manually by an operator who will convey the results to the user through the remote laboratory portal. In addition, users cannot replace automatic liquids during experiments online. Fluid replacement is carried out by an operator based on user's requests. However, the accuracy and precision resulting from the apparatus are close to the value theoretically expected, so it can be used for learning physics with the online experimental method.

After experimenting in R-PhyLab, users fill out a questionnaire created based on the USE Questionnaire [14], which examines several dimensions of usability, including usefullnes, easy of use, easy of learning, and satisfaction. Usefulness refers to the benefits of R-PhyLab for users. Easy of use examines how easy it is to use R-PhyLab. Ease of learning shows how easy it is to learn to operate R-PhyLab, while satisfaction examines user's satisfaction after using R-PhyLab.

The results of the questionnaire survey show that R-PhyLab gets a positive response from users. According to the users, some aspects of R-PhyLab operation that cannot be done at any time must be considered. This is because the use R-PhyLab typically depends on the role of an operator. In addition, the use of R-PhyLab requires a fast and stable internet connection, and this may not be possible for some users who have unstable or inconsistent internet access due to geographical location [15].

Future research, could develop an R-PhyLab system that minimizes the operator's role so that R-PhyLab can be accessed anytime.

4. Conclusion

An experimental apparatus for remote physics laboratories based on Archimedes' principle has been successfully developed. This apparatus and its data acquisition system have demonstrated a linear relationship between the volume of an immersed object and the buoyant force that the object experiences. Thus, the apparatus is feasible to be used for experiments to verify the density value of a liquid through the application of Archimedes' principle.

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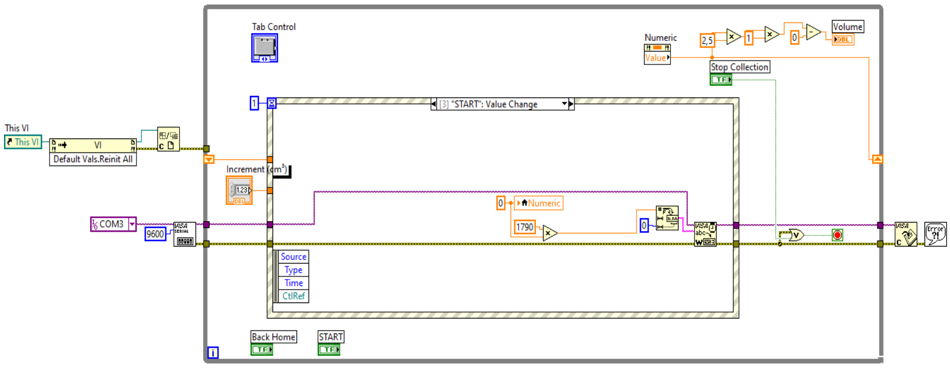
Toni Kus Indratno is a lecturer in the physics education department at Universitas Ahmad Dahlan. His current research interest focuses on the application of ICTs (smartphones/computers) in learning physics. Besides, he and his team are developing a remote-based laboratory (R-Phylab) for distance physics learning.

Ishafit is an Associate Professor in the Department of Physics Education at Universitas Ahmad Dahlan. He received his doctoral degree at Universitas Negeri Yogyakarta in 2021 and has taught physics for over 25 years. His current research interests are laboratory-based physics instruction and ICT-based physics experiments.

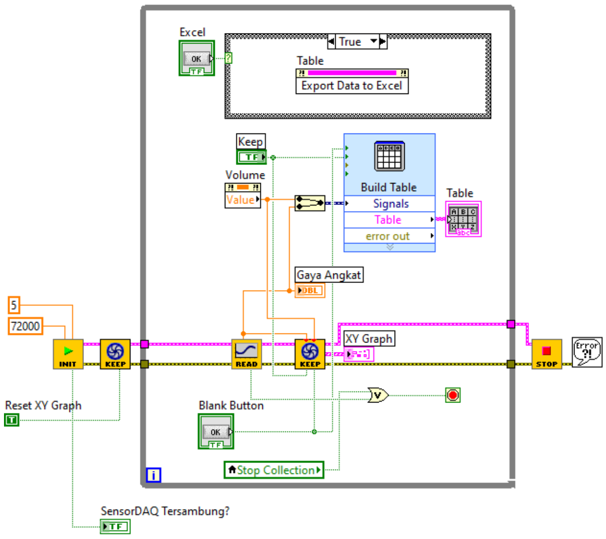
Yoga Dwi Prabowo is a laboratory assistant at the Ahmad Dahlan University Science Learning Technology Laboratory (LTPS). Currently he is actively part of the team that developed the Remote Physics Laboratory (R-Phylab).

APPENDIX

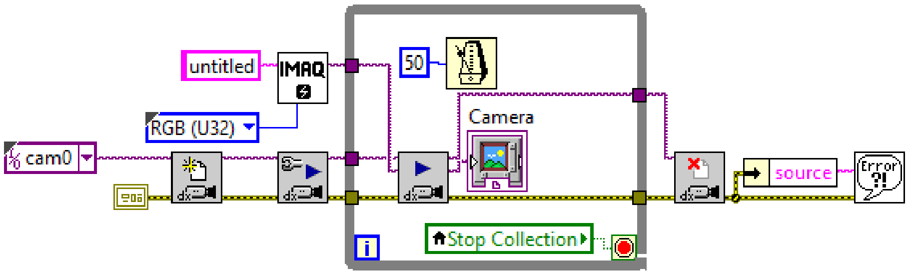
Appendix 1. Block diagram for device setup and stepper motor control



Appendix 2. Data acquisition system block diagram



Appendix 3. Camera panel block diagram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17. Permissions request for manuscript

13 November 2023

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AHMAD DAHLAN

Toni Kus Indratno <tonikus@staff.uad.ac.id>

Permissions query for your manuscript PED-103593.R4

1 pesan

Physics Education <onbehalfof@manuscriptcentral.com> 15 November 2023 pukul 21.57
Balas Ke: ped@ioppublishing.org
Kepada: tonikus@staff.uad.ac.id

Dear Mr Indratno,

Re: "Archimedes' Principle Experimental Apparatus for Remote Physics Laboratory"

Manuscript reference: PED-103593.R4

Apologies for the spelling error in the previous email.

For Figures 1 & 2 you will need to provide proof of permission from Brooklyn College, or evidence that the reused content is Open Access as you have stated.

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I have attached the permissions spreadsheet that you provided us previously.

We look forward to hearing from you.

Yours sincerely,

Poppy Clark

On behalf of:
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PED-103593.R4-Indratno--1-.xlsx
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Toni Kus Indratno <tonikus@staff.uad.ac.id>

Permissions request for your manuscript PED-103593.R4

1 pesan

Toni Kus Indratno <tonikus@staff.uad.ac.id> 13 November 2023 pukul 12.32
Kepada: PED Mailbox <ped@ioppublishing.org>

Dear Editor,,

Thank you for your email,

Regarding Figures 1 and 2 in our manuscript, Manuscript reference: PED-103593.R4, we have redrawn these images from the source, and the source is also a document that can be accessed freely via the link: http://depthome.brooklyn.cuny.edu/physics/lab/phy1/Archimedes-principle-rev-20190619.pdf.

However, because we cannot provide permission from the original owner, we have changed the source of the image to [6] C. Gianino, "Microcomputer-Based Laboratory for Archimedes' Principle and Density of Liquids," Phys. Teach., vol. 46, no. 1, pp. 52–54, Jan. 2008, doi: 10.1119/1.2824002, because the picture is more or less the same. We have also applied for permission from AIP Publishing to use the image. We include permission from AIP Publishing in this email. We also resend the manuscript, which we have revised in the image reference section, via this email.

Best regards,
Toni Kus Indratno

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DINAR & DIRHAM
Hidup Bahagia Tanpa Riba

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URGENT - Permissions query for your manuscript PED-103593.R4

2 pesan

Physics Education <onbehalfof@manuscriptcentral.com> 16 Januari 2024 pukul 15.35
Balas Ke: ped@ioppublishing.org
Kepada: tonikus@staff.uad.ac.id

Dear Mr Indratno,

Re: "Archimedes' Principle Experimental Apparatus for Remote Physics Laboratory"

Manuscript reference: PED-103593.R4

Following up on our previous emails.

We need:

For Figures 1 & 2 you will need to provide proof of permission from Brooklyn College, or evidence that the reused content is Open Access as you have stated.

For Figure 6 nothing further is needed since IOPP already own the copyright. As long as it's referenced correctly no permission is needed.

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I have attached the permissions spreadsheet that you provided us previously.

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We look forward to hearing from you.

Yours sincerely,

Poppy Clark

On behalf of:
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Letter reference: HYP:QueryPermsShrt

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Toni Kus Indratno <tonikus@staff.uad.ac.id> 18 Januari 2024 pukul 06.36
Kepada: ped@ioppublishing.org

Dear Editors,

Thank you for your email.

Regarding Figures 1 and 2 in our manuscript (Manuscript reference: PED-103593.R4), we have redrawn them from the original source, http://depthome.brooklyn.cuny.edu/physics/lab/phy1/Archimedes- principle-rev-20190619.pdf. However, we cannot provide proof of permission from Brooklyn College or evidence that the content we use is open access. At other times, we have also tried to search for alternative references. We found that C. Gianino, in 2008, had also published relatively similar images in Phys. Teach., vol. 46, no. 1, pp. 52–54.

Publication of C. Gianino in Phys. Teach. including primary reference types. Meanwhile, references from https://www.brooklyn.edu/ are secondary references. Therefore, we have changed the references to Figures 1 and 2. We have also obtained permission from AIP Publishing, and we sent it in this email. We also attach a manuscript whose references have been corrected.

Notes:
Our latest reference is [6] C. Gianino, "Microcomputer-Based Laboratory for Archimedes' Principle and Density of Liquids," Phys. Teach., vol. 46, no. 1, pp. 52–54, Jan. 2008, doi: 10.1119/1.2824002, which appeared earlier than the source image from Brooklyn College.

So, this can be considered by the Physics Education Journal editor.

Best regards,
Toni Kus Indratno
[Kutipan teks disembunyikan]
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Title of new article	Archimedes' Principle Experimental Apparatus for Remote Physics Laboratory
Lead author	Toni Kus Indratno
Title of targeted journal	Physics Education
Publisher	IOP Publishing
Expected publication date	Jan 2024
Portions	Figure 1, Figure 2
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18. Article has been accepted for publication

08 February 2024

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Toni Kus Indratno <tonikus@staff.uad.ac.id>

Your manuscript PED-103593.R4 has been accepted for publication

1 pesan

Physics Education <onbehalfof@manuscriptcentral.com> 8 Februari 2024 pukul 17.35
Balas Ke: ped@ioppublishing.org
Kepada: tonikus@staff.uad.ac.id, ishafit@pfis.uad.ac.id, yoga.prabowo@staff.uad.ac.id

Dear Mr Indratno,

Re: "Archimedes' Principle Experimental Apparatus for Remote Physics Laboratory"

Manuscript reference: PED-103593.R4

We are pleased to tell you that we are accepting your Paper. We now have everything we need to publish it in Physics Education.

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Poppy Clark

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19. Article is ready to check

17 February 2024

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Toni Kus Indratno <tonikus@staff.uad.ac.id>

Your Physics Education article ad27a6 is ready to check

1 pesan

ped@ioppublishing.org <ped@ioppublishing.org> 17 Februari 2024 pukul 17.22
Kepada: tonikus@staff.uad.ac.id

Re: "Archimedes' Principle Experimental Apparatus for Remote Physics Laboratory" by Indratno et al

Dear Mr Indratno,

Your article is ready to check and make final corrections. Please click the link below to start.

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Best regards,

Martin Kitts
Production Editor
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ped@ioppublishing.org

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20. Proof corrections received

18 February 2024

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Toni Kus Indratno <tonikus@staff.uad.ac.id>

Your Physics Education article ad27a6 - Proof corrections received

1 pesan

ped@ioppublishing.org <ped@ioppublishing.org> 18 Februari 2024 pukul 07.12
Kepada: tonikus@staff.uad.ac.id

Dear Mr Indratno
Re: "Archimedes' Principle Experimental Apparatus for Remote Physics Laboratory" by Indratno et al
Thank you for submitting your proof corrections. We will next contact you when your article has been published online unless we have any further queries or if you have previously requested a second proof.
We cannot guarantee that any late corrections received after the proof check has been completed will be made before publication.

Yours sincerely
Martin Kitts
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Physics Education
ped@ioppublishing.org

21. Article has been published

23 February 2024

UNIVERSITAS
AHMAD DAHLAN

Toni Kus Indratno <tonikus@staff.uad.ac.id>

Your Physics Education article ad27a6 has been published

1 pesan

ped@ioppublishing.org <ped@ioppublishing.org> 23 Februari 2024 pukul 21.08
Kepada: tonikus@staff.uad.ac.id

Re: Archimedes' Principle Experimental Apparatus for Remote Physics Laboratory by Indratno et al

Dear Mr Indratno,

Your article has been published on IOPscience with the following DOI: https://doi.org/10.1088/1361-6552/ad27a6

This notice of publication has been sent to you (as the corresponding author) only, so you may wish to forward the link to your co-authors.

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Best regards,

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ACTION	STATUS	ID	TITLE	SUBMITTED	DECISIONED
Copyright Completion submitted (12-Dec-2022) - view	• Formal Accept (08-Feb-2024) view decision letter	PED-103593.R4	Archimedes' Principle Experimental Apparatus for Remote Physics Laboratory View Submission	19-Oct-2023	08-Feb-2024
a revision has been submitted (PED-103593.R4)	• Minor Revision (16-Oct-2023) • a revision has been submitted view decision letter	PED-103593.R3	Archimedes' Principle Experimental Apparatus for Remote Physics Laboratory View Submission	26-Sep-2023	16-Oct-2023

ACTION	STATUS	ID	TITLE	SUBMITTED	DECISIONED
a revision has been submitted (PED-103593.R3)	• Minor Revision (20-Sep-2023) • a revision has been submitted view decision letter	PED-103593.R2	Archimedes' Principles Experimental Apparatus for Remote Physics Laboratory View Submission	09-Mar-2023	20-Sep-2023
a revision has been submitted (PED-103593.R2) Copyright Completion submitted (12-Dec-2022) - view	• Moderate Revision (27-Feb-2023) • a revision has been submitted view decision letter	PED-103593.R1	Archimedes' Principles Experimental Apparatus for Remote Physics Laboratory View Submission	24-Jan-2023	27-Feb-2023
a revision has been submitted (PED-103593.R1)	• Major Revision (03-Jan-2023) • a revision has been submitted view decision letter	PED-103593	Archimedes' Principles Experimental Apparatus for Remote Physics Laboratory View Submission	29-Nov-2022	03-Jan-2023
	• Reject (25-May-2021) *Archiving completed on 29-Jul-2021* view decision letter	PED-102812	Magnetic field on a square Helmholtz coil experiments using R-PhyLab *Files Archived*	30-Apr-2021	25-May-2021
a resubmission has been submitted (PED-102812)	• Reject to Resubmit	PED-102658	R-PhyLab user experience for magnetic	28-Jan-2021	19-Feb-2021

ACTION	STATUS	ID	TITLE	SUBMITTED	DECISIONED
	(19-Feb-2021) • a resubmission has been submitted *Archiving completed on 29-Jul-2021* view decision letter		field experiments using a square Helmholtz coil *Files Archived*		